Canadian Military History

Volume 32 | Issue 2 Article 2

2023

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Abstract: This article examines the operational research conducted by the counter-battery staff office (CBO) in the headquarters of 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 and expands upon the initial inquiry performed by scholars J.S. Finan and W.J. Hurley in a 1997 journal article. While the staff of the CBO never used the term "operational research" to describe their scientific studies, they were undoubtedly its practitioners through their innovating, trialling, experimentation and dissemination of knowledge–the four pillars of the discipline. These artillerymen applied science to their 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 perfected the use of counter-battery fire to attrit 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.

Field marshal Field Marshal Sir Douglas Haig, the Commander-in-Chief of the British Expeditionary Force (BEF), 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 during the Great War:

> 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.[1]

Haig's armies depended on the artillerymen to neutralise the enemy's guns before the infantry launched their assaults against the opposing trench lines. Artillery, not the machine gun, was the real killer on the battlefield, accounting for approximately sixty percent of all battlefield casualties in the First World War.[2] 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 with high casualties. BEF gunners knew they had to silence the German guns, but how?

The Canadian Corps counter-battery staff under command of Lieutenant-Colonel (Lt.-Col.) Andrew G.L. McNaughton used operational research (OR) to neutralise the German artillery. After the Battle of the Somme (1 July–18 November 1916), the Canadian Corps rarely attacked with fewer than half of the German guns suppressed. Through innovation, trialling, experimentation and dissemination—the four indicators of OR—the counter-battery staff officer (CBSO) and his officers developed the necessary technology, staff structure and methods. 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 OR process and produced "lessons

[1] 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.

[2] 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.

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. 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 had to trial novel techniques and faced certain constraints, from difficult terrain to the accelerating operational tempo of the corps. Despite these considerable challenges, OR enabled McNaughton and his staff to continuously improve the counter-battery work done by the Canadian Corps.

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."[3] Finan and Hurley's argument challenges the claims made by most historians of OR, 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.[4] Some historians have cited forerunners to OR 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

[3] J.S. Finan and W.J. Hurley, "McNaughton and Canadian Operational Research at Vimy," *The Journal of the Operational Research Society* 48, 1 (January 1997): 14.
[4] Terry Copp, "Scientists and the Art of War: Operational Research in 21 Army Group," *The RUSI Journal* 136, 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* 35, 1 (January – February 1987): 143.

techniques in the planning and execution of military operations."[5] Semantics also complicate scholarship on the origins of OR since the term "operational research" did not enter the military lexicon until the 1930s. Still, the consensus amongst historians is that OR 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 OR has significantly developed. In addition to the official history, several historians have published monographs on the Canadian Expeditionary Force (CEF) and its campaigns during the First World War.[6] These scholars have disproved that the pluck and non-conventional approaches of the corps' non-regular soldiers made it successful.[7] Pertinent to this study, historians have also examined how the Canadian Corps used new technology.[8] Crucially, these studies examine people, as well as tactical methods and weapon systems. The best systems and kit

[5] Kirby, *Operational Research in War and Peace*, 42.

[6] 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* (Toronto: Penguin Canada, 2007); and Tim Cook, *Shock Troops: Canadians Fighting the Great War, 1917-1918, Volume Two* (Toronto: Penguin Canada, 2008). Campaign histories include: 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: Wilfrid 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] 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); and Tim Cook, *No Place to Run: The Canadian Corps and Gas Warfare in the First World War* (Vancouver and Toronto: UBC Press, 1999).

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."[9] Improved command and control of the artillery also contributed to battlefield successes. Albert Palazzo argues the formation of the counter-battery staff office (CBO) was instrumental in achieving tactical and operational superiority over the Germans and its formation "was a reflection of the vibrancy of British *experimentation* and their determination to find solutions to the stalemate."[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 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] Tim Cook partially attributes the success of the Canadian artillery during the Battle of Vimy Ridge (9—12 April 1917) to "operational analysis."[13]

This article seeks to enhance and challenge the initial enquiry by Finan and Hurley. It examines how McNaughton and his staff conducted OR to improve counter-battery work from the formation of the Canadian Corps CBO until the end of the First World War rather than focusing on McNaughton alone and the fielding of flash-spotting and sound-ranging technologies at Vimy. The sources consulted for this examination are much broader than those that Finan and Hurley relied upon. Factual inconsistencies initially made by McNaughton in postwar interviews and subsequently quoted by historians have been addressed. Lastly, through examining the people involved with the Canadian Corps CBO, many of whom continued to serve into the Second World War, this article plots a point on the trajectory of OR

[9] Rawling, *Surviving Trench Warfare*, 223.
[10] Albert P. Palazzo, "The British Army's Counter-Battery Staff Office and Control of the Enemy in World War I," *The Journal of Military History* 63, 1 (January 1999): 56, 74. Emphasis added by the author.
[11] Nicholson, *The Gunners of Canada*, 214.
[12] Nicholson, *The Gunners of Canada*, 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: Wilfrid Laurier University Press, 2007), 120.

between its infancy to the formation of OR units during the Second World War.

OR supports decision-making with science. Defined by the United Kingdom's Operational Research Society as a branch of managerial science, OR is:

> [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.[14]

The discipline adheres to the scientific method in that hypotheses examined through OR are testable, replicable and observable. While OR does not necessarily lead to better decisions, it does, as one OR practitioner noted, improve "the degree of confidence that can be placed in the correctness of the result."[15] OR methodology is quantitatively based; however, the discipline of OR does not necessarily involve complicated mathematics. In a military context, OR provides commanders and staffs with a method to measure performance and effectiveness. These measures inform researchers 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 OR provides commanders and their staffs quantitative tools to measure how well they are using their forces and how well their forces are performing.

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 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."[16] The *FSR* only mentions counter-battery fire as a possible task for

[14] Kirby, *Operational Research in War and Peace*, 3.
[15] Kirby, *Operational Research in War and Peace*, 25.
[16] General Staff, War Office, *Field Service Regulations, Part I: Operations, 1909* (London: His Majesty's Stationery Office, 1912), 15-16.

howitzers and heavy artillery. *Field Artillery Training* (*FAT*) of 1914 furnished a bit more direction on counter-battery work.[17] 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."[18] *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 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."[19] If the enemy 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 technical knowledge, the Royal Artillery struggled to develop techniques for counter-battery during the early period of the war.

BEF gunners understood the necessity of suppressing 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 the absence of a centralised counter-battery staff at any command level.[20] These shortcomings often resulted in unsatisfactory engagements. 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)

[17] General Staff, War Office, *Field Artillery Training, 1914* (London: His Majesty's Stationery Office, 1914).
[18] General Staff, War Office, *Field Artillery Training, 1914*, 246.
[19] General Staff, War Office, *Field Artillery Training, 1914*, 247.
[20] "'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, Papers of Field Marshal Viscount Alanbrooke of Brookeborough (Alanbrooke Papers), 3/10, King's College London, Liddell Hart Centre for Military Archives [LHCMA].

and Loos (25 September–8 October).[21] The infantry also pressured the artillery to prioritise fire missions 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."[22] 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.[23] 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 "deep" 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.[24] After the campaign ended in November 1916, Major (Maj.) 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."[25] However, he noted that the BEF 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

[21] Martin Farndale, *History of the Royal Regiment of Artillery: Western Front, 1914-18* (Woolwich: The Royal Artillery Institution, 1986), 90, 99, 106, 109, 124; and Nicholson, *The Gunners of Canada*, 210, 231.

