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Operational Research and the Royal Canadian Air Force Eastern Air Command's

Search for Efficiency in Airborne Anti-Submarine Warfare, 1942-1945

By

Dean C. Ruffilli

B.A. (Honours), Huron College, The University of Western Ontario. 2000

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Abstract

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Dean C. Ruffilli

Advisor

Wilfrid Laurier University, 2001

Prof. T. Copp

This thesis analyses the contributions of operational research to the work of the Royal Canadian Air Force Eastern Air Command during the Second World War. The efforts of the handful of Canadian operational researchers in the Allied campaign against the German U-boat force, although having produced only modest results, did make a small but important contribution to the war which have been neglected by historians.

The use of aircraft against submarines began during the First World War when both technologies were still in their infancy. Although initial results were poor, the handful of sinkings by aircraft demonstrated its potential as a counter to the seemingly invulnerable submarine. Great Britain, with its vulnerable seaward lines of communication, emerged by 1918 as the leader in the development of anti-submarine aircraft, largely through the co-operative efforts of scientists and airmen to refine and advance the concept of airborne anti-submarine warfare. Although much of this knowledge was squandered through the neglect of the Royal Air Force's land-based anti-submarine aircraft force during the inter-war period, the early introduction of scientists to the field of airborne anti-submarine warfare provided a precedent for a future revival of this relationship.

The techniques of operational research, first promulgated during the British experiments with radar during the 1930s, were, by 1941, applied to assist Royal Air Force

Coastal Command in its campaign against the German U-boats which were taking an ever-increasing toll of Allied shipping. The work of P.M.S. Blackett and his staff at Coastal Command Operational Research Section would serve as the foundation upon which Eastern Air Command's Operational Research Section (ORS) would be constructed when it was created in November 1942.

Under the leadership of Professor Colin Barnes and later Dr. J.W.T. Spinks, Eastern Air Command ORS produced a series of studies which explored issues of concern to the Command's anti-submarine (bomber-reconnaissance) squadrons. They used methodologies adapted for Canadian purposes from the original British and American models. These studies of diverse topics such as bombing accuracy and search techniques for missing aircraft, along with the squadron and Command efficiency data collected in operational planning role assumed by Eastern Air Command ORS (one which had earlier been rejected as unproductive clerical work by Coastal Command ORS), characterized the growth of Canadian-oriented operational research during the final three years of the Second World War. The work of the handful of civilian and military operational researchers at Eastern Air Command ORS, although threatened with elimination during the deep cuts to the military in the immediate post-war years, survived to form part of the body of Canadian military operational research techniques which has assisted the Canadian Forces in their duties throughout the last half-century.

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Dean C. Ruffilli

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Preface: Operational Research Defined

Air Ministry Operational Research Centre, 1942:

“Numerical thinking about operations, with the aim of formulating conclusions which, applied to operations, may give a profitable return for a given expenditure of effort.”

(From Air Ministry, The Origins and Development of Operational Research in the Royal Air Force (London: Her Majesty’s Stationery Office, 1963): xvii.)

Professor C.H. Waddington:

“The application of scientific method (i.e. quantitative, analytical thinking with empirical checking) to the problems of an executive authority.”

(From Professor C.H. Waddington, O.R. In World War 2: Operational Research Against the U-boat (Unpublished manuscript, 1946; London: Elek Science, 1973): 10.)

Introduction

When Great Britain and its dominions went to war in 1939 the supremacy of the Royal Navy seemed to guarantee control of the seas. The German surface fleet was large enough to force the Royal Navy to maintain a blockade and although the Kriegsmarine could attempt occasional breakouts, little more was to be expected. The German U-boat arm, which had threatened the Atlantic lifeline in the First World War, was scarcely more advanced than it had been in 1918 and could deploy less than 50 ocean-going U-boats. Royal Navy destroyers, employing Asdic (Sonar in American parlance) to locate submerged U-boats and RAF Coastal Command based in Northern England and Scotland were poised to find and destroy U-boats which would have to enter the Atlantic via the German North Sea Ports. This at least was the prevalent theory!

During the Great War, Britain had begun development of anti-submarine aircraft but post-war disarmament and RAF priority to bomber and later fighter-interceptor aircraft meant little attention was paid to Coastal Command until 1937. The German threat to merchant shipping forced the Air Ministry to concede that “trade protection, reconnaissance and co-operation with the Royal Navy” were the primary tasks of Coastal Command and new equipment was required.¹ The replacement of the short-range (250 miles) Anson with the American-built Lockheed Hudson and the introduction of the Sunderland flying boat reflected this new priority.