[22] War Office, *Field Service Regulations*, 135.

[23] 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), 75.

[24] Paul Strong and Sanders Marble, *Artillery in the Great War* (Barnsley: Pen & Sword Military, 2013), 91-93.

[25] Brooke went on to become Field Marshal Viscount Alanbrooke and served as Chief of the Imperial General Staff during the Second World War. "Notes on My Life," 57, November – December 1916, Alanbrooke Papers, 5/2/13, LHCMA.

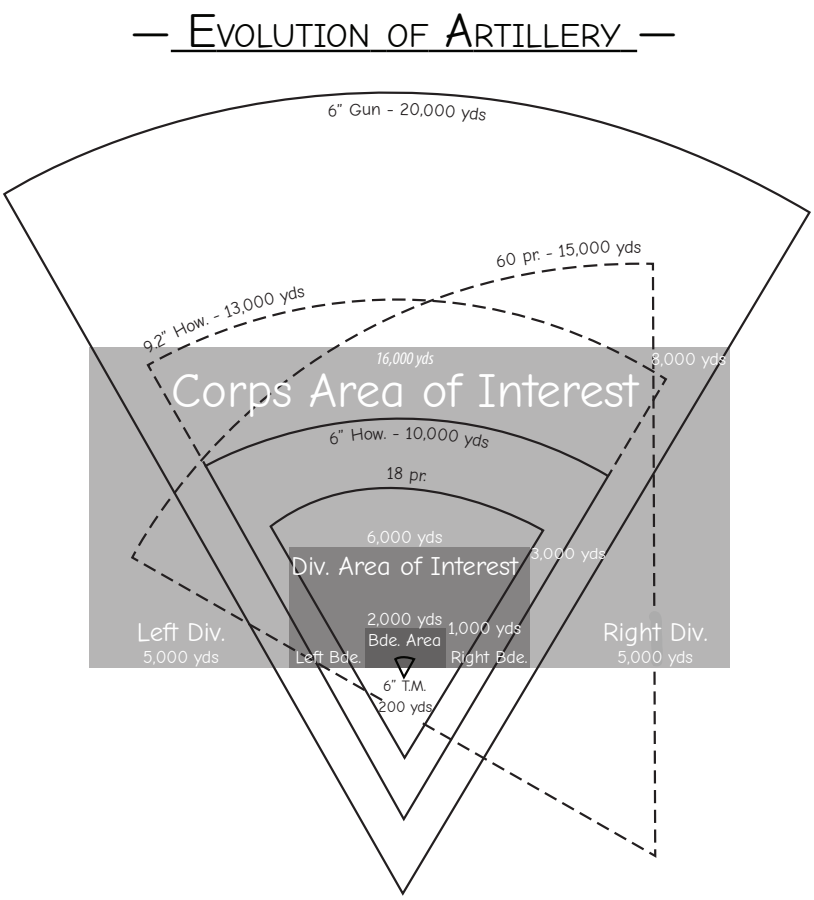

Figure 1. Distribution of Artillery Pieces to Formations in Accordance with Their Ranging Powers. ["Evolution of Artillery in the Great War 1914-1918," insert 370-371, Alanbrooke Papers, 3/10, LHCMA]

of trenches and obstacles."[26] As Brooke notes, the artillery still had much work to do. By the end of 1916, however, the BEF had enough shells and heavy guns.[27] Major-General (Maj.-Gen.) J.F.N. Birch, Haig's chief gunner at General Headquarters (GHQ), shared several of Brooke's observations and issued direction for the BEF artillery to develop its counter-battery capabilities during the winter of

[26] "Notes on My Life," 57, November – December 1916 Alanbrooke Papers, 5/2/13, LHCMA.
[27] Farndale, *History of the Royal Regiment of Artillery*, 149.

1916—1917.[28] 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 OR to win the artillery fight.

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.[29] 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). 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, with 2,204 heavy guns.[30] 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.[31] 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 2).[32] The adjutant of each heavy artillery group acted as a liaison between the CBO and, most critically, provided battle damage assessment after each engagement.[33] 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 operational research section for the Canadian Corps artillery.

Maj.-Gen. E.W.B. Morrison, the GOC RA for the Canadian Corps, named McNaughton as CBSO when the Canadian Corps formed its CBO on 10 February 1917. With his hydroelectrical

[28] Farndale, *History of the Royal Regiment of Artillery*, 156.

[29] "Evolution of Artillery in the Great War 1914-1918," 373, 478, Alanbrooke Papers, 3/10, LHCMA; and Andy Simpson, *Directing Operations: The British Corps Command on the Western Front, 1914-18* (Stroud: Spellmount, 2006), 64.

[30] Nicholson, *The Gunners of Canada*, 311.

[31] Simpson, *Directing Operations*, 231-35.

[32] CBO, "Memoranda on the Organization of Counter-Battery Work in the Canadian Corps," 16, 20 May 1918, RG9-III-C-1, Canadian Corps Headquarters Royal Artillery, Vol. 3903, Folder 19, File 2, Library and Archives Canada [LAC].

[33] CBO, C.B. 186/2, "Duties of Counter-Battery Adjutants with Heavy Artillery Groups," 1-2, 9 June 1918, RG9-III-C-1, Canadian Corps Headquarters Royal Artillery, Vol. 3903, Folder 19, File 3, CBO, LAC.

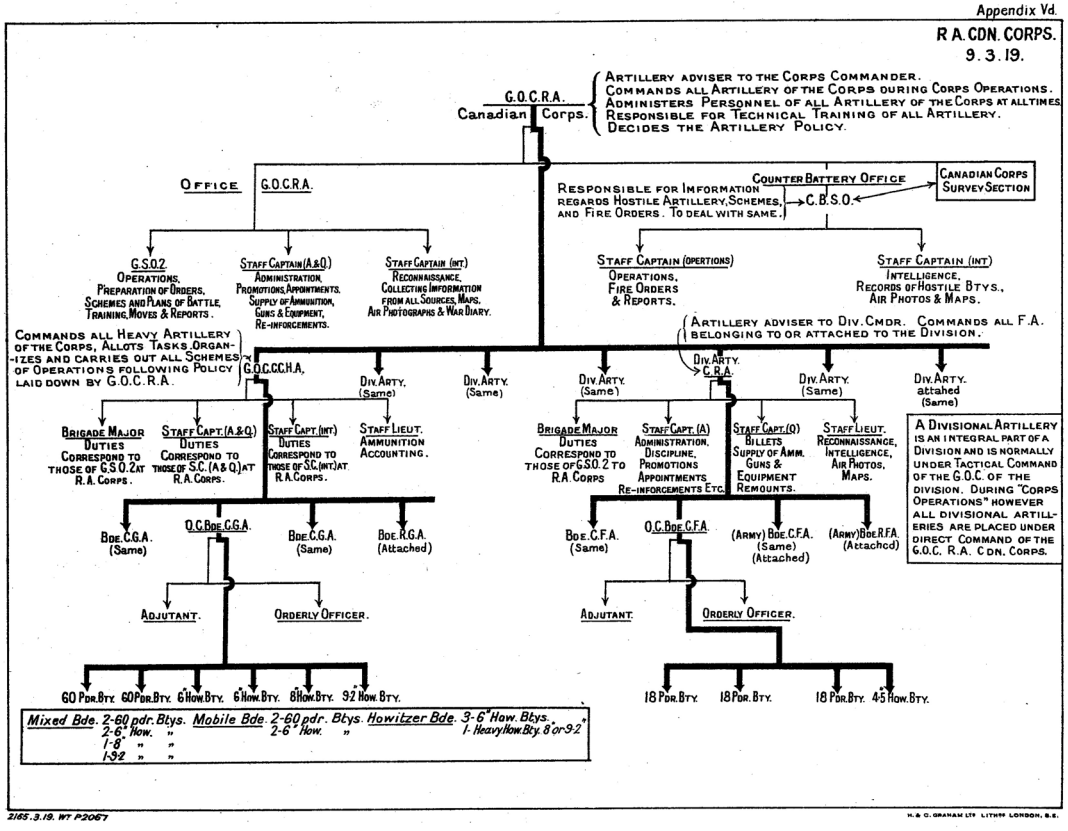

Figure 2. Organisation and Staff Structure of the Canadian Corps Artillery, 1918. [Ministry Overseas Military Forces of Canada (OMFC), Report of the Ministry Overseas Military Forces of Canada, 1918 (London: His Majesty's Stationery Office, 1919), insert page 240-241]

engineering background, McNaughton was well suited to this technical appointment.[34] 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.[35]

As an electrical engineer, he understood the many characteristics of complex systems—their interdependent parts that interacted with each other in their environment, were everchanging, difficult to model and depended on each other for the proper functioning of the entire system. One of McNaughton's colleagues at McGill University remarked that: "If war had not broken out in 1914 Andy McNaughton, instead of being a general, would have become the most eminent engineer in Canada."[36] McNaughton also applied this systematic approach of understanding complex systems to the enemy's artillery, 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 (Capt.) A.E.W. Nesbitt, a Royal Garrison Artillery officer on loan from the British Army, filled the staff captain (operations) appointment.[37] When Nesbitt sustained an injury on 3 November

[34] Andrew George Latta McNaughton Personnel File, RG150, Accession 1992-93/166, Box 7142-18, LAC.

[35] Quoted in John Swettenham, *McNaughton: Volume 1, 1887-1939* (Toronto: The Ryerson Press, 1968), 74. Emphasis added by the author.

[36] Swettenham, *McNaughton: Volume 1, 1887-1939*, 15.

[37] Medal Card of Andrew Edmundson Walsh Nesbitt, WO 372/14/196493, The National Archives, Kew [TNA]; 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 RG24, Department of National Defence, Vol. 447, LAC; and "Officers Commanding Units – Headquarters Canadian Army Corps," n.d., RG150, Vol. 473, LAC.

Brig.-Gen. A.G.L. McNaughton, Commander, Canadian Corps Heavy Artillery. [Library and Archives Canada PA-034150]

1918, he was replaced by the able Lieutenant (Lieut.) P.H. Skelton, a former mechanical engineer from Montreal.[38] As his orderly officer, McNaughton brought his adjutant from the 11th (Howitzer) Brigade, Canadian Field Artillery, Capt. 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.[39] Indeed McNaughton noted that Napier was "absolutely one hundred percent efficient."[40] Capt. E.H. Davidson, another officer on loan from the British Army, worked as the intelligence officer in the CBO.[41] An injury had left him unfit for frontline duty, so he transferred to the Royal Flying Corps (RFC) and specialised in the analysis of aerial photographs. His older brother, Maj.-Gen. Sir John Davidson, held senior staff appointments at GHQ, which McNaughton exploited to get information and support for his ideas.[42] The combined technical, practical and administrative talent of the staff in the CBO set the conditions for the staff to quantitatively analyse 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.[43] 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 work, which they almost always did.[44] Experimentation proved that destructive counter-battery shoots required the heavy guns controlled

[38] Philip Hanbury Skelton Personnel File, RG150, Accession 1992-93/166, Box 8958-53, LAC.

[39] Lennox Pelham Napier Personnel File, RG150, Accession 1992-93/166, Box 7233-23, LAC.

[40] J.A. Swettenham, "Transcripts of Tapes of General McNaughton's Recollections of the First World War (Flanders Fields Transcripts)," Tape 11, 9, 15 February 1963, MG30-E133, General Andrew George Latta McNaughton Fonds (McNaughton Papers), Vol. 358, LAC.

[41] Edward Humphrey Davidson Personnel File, WO 339/6574, TNA; and Edward Humphrey Davidson Personnel File, AIR 76/123/159, TNA.

[42] "Flanders Fields Transcripts," Tape 11, 14-15, 15 February 1963, MG30-E133, McNaughton Papers, Vol. 358, LAC.

[43] A.G.L. McNaughton, "Counter-Battery Work," *Canadian Defence Quarterly* 3, 4 (July 1926): 380.

[44] "The Canadian Artillery in the Great War," 6-8, n.d., MG30-E81, Major-General Sir Edward Whipple Bancroft Morrison Fonds (Morrison Papers), Vol. 2, Artillery Corps Notes and Pamphlets, LAC.

at the army level, but the battles of 1916 had proved that guns and ammunition alone could not win the artillery fight.[45] They had to be used intelligently and with purpose.

Through OR, McNaughton sought to optimise the organisation and equipment of the CBO (see figure 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."[46] The intelligence officer then needed to analyse 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.

Intelligence reports were responsible for not only determining where German artillery was, but also informed the CBSO of the calibre, disposition, degree of protection and arcs of fire of German batteries.[47] Counter-battery work relied upon efficient communications between observers, the CBO and the guns. It also required the staff to standardise its work with GHQ standards to ensure that reinforcing artillery could prosecute enemy batteries in accordance with the counter-battery programme. Technical abilities entailed the whole gamut of gunnery.[48] 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.[49] 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. All these factors helped batteries conduct somewhat accurate, predicted fire—the engagement of a target without

[45] First Army Headquarters, "Artillery Instruction No. 2 Employment of 12-inch and 15-inch Howitzers," 17 March 1917, RG9-III-C-1, Canadian Corps Headquarters Royal Artillery, Vol. 3903, Folder 20, File 2, LAC.

[46] "Flanders Fields Transcripts," Tape 2, 5, 17 January 1963, MG30-E133, McNaughton Papers, Vol. 358, LAC.

[47] Nicholson, *The Gunners of Canada*, 313, 316.

[48] "Evolution of Artillery in the Great War 1914-1918," 37-51, Alanbrooke Papers, 3/10, LHCMA.

[49] 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).