After the fall of France in June 1940, the rapidly expanding U-boat fleet, using bases on the Atlantic Coast, posed a new threat to Britain’s Atlantic lifeline, forcing the Royal Navy and RAF Coastal Command to develop new techniques as well as new weapons to combat the U-boat menace. One of the most important developments was the decision to

appoint P.M.S. Blackett, a physicist working with Anti-Aircraft Command's operational research group, to the post of Scientific Advisor to Coastal Command. Blackett joined the Command in March 1941 and in December published "Scientists at the Operational Level," a paper which outlined the early achievements of his operational research team and argued for the transfer of "the best scientists from technical establishments to the operational commands."² Blackett moved to the Admiralty in 1942 but not before establishing a strong OR team at Coastal Command.

At the outbreak of hostilities the Royal Canadian Air Force was entirely unprepared to play a major role in anti-submarine warfare. Eastern Air Command, with headquarters at Halifax, lacked adequate equipment, doctrine and training. Between 1939 and 1942 improvements, especially with respect to aircraft quality, were made and in the summer of 1942 several Canadian operational research sections were established including one for Eastern Air Command.

The primary purpose of this thesis is to analyse the contributions of operational research to the work of RCAF Eastern Air Command. The argument of the essay is that Canadian operational research made a small but important contribution to the war against the U-boat which has been neglected by historians. The analysis and argument are presented in five chapters. Chapter 1, The Nature of Airborne Anti-Submarine Warfare, establishes the dimensions of the problem confronting the Allied air forces in the First and Second World Wars. Chapter 2 reviews the development of operational research in RAF Coastal Command. Chapter 3 investigates the role of the RCAF's Eastern Air Command in anti-submarine warfare and describes the reasons for the development of a specifically Canadian operational research capacity. Chapter 4, the heart of the thesis.

offers a detailed examination of the contribution of Eastern Air Command operational research to the war against the U-boat in the Northwest Atlantic. Chapter 5 explores a specific aspect of EAC operational research, the study of operational efficiency. The conclusion provides a summary of that achievement and suggests that the wartime work of the OR scientists laid the foundation for post-war operational research in the Canadian forces. This thesis is based upon research carried out in the National Archives and the Directorate of History and Heritage, Department of National Defence.

Very little has been written about RAF Coastal Command's OR experience during the Second World War while the activities of the RCAF's operational research sections have not been explored in any great detail. This is surprising given the post-war rise of operational research as a major field of academic study with applications in business, industry, government and the military. Indeed, except for aircraft studies in the Canada's Wings series and the Department of National Defence Directorate of History's Official History of the RCAF during the Second World War, the RCAF's contribution to victory over the U-boat has been largely passed over by historians. The literature regarding Canadian airborne anti-submarine warfare operational research activities during the Second World War and its British progenitor falls into two distinct categories. One is the product of participants in wartime operational research or those acquainted with the ORS's activities who sought to publicize and record the range of activities of the OR researchers as a form of commemoration. The other is the product of a handful of historians who have explored more recently the Anglo-Canadian airborne anti-submarine operational research activities in varying degrees of detail. They sought either to provide a more complete picture of the air component of the Battle of the Atlantic or to examine

the activities of the Coastal Command and Eastern Air Command ORS's in the broader context of operational research during the Second World War.

The British operational researchers and their associates provided the earliest body of airborne anti-submarine operational research literature. In 1946, Professor C.H. Waddington, who had been appointed to the Coastal Command ORS in 1942, drafted in conjunction with several of his wartime colleagues, a monograph detailing the activities of the section from 1941-45. This monograph, entitled OR in World War 2: Operational Research against the U-boat, was not published until 1973 because of security considerations stemming from the growing Cold War.³ Although Waddington advises the reader that his book is “intended to provide a concrete example which will illustrate and explain the meaning of the concept of ‘operational research’,” it is also, in fact, a highly valuable primary source for historians given Waddington’s detailed discussion of all of the major areas of anti-submarine warfare study undertaken by the Coastal Command ORS and the findings contained within the reports the section produced.⁴ Waddington explores the nature and unique problems of airborne anti-submarine warfare by weaving the operational record into his discussion of the various studies on diverse subjects such as organization of effort, radar and U-boat density. He does not explicitly refer to Eastern Air Command ORS’s activities but nevertheless, his book is extremely valuable as a firsthand narrative by a participant in the activities which formed the foundations of the Canadian researchers’ activities in 1943-45.

Similarly, in 1963, the British Air Ministry published an official history of wartime RAF OR activities based “on the accounts of individual operational research sections prepared for the Deputy Director of Science at the Air Ministry after the war.”⁵ This

source provides a general survey of the broad range of British air-related operational research from Fighter Command's early radar studies during 1941 to Bomber Command ORS's large-scale investigations into bombing efficiency and the activities of the various ORS's in all home and overseas commands. The activities of Coastal Command ORS are discussed in a single chapter in conjunction with the studies undertaken by similar sections in Transport and Flying Training Commands. All of the major aspects examined in depth by Professor Waddington are present although not in any detail. There is, however, a very useful series of appendices provided which reprint in their entirety four seminal wartime ORS papers including Professor P.M.S. Blackett's seminal 1941 paper "Scientists at the Operational Level" which served as the theoretical foundation for wartime operational research.