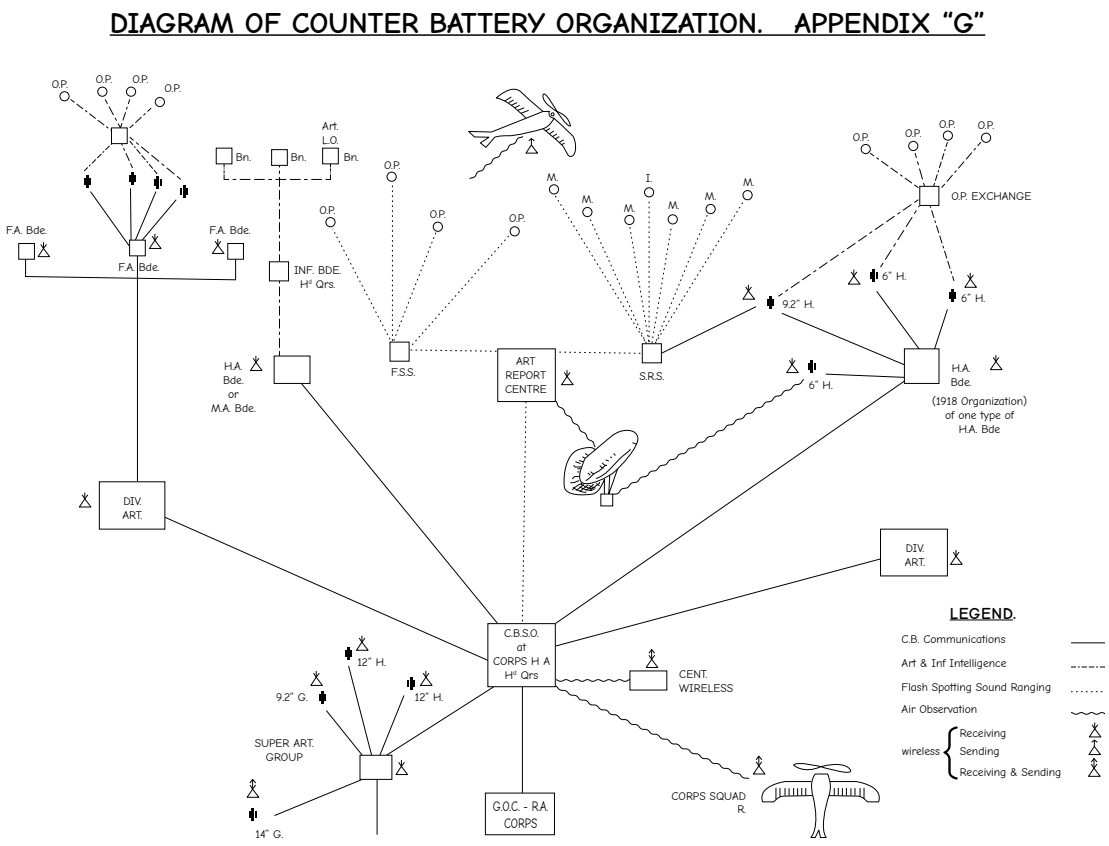

Figure 3. The BEF Counter-Battery System, 1918. ["Evolution of Artillery in the Great War 1914-1918," insert 386-387, Alanbrooke Papers, 3/10, LHCMA]

any previous adjustment to the fall of shot.[50] By synchronising the engagements of targets by fires with the manoeuvre of infantry and cavalry, surprise on the battlefield was again possible. OR 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.

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.[51] 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*.[52] 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.[53]

SS139/3 delineated organisation 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."[54] The BEF never entirely centralised learning, which would have stifled innovation and these pamphlets disseminated lessons learned amongst the formations on the Western Front and thereby minimised duplication of effort from

[50] 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.

[51] Berton claims that McNaughton was "given carte 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.

[52] General Staff, General Headquarters, *SS193/3 Artillery Notes No. 3 – Counter-Battery Work* (February 1917).

[53] General Staff, General Headquarters, *SS193/3 Artillery Notes No. 3 – Counter-Battery Work*, 3.

[54] Aimée Fox, *Learning to Fight: Military Innovation and Change in the British Army, 1914-1918* (Cambridge: Cambridge University Press, 2018), 81.

multiple staffs working on the same product. Direction from GHQ also helped to standardise the counter-battery work that had been quite haphazard during the Somme.[55] 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 clarified the direction from GHQ.[56] Still, the system was mostly untried and McNaughton and his OR 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."[57] However, he later stated that the French artillery in Verdun did not impress him. He found their methods and organisation chaotic and inefficient.[58] And in a 1963 interview, he 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."[59] Curiously, both Brooke and then Maj.-Gen. 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

[55] Marble, *British Artillery on the Western Front in the First World War*, 152.

[56] First Army Headquarters, No.1101, "Status and Duties of the Counter-Battery Lieutenant-Colonel in a Corps," 7 February 1917, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 7 File 7, LAC.

[57] Letter from Lieutenant-Colonel A.G.L. McNaughton to Lieutenant-Colonel Pievet, 5 June 1917, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 4, C.B. 15/65, LAC.

[58] 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, MG30-E100, General Sir Arthur William Currie Fonds (Currie Papers), Vol. 35, File 160, Memoranda and Reports, January – June 1917, LAC.

[59] "Flanders Fields Transcripts," Tape 3, 7-8, 17 January 1963, MG30-E133, McNaughton Papers, Vol. 358, LAC.

> explained all the dispositions and the results of the attacks.... The whole trip was intensely interesting.[60]

Currie wrote in his report that the primary aim of the artillery before an attack must be neutralising the enemy's guns.[61] 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."[62] This lesson highlighted the importance of accurate and timely intelligence. In McNaughton's fire plans, he frequently re-engaged batteries that had been neutralised or destroyed to ensure suppression when the infantry began their attacks.[63]

McNaughton found the visit to British V Corps much more profitable. Brigadier-General (Brig.-Gen.) Percy Radcliffe, the chief of staff of the Canadian Corps, suggested that McNaughton visit the British corps headquarters since it had established a reputation for counter-battery efficiency. At V Corps, McNaughton met Lt.-Col. A.G. Haig, the CBSO, who has been described by one historian as "the father of the counter-battery staff."[64] Haig had been a professional artillery officer in the Royal Garrison Artillery with experience in South Africa and the Northwest Frontier. In May 1916, Maj.-Gen. C.E.D. Budworth, the chief gunner in Fourth Army, ordered Haig to form "a special counter battery organization… The duties were to be

[60] "Notes on My Life," 58, January – February 1917, Alanbrooke Papers, 5/2/13, LHCMA.

[61] Major-General Arthur Currie, "Notes on French Attacks, North-East of Verdun in October and December 1916," 23 January 1917, MG30-E100, Currie Papers, Vol. 35, File 160, Memoranda and Reports, January – June 1917, LAC.

[62] 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, MG30-E100, Currie Papers, Vol. 35, File 160, Memoranda and Reports, January – June 1917, LAC.

[63] 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 neutralising fires to achieve the desired effect. 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, RG9-III-D-3, Vol. 4957, File 504, LAC.

[64] 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), 151; and Medal Card of Alan Gordon Haig, WO 372/8/194084, TNA.

the collection and collation of all information about the enemy artillery, and the schemes and orders for their destruction and neutralization."[65] 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 engagements. These innovative procedures shaped those that McNaughton implemented for the Canadian Corps.[66] Lt.-Col. 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.[67] 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 article 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 techniques.[68] 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-

[65] 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.

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

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

[68] 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.

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 Lieut. Lawrence Bragg, a Territorial Force Royal Horse Artillery officer and winner of the 1915 Nobel Prize for physics.[69] Further experimentation throughout 1916 resulted in the introduction of the Tucker microphone (developed by Bragg and Lieut. William Tucker, a physics lecturer at Imperial College London) and the formation of a Field Survey Company (FSC), Royal Engineers in each army.[70] The staff at GHQ collated the results of these trials and experiments and published *SS552 Sound Ranging* in March 1917.[71] 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.[72] 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.[73] Indeed, the present-day artillery still conducts this procedure.[74] Flash-spotting evolved along similar lines. Prewar doctrine mentioned flash-spotting, and much innovation had occurred in the intervening years. Lieut. H.H. Hemming, a graduate of McGill University serving with the British Army, designed the "Flash and

[69] 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), 129-61.

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

[71] General Staff, General Headquarters, *SS552 Sound Ranging* (March 1917).

[72] General Staff, General Headquarters, *SS552 Sound Ranging*, 6-9.

[73] 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).

[74] DND, *Duties of the Battery Commander and the Observer*, 102-103.

Buzzer Board" in May 1916, which the BEF widely distributed that November.[75]

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.[76] In postwar interviews, McNaughton exaggerated his role in the development of these techniques and historians have propagated his claims since.[77]

Nor did McNaughton recruit three "civilian" scientists—Lawrence Bragg, Charles Darwin, and Lucien Bull—into his "research team" at Vimy.[78] 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.[79] During the Vimy operation, L and V Sections, not the section commanded by Darwin, supported the Canadian Corps.[80] Bull, the only civilian of the three, headed the Marey Institute in Paris and supported the British and French war efforts with scientific research.[81] Darwin and Bull served in the army for the remainder of the war. Darwin's

[75] Harold Hemming Personnel File, WO 339/78438, TNA; and War Office, *Report on Survey on the Western Front*, 106-107.

[76] 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., RG9-III-C-1, Vol. 3922, Canadian Corps Headquarters Heavy Artillery, Folder 8, File 3, LAC.

[77] Nicholson, *The Gunners of Canada*, 315n1; Swettenham, *McNaughton*, 78-83; Jeffrey Williams, *Byng of Vimy: General and Governor General* (London: Leo Cooper, 1983), 144-46; Berton, *Vimy*, 164-166; Finan and Hurley, "McNaughton and Canadian Operational Research at Vimy," 10; and Cook, *Shock Troops*, 34-37.

[78] Finan and Hurley, "McNaughton and Canadian Operational Research at Vimy," 10; and Berton, *Vimy*, 164.

[79] Chasseaud, *Artillery's Astrologers*, 98, 167-168.

[80] CBO, "Artillery Order No. 18," 2, 7 April 1917, RG9-III-C-1, Canadian Corps Headquarters Royal Artillery, Vol. 3916, Folder 54, File 6, LAC.

[81] Chasseaud, *Artillery's Astrologers*, 97-98.

involvement with military OR carried on into the Second World War. In May 1942, the Chief of the Imperial General Staff (CIGS) had appointed Darwin to the Army Council as its scientific advisor, and Darwin obtained approval to have OR sections added to the staff of deployed operational-level headquarters by November 1942.[82] Bull continued his work at the institute. McNaughton may have interacted with 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.[83] Bragg did later state that "an almost impassable barrier had been encountered between the military and scientific minds. The military thought us scientists far too visionary and gadgetry to be of any help in the field."[84] 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.[85]

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. OR 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* emphasised the capabilities of aircraft for counter-battery work and by 1918, each corps had an attached RFC

[82] 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), 10, 18.
[83] Berton, *Vimy*, 164.
[84] Swettenham, *McNaughton*, 77.
[85] "Flanders Fields Transcripts," Tape 2, 8, 17 January 1963, MG30-E133, McNaughton Papers, Vol. 358, LAC.

squadron.[86] At Vimy, air observers adjusted the fire for seventy-five per cent of all counter-battery shoots.[87] And that percentage only increased as 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 analysed. 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."[88] 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 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 engagements.[89] This full integration of assets required a robust and innovative staff like the CBO to manage.

Counter-battery fire missions 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 Maj. William A. Bishop described the process of a counter-battery shoot observed from the air:

[86] 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.

[87] Lieutenant-Colonel A.G.L. McNaughton, C.B. 20/8, "Counter-Battery Office Report," 2, 25 June 1917, MG30-E100, Currie Papers, Vol. 35, File 160, Memoranda and Reports, January – June 1917, LAC.

[88] "Flanders Fields Transcripts," Tape 2, 10, 17 January 1963, MG30-E133, McNaughton Papers, Vol. 358, LAC.

[89] CBO, C.B. 3/5, "Memorandum on Co-operation with the RFC," 18 February 1917, RG9-III-C-1, Canadian Corps Headquarters Royal Artillery Vol. 3915, Folder 51, File 1, LAC.

> [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 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.[90]

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.[91] In her examination of patronage and social relations in the British Army, Aimée Fox asserts that patronage "acted as the means through which the social and political networks that underpinned the Army were mobilised to facilitate its intellectual development and day-to-day functioning."[92] Perhaps the patronage of successful, competent officers like Radcliffe, Lt.-Gen. Sir Julian Byng and Lt.-Gen. Sir Arthur Currie (second and third commanders of the Canadian Corps, respectively) explains why the Canadian Corps is well known for its counter-battery work, almost to the complete exclusion of other British corps. Lieutenant-

[90] William A. Bishop, *Winged Warfare* (New York: George H. Doran Company, 1918), 27-28.
[91] "Flanders Fields Transcripts," Tape 2, 14, 17 January 1963, MG30-E133, McNaughton Papers, Vol. 358, LAC.
[92] Aimée Fox, "The Secret of Efficiency? Social Relations and Patronage in the British Army in the Era of the First World War," *English Historical Review* CXXXV, 577 (December 2020): 1535.

Colonels John Dill and Edmund Ironside, British staff officers serving with the Canadian Corps, frequently visited the CBO.[93] Both went on to serve as CIGS during the Second World War and, during Dill's tenure as CIGS, the first army OR unit formed to support Anti-Aircraft Command.[94] 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.[95] 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.[96]

McNaughton also got on with the two head gunners in the Canadian Corps headquarters. Maj.-Gen. Morrison, the GOC RA, supported the OR done by the CBO and got McNaughton the guns and ammunition that he needed.[97] 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.[98] 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."[99] The relationship was not quite as harmonious with the commander of the Canadian Corps Heavy Artillery (CCHA), Brig.-Gen. R.H. Massie.[100] McNaughton claimed that this

[93] Swettenham, *McNaughton*, 75.
[94] Kirby, *Operational Research in War and Peace*, 92.
[95] "Flanders Fields Transcripts," Tape 3, 3-5, 17 January 1963, MG30-E133, McNaughton Papers, Vol. 358, LAC.
[96] A.G.L. McNaughton, "The Development of Artillery in the Great War," *Canadian Defence Quarterly* XI, 2 (January 1929): 163.
[97] Cook, "The Gunners at Vimy," 111.
[98] "Notes on My Life," 59, February – April 1917, Alanbrooke Papers, 5/2/13, LHCMA.
[99] General H.D.G. Crerar to Colonel G.W.L. Nicholson, 10 March 1965, quoted in Swettenham, *McNaughton*, 97.
[100] Medal Card of R.H. Massey, WO 372/24/42474, TNA.

professional British garrison artilleryman resented the control that the "amateur" had over his guns for counter-battery fire.[101] That may well have been the case, 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.[102] Morrison recalled that when Haig would visit the Canadian Corps, he would ask, "Have they given you all the ammunition that you want?"[103] 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."[104] 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 OR that improved detection techniques and shaped the targeting process controlled by the CBSO, 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.[105] The British had reinforced the heavy artillery of the Canadian Corps for the attack, so McNaughton

[101] "Flanders Fields Transcripts," Tape 8, 4, 17 January 1963, MG30-E133, McNaughton Papers, Vol. 358, LAC.
[102] Swettenham, *McNaughton*, 161-162; and "Flanders Fields Transcripts," Tape 12, 7, 15 February 1963, MG30-E133, McNaughton Papers, Vol. 358, LAC.
[103] "The Canadian Artillery in the Great War," 8, n.d., MG30-E81, Morrison Papers, Vol. 2, Artillery Corps Notes and Pamphlets, LAC.
[104] "Flanders Fields Transcripts," Tape 3, 11, 17 January 1963, MG30-E133, McNaughton Papers, Vol. 358, LAC.
[105] Chasseaud, *Artillery's Astrologers*, 270.

wielded 245 heavy guns to prosecute hostile batteries.[106] Aircraft and FOOs provided battle damage assessments from these engagements and the hostile battery was either removed from the target list or reengaged.[107] Morrison exaggerated when he claimed that all of the German artillery had "been discovered and successfully dealt with."[108] 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.[109] The confined terrain of the battlefield forced the Germans to group their batteries tightly together, which made finding them more manageable.[110]

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 neutralising fires on forty-seven German batteries.[111] In his intelligence reports, Davidson listed these batteries as active or possibly active. The Canadian Corps sustained 10,602 casualties, including 3,598 fatalities.[112] 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.[113] 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 organisation and procedures of the CBO.

[106] 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, RG9-III-D-3, Vol. 4957, File 503, LAC.

[107] WD, Canadian Corps Heavy Artillery, 1 March – 8 April 1917, RG9-III-D-3, Vol. 4973, File 561, LAC.

[108] Morrison, *Morrison*, 124.

[109] "Notes on Counter-Battery Work in Connection with the Capture of Vimy Ridge by Canadian Corps, 9 April 1917," 18, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3, LAC.

[110] Farndale, *History of the Royal Regiment of Artillery*, 165.

[111] 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 "Notes on Counter-Battery Work in Connection with the Capture of Vimy Ridge by Canadian Corps, 9 April 1917," 17, 19, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3, LAC.

[112] Nicholson, *Official History of the Canadian Army in the First World War*, 265.

[113] Mitchell, *Medical History of the War*, 41.

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.[114] The report scrutinised 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."[115] A separate report prepared by Capt. 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 by conventional shells but remained in action.[116] The corps artillery could quickly implement these recommendations. Addressing the shortcomings in the intelligence-gathering and analysis required more thought.

The intelligence collected and analysed before Vimy was mostly accurate. Of the forty-seven German batteries engaged at zero hour, McNaughton determined that eighty-three percent were active.[117] Intelligence is never perfect, though. The report noted that eighteen percent of the thirty-four hostile battery positions that Davidson had assessed as "not active" fired on the Canadian Corps during

[114] "Notes on Counter-Battery Work in Connection with the Capture of Vimy Ridge by Canadian Corps, 9 April 1917," 2, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3, LAC.

[115] "Notes on Counter-Battery Work in Connection with the Capture of Vimy Ridge by Canadian Corps, 9 April 1917," 12, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3, LAC.

[116] "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., RG9-III-C-1, Vol. 3922, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3, LAC.

[117] "Notes on Counter-Battery Work in Connection with the Capture of Vimy Ridge by Canadian Corps, 9 April 1917," 18-19, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3, LAC.

the battle.[118] 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.[119] To confirm hostile batteries, McNaughton noted, "in no case should a [hostile battery] be confirmed on less than two reports from entirely different sources."[120] 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 report, at least not officially.[121] This conclusion, however, is incorrect. McNaughton sent a full copy of the report with appendices to Lt.-Col. Pievet, a French artillery officer in the French XI Corps.[122] McNaughton hoped the French artillery officer could criticise the report based on his own extensive experience with counter-battery. McNaughton had learned much from Pievet's demonstration of massed, destructive fire missions on enemy guns controlled from an aeroplane. This exchange is but one example of what Aimée Fox describes as

[118] "Notes on Counter-Battery Work in Connection with the Capture of Vimy Ridge by Canadian Corps, 9 April 1917," 10, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3, LAC.
[119] "Notes on Counter-Battery Work in Connection with the Capture of Vimy Ridge by Canadian Corps, 9 April 1917," 7, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3, LAC.
[120] "Notes on Counter-Battery Work in Connection with the Capture of Vimy Ridge by Canadian Corps, 9 April 1917," 10, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 3, LAC.
[121] Marble, *British Artillery on the Western Front in the First World War*, 183.
[122] Lieutenant-Colonel A.G.L. McNaughton to Lieutenant-Colonel Pievet, 5 June 1917, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 8, File 4, C.B. 15/65, LAC.

"an effective Anglo-French lessons learned partnership."[123] 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).[124] 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 engagements, 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."[125] 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."[126] To further suppress German batteries, the fire plan stated, "a free use will be made of 4.5" and 60-pdr. gas shell[s]."[127] 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 neutralised between forty and sixty-three hostile batteries of an estimated 102

[123] Fox, *Learning to Fight*, 142.
[124] Marble, *British Artillery on the Western Front in the First World War*, 183.
[125] WD, Canadian Corps Heavy Artillery, 4 August 1917, RG9-III-D-3, Vol. 4973, File 561, LAC.
[126] Counter-Battery Office, "Canadian Corps Artillery Order No. 39," 1, 1 August 1917. RG9-III-C-1, Canadian Corps Headquarters Royal Artillery, Vol. 3916, Folder 54, File 9, LAC.
[127] 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, RG9-III-D-3, Vol. 4957, File 504, LAC.

battery positions.[128] 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.[129] 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.[130] At Hill 70, McNaughton and the CBO incorporated the lessons from Vimy and applied newer methods like gas for neutralisation 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 OR continued. Terrain, short planning cycles, poor intelligence and worn-out guns all hindered counter-battery work.[131] The morale of the gunners suffered as well. McNaughton recalled, "Orders were being given to fire ammunition that was never, in fact, being fired."[132] 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."[133] Unlike earlier operations, the report mostly relied on anecdotal evidence:

[128] CBO, C.B. 7/27, "Weekly Intelligence Summary of 16-22 August 1917," 2, 23 August 1917, RG9-III-D-3, Canadian Corps Headquarters Royal Artillery, Vol. 3899, Folder 12, File 1, LAC; 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 an excellent 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), 102-36.

[129] Nicholson, *The Gunners of Canada*, 297.

[130] CBO, C.B. 7/27, "Weekly Intelligence Summary of 16-22 August 1917," 1, 23 August 1917, RG9-III-D-3, Canadian Corps Headquarters Royal Artillery, Vol. 3899, Folder 12, File 1, LAC.

[131] 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, RG9-III-D-3, Vol. 4957, File, 504, LAC.

[132] "Flanders Fields Transcripts," Tape 6, 15-16, 17 January 1963, MG30-E133, McNaughton Papers, Vol. 358, LAC.

[133] 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, RG9-III-D-3, Vol. 4957, File, 504, LAC.

Gen. Morrison, G.O.C. Artillery and Railway and Staff. Battle of Passchendaele. November, 1917. [Library and Archives Canada PA-002177]

> [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.[134]

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.[135] The pigeon arrived at the CBO in half an

[134] 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," 30, 21 December 1917, RG9-III-D-3, Vol. 4957, File, 504, LAC.
[135] "Flanders Fields Transcripts," Tape 7, 5, 17 January 1963, MG30-E133, McNaughton Papers, Vol. 358, LAC.

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. Artillery would not 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 ANZAC counter-battery methods. "It is almost impossible, from the Records left by the Corps which the Canadian Corps relieved," CBO reports stated, "to establish any comparison between the results of Counter Battery Intelligence obtained this week with those obtained last week."[136] Sound-ranging and flash-spotting sections had difficulty keeping up with the infantry, so intelligence collection depended almost 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.[137] 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 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 OR and tweak the counter-battery system. During this period, the Canadian Corps artillery had the opportunity to carry out training and "experimental work."[138] And they were not alone. Sound-

[136] Lieutenant L.P. Napier, C.B.7/36/1, "Memorandum from CBSO Canadian Corps to GOC RA Canadian Corps," 25 October 1917, MG30-E81, Morrison Papers, Vol. 4, Materiel, Hostile Batteries, LAC.
[137] Major-General E.W.B. Morrison, "Operations of the Canadian Corps during October 1917," 8, n.d., MG30-E81, Morrison Papers, Vol. 2, Artillery Corps Operations, LAC.
[138] Artillery Corps Notes and Pamphlets, "The Canadian Artillery in the Great War," 8, n.d. MG30-E81, Morrison Papers, Vol. 2, LAC.

ranging sections held regular conferences with the other sections to disseminate new ideas and share best practices.[139] 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."[140] Second Army listed eighteen points to be addressed. Questions that asked for an "appreciation," "estimated effect" and "available figures" all required OR 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.[141] It also helped interoperability. British guns frequently supported the Canadian Corps, but standardised 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."[142]

Collaboration between the BEF and French Army continued 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.[143] GHQ sent an officer to attend this lecture and distributed his notes across the BEF. In particular, one observation noted by the French gunners

[139] Innes, *Flash Spotters and Sound Rangers*, 153.

[140] R.A. Canadian Corps, 760/21-6, "Questionnaire on Experience Gained While on Second Army Front," 20 November 1917, RG9-III-C-1, Canadian Corps Headquarters Royal Artillery, Vol. 3915, Folder 50, File 3, LAC.

[141] 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. Lieutenant-Colonel A.G.L. McNaughton, C.B. 497/3-3, "Artillery Contact Aeroplanes during Mobile Warfare," 29 April 1918, MG30-E81, Morrison Papers, Vol. 4, Materiel, Artillery Contact Aeroplanes, LAC.

[142] "Flanders Fields Transcripts," Tape 2, 13, 17 January 1963, MG30-E133, McNaughton Papers, Vol. 358, LAC.

[143] 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, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3921, Folder 5, File 1, LAC.

was later replicated by the Canadians during the Hundred Days. "The Germans had a considerable strength in artillery," the French noted on their assault at Malmaison, "… 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."[144] Forcing guns to move was just as effective as neutralising them with gas or high explosive and many of the infantry penetrations 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 their OR. First, McNaughton and his team did not work in typical laboratory conditions. The German Army was a first-class enemy that was evolving and innovating its own artillery and counter-battery methodology.[145] On several occasions, German gunners won the day and lessened the CBO's ability to measure their own effectiveness. 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.[146] Second, the CBO staff and accompanying heavy guns 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 and long-term exchanges with enemy guns. Being static on a single front 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 OR.

Consequently, 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

[144] Headquarters *Groupe d'armées du Nord*, V.B. 17, "Artillery Notes on the Battle of La Malmaison Attack," 3, 6 November 1917, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3921, Folder 5, File 1, LAC.

[145] Strong and Marble, *Artillery in the Great War,* 125-127, 153-154.

[146] CBO, C.B. 7/26, "Weekly Intelligence Summary of 9-15 August 1917," 1, 16 August 1917, RG9-III-D-3, Canadian Corps Headquarters Royal Artillery, Vol. 3899, Folder 12, File 1, LAC.

the burst.[147] 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.[148] 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.

After-action OR 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 target representing a dugout, trench junction or cable centre.[149] The results proved disappointing. Out of every one hundred predicted rounds fired at the target, only 0.2 to 1.5 rounds impacted within the fifty-yard-by-ten-yard target.[150] The report noted: "the Errors introduced in Map shooting are very large, and the expectation of hitting a Target is consequently

[147] WD, Canadian Corps Survey Section, 8 June 1918, RG9-III-D-3, Vol. 5006, File 697, LAC.

[148] Canadian Corps General Staff, G.632/23-9, "Report on Variations in Prismatic Compass Bearings Caused by Respiratory and Helmet," 23 July 1918, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 7, File 4, LAC.

[149] 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, MG30-E81, Morrison Papers, Vol. 4, Materiel, Artillery Contact Aeroplanes, LAC.

[150] CBO, C.B. 636/20, Appendix D, "Accuracy of Fire Based on Appendix 'B' and Range Tables of the Various Calibres," 17 June 1918, MG30-E81, Morrison Papers, Vol. 4, Materiel, Artillery Contact Aeroplanes, LAC.

reduced to a low figure."[151] Interestingly, the test also determined that firing artillery in enfilade, which was the preferred method, offered no discernible advantage for accuracy over engaging a target frontally.[152] Still, artillery is an area suppression weapon and not all rounds need to impact accurately on the target to achieve neutralisation 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 emphasised neutralisation.

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.[153] 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.[154] In his own words, he intended to "swamp" the German guns with neutralising fire.[155] Statistically, some of these rounds had to strike the target and a lot of close-enough rounds would have had some neutralising 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

[151] 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, MG30-E81, Morrison Papers, Vol. 4, Materiel, Artillery Contact Aeroplanes, LAC. These results are also comparable to the data collected by No. 2 Operational Research Section 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.

[152] General Staff, General Headquarters, *SS139/4 Artillery Notes No. 4 – Artillery in Offensive Operations* (London: His Majesty's Stationery Office, February 1917), 26-28.

[153] WD, GOC RA Canadian Corps, 31 July 1918, RG9-III-D-3, Vol. 4957, File 504, LAC. 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.

[154] CBO, C.B. 872/4-2, "General Notes on Operations Commencing August 8th, 1918," 22 August 1918, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3923, Folder 10, File 4, LAC.

[155] Lieutenant-Colonel A.G.L. McNaughton to his wife, 15, 7-8 August 1918, MG30-E133, McNaughton Papers, Series I, Vol. 2, War Diaries – Miscellaneous, LAC.

[mean point of impact] were on target."[156] Historian Shane Schreiber accurately summarised 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."[157] Some German batteries laid 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.[158] Overrunning and forcing evacuation was vital, as it would render enemy guns more vulnerable to destruction in subsequent engagements since they would occupy less prepared positions.[159]

The after-action review from Amiens also portended many of the findings of OR 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.[160] By 1918, fires still supported the close battle but principally focused on the enemy's depth, particularly command and control nodes and artillery.[161] British and Canadian artillery fought the deep battle with heavy guns and the cooperation of the RAF, which conducted early forms of close air support and

[156] CBO, C.B. 872/4-2, "General Notes on Operations Commencing August 8th, 1918," 1, 22 August 1918, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3923, Folder 10, File 4, LAC.

[157] Schreiber, *Shock Army of the British Empire,* 44.

[158] CBO, C.B. 843/4-2, Memorandum on Employment of Artillery at Amiens, 19 August 1918, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3923, Folder 10, File 4, LAC.

[159] 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), 228-29.

[160] CBO, "Notes on Counter-Battery Support and Capture of Mont Houy by the Canadian Corps, 1 November 1918," 3 February 1919, RG9-III-C-1, Canadian Corps Headquarters Royal Artillery, Vol. 3923, Folder 11, File 8, LAC.

[161] 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), 31.

battlefield air interdiction.[162] OR 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. In contrast to earlier periods in the war, the operational art exceeded what technology could do.

After Amiens, high operational tempo limited the ability of the staff to conduct after-battle reconnaissance and prepare analytical reports like they had 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.[163] 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.[164] 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 Lt.-Col. 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."[165] 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

[162] Schreiber, *Shock Army of the British Empire,* 44.
[163] Nicholson, *Official History of the Canadian Army in the First World War*, 555-556.
[164] Nicholson, *The Gunners of Canada*, 367.
[165] Marble, *British Artillery on the Western Front in the First World War*, 241.

60 pounder in action along side Arras-Cambrai road. Advance East of Arras. August, 1918. [Library and Archives Canada PA-003029]

and Italian campaigns of the Second World War.[166] During the 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 could not keep up with the advance.[167] 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 issuing wireless sets to flash-spotters.[168]

[166] CBO, C.B. 18/4-4, "Organization and Procedure of the Counter-Battery Staff Office," 25 January 1919, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 7, File 10, LAC; "Discussion of Evidence as to the Organization of Heavy Artillery for an Imperial Army," 2, 3 April 1919, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 7, File 10, Canadian Corps, B.M. 140/205, LAC; and Nicholson, *The Gunners of Canada,* 367.
[167] Innes, *Flash Spotters and Sound Rangers*, 84, 147.
[168] "Flanders Fields Transcripts," Tape 5, 6-7, 17 January 1963, MG30-E133, McNaughton Papers, Vol. 358, LAC.

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, rendering their pieces less vulnerable to counter-battery fire and easier to withdraw.[169] But, siting their guns farther back meant that they could not target infantry advancing through their forward defensive zone. With German artillery ammunition stockpiles running low in 1918, the artillery had strict engagement criteria to conserve ammunition and avoid being detected by the Allies.[170] 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 plotted, but only twenty-two counter-battery engagements carried out.[171] 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 neutralisation 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 maximise the range into the Anglo-Canadian depth. This positioning only made their guns easier to target. No registration or destructive fire missions proceeded the counter-battery programme that began ten minutes before zero

[169] Strong and Marble, *The Artillery in the Great War*, 153.

[170] Strong and Marble, *The Artillery in the Great War*, 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* 59, 3 (September 2005): 280.

[171] Reconnaissance Officer for GOC RA First Army, "Information Obtained from Captured German Counter-Battery Maps," 1 October 1918, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3921, Folder 6, File 1, LAC.

hour, 0515hrs 1 November.[172] They were not necessary. The fire plan neutralised known hostile batteries while aircraft or FOOs called for fire on German guns and other high-payoff targets that the CBO had not previously identified, all to great effect.[173] These were all lessons learned at Amiens and the report produced on Valenciennes explicitly mentioned this link.

The counter-battery system perfected by McNaughton lasted through the Second World War. In January 1919, Crerar prepared a report on the organisation and procedures of the CBO in the Canadian Corps for submission to GHQ.[174] The report was well-received. "Got an acknowledgement from G.H.Q. on the C.B. report…" McNaughton wrote his protégé, "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."[175] The Royal Artillery's counter-battery techniques during the Second World War 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.[176] 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

[172] CBO, "Notes on Counter-Battery Support and Capture of Mont Houy by the Canadian Corps, 1 November 1918," 3-4, 3 February 1919, RG9-III-C-1, Canadian Corps Headquarters Royal Artillery, Vol. 3923, Folder 11, File 8, LAC.

[173] WD, Canadian Corps Heavy Artillery, 1 November 1918, RG9-III-D-3, Vol. 4974, File 561, LAC.

[174] CBO, C.B. 18/4-4, "Organization and Procedure of the Counter-Battery Staff Office," 25 January 1919, RG9-III-C-1, Canadian Corps Headquarters Heavy Artillery, Vol. 3922, Folder 7, File 10, LAC. 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.

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

[176] 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.

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."[177]

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."[178] Brooke emphasised the scientific methods required for counter-battery work to his students and later, as CIGS during the Second World War, authorised the formation of OR sections to serve within operational headquarters in Italy and Northwest Europe.[179] He stressed that neutralising 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."[180] 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."[181] As commander of First Canadian Army during the Second World War, McNaughton again took an interest in OR and supported the formation of OR units. 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

[177] Headquarters Third Army Corps, American Expeditionary Forces Germany, to Lieutenant-Colonel H.D.G. Crerar, 27 January 1919, MG30-E157, Crerar Papers, Vol. 18, Field Messages and Correspondence, LAC.
[178] Bailey, "British Artillery in the Great War," 38-39.
[179] On Brooke's time as Directing Staff at Camberley, see David Fraser, *Alanbrooke* (New York: Atheneum, 1982), 86-92. Copp, ed., *Montgomery's Scientists*, 18.
[180] "Evolution of Artillery in the Great War 1914-1918," 478, Alanbrooke Papers, 3/10, LHCMA.
[181] McNaughton, "Counter-Battery Work;" and "The Development of Artillery in the Great War."

meagre few paragraphs of *FAT* that they may or may not have read in 1914.

Five principal conclusions are evident from this assessment of the scientific work conducted by McNaughton and the staff of the CBO. First, they conducted OR as we now understand it. Second, the Canadian Corps and the BEF were learning organisations that gave these officers the support they needed to conduct their research. Third, the findings of their OR reports were widely disseminated across the BEF, the French Army, the United States 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 analysed. For instance, the limitations of predicted fire needed to be understood before a counter-battery plan predicated on predicted fire could be executed. Last, OR 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 and they mostly did benefit from OR during the Second World War.

Neither Andrew McNaughton nor the gunners of the CBO 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. These artillerymen 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 mastered counter-battery fire to attrit the German Army and strike their most important systems. The application of OR to counter-battery work 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.[182]

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 technology and gunnery techniques, lack of intelligence and decentralised 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 operational research section. OR 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. 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 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

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

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*. The American III Corps asked Crerar for a copy of the report he had prepared for GHQ on the organisation and procedures of the Canadian Corps CBO so that they could structure their counter-battery capability based on the Canadian example. OR 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.

OR enabled the Canadian Corps to manage and understand the effects of its weapon systems. While the development of flash-spotting and sound-ranging techniques were feats, they still had to be integrated into a targeting system to attack identified hostile batteries. The report prepared by McNaughton after Vimy highlighted the staffing shortfalls in the CBO, which made it difficult to analyse 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.

The history of OR needs revision and further inquiry. While this study examined the work of McNaughton and the CBO of the Canadian Corps, other officers serving in the headquarters also conducted OR. 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. Several key personalities associated with OR in the Canadian Corps during the Great War, including Charles Darwin, John Dill, Brooke and McNaughton, had a direct role in the formation of army OR 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 strong BEF that 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 OR to solve these problems and support the decision-making of commanders with science. Also required is an assessment of the legacy of their scientific enquiries to refine the trajectory of OR. To do so, historians must move beyond semantics and recognise earlier forms of OR that predate its supposed origins in the mid-1930s. Instead of looking for the term "operational research," scholars should look for the indicators of OR itself.

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