Professor Blackett's key role in the formation of Coastal Command ORS in March 1941 is explored in P.M.S. Blackett: A Biographical Memoir produced in 1976 by Sir Bernard Lovell on behalf of The Royal Society.⁶ This source provides a limited but informative discussion of the research activities of Coastal Command ORS but is more useful in detailing Professor Blackett's First World War naval service, primarily in surface anti-submarine operations and its influence on his development as a scientist and operational researcher keenly aware of the needs of the sailors and airmen attempting to combat the U-boat.⁷

Canadian operational researchers have been less forthcoming in publishing memoirs of their wartime activities. Two short summaries of Canadian operational research establishments are housed at the Department of National Defence Directorate of History where they rarely see the light of day. Dr. N.W. Morton's "Brief History of the

Development of Canadian Military Operational Research,” provides only the most limited sketch of the RCAF’s operational research with Eastern Air Command ORS receiving only a small portion of one paragraph.⁸ However, Morton does briefly explore the postwar decommissioning and subsequent rebuilding of the Canadian ORS’s, emphasizing the need for continuity in the provision of operational research for the Canadian military in an increasingly technical age.⁹ Squadron Leader Peter M. Millman’s edited volume, “Operational Research in the RCAF During World War II,” is altogether more useful. Indeed, this is a valuable primary source as the component sections were drafted by the leading operational researchers themselves such as Professor J.O. Wilhelm (RCAF Headquarters OR Centre) who provided a useful summary of the diverse operational research activities of the RCAF.¹⁰ Although there is no section specifically exploring the Eastern Air Command ORS, the history of the Section’s investigation into searches for missing aircraft is provided by Professor J.W.T. Spinks (Western Air Command and Eastern Air Command ORS). As well, a short inquiry into the activities of Western Air Command ORS provides an interesting contrast in the varied investigations conducted by the Home War Establishment operational research sections.¹¹

In 1950, the National Research Council, which recruited many Canadian operational researchers during the Second World War, commissioned Wilfrid Eggleston to write a general history of its scientific research for the Canadian military.¹² The focus of this source is on the technological/experimental research undertaken by the NRC. Operational research is not explored, a rather puzzling omission considering the NRC’s role as an umbrella organization covering all aspects of the scientific contribution to the Canadian war effort. A more recent work, edited by George R. Lindsey, a wartime Army

operational researcher and postwar Chief of Operational Research and Analysis, Department of National Defence, explores many of the same areas discussed by Eggleston but often in the words of wartime scientists who participated in the research they describe.¹³ There are three chapters devoted to operational research (two written by Lindsey himself) but Eastern Air Command ORS is only explored as part of a general summary of the wartime operational research conducted by all three Canadian services.¹⁴

Current historical investigations into Anglo-Canadian wartime operational research activities again tend to devote only limited attention to the work undertaken by Eastern Air Command ORS and in Britain, by Coastal Command ORS. Regarding the latter, Joseph McCloskey has published two superb articles which trace the development of British operational research from its very roots during the First World War through the growth and refinement of operational research during the Second World War.¹⁵ In the second article, “British Operational Research in World War II,” McCloskey explores the activities of Coastal Command ORS and concludes it had an unusually influential position in the ‘halls of command’ which he attributes to the “open-mindedness” of Coastal Command senior officers as well as to the high quality of the operational researchers themselves.¹⁶

Similarly, Terry Copp briefly explores the origins of operational research in the introduction to his edited volume, Montgomery’s Scientists: Operational Research in Northwest Europe- The Work of No. 2 Operational Research Section with 21 Army Group, June 1944 to July 1945 while also providing a particularly good discussion of Professor Blackett’s early operational research activities for Lieutenant-General Sir Frederick Pile’s Anti-Aircraft Command during 1940-41.¹⁷

The most comprehensive examination of the airborne anti-submarine warfare studies undertaken by Eastern Air Command ORS is to be found in W.A.B. Douglas' second volume of The Official History of the Royal Canadian Air Force.¹⁸ The discussions of the Eastern Air Command ORS, given the scope of the narrative which covers all aspects of the Home War Establishment, are by necessity quite short and are integrated in Douglas' analysis of the operational activities of the Command versus the U-boat.¹⁹ Douglas does note the valuable contribution the Eastern Air Command ORS made to the Canadian policy of hunting U-boat contacts to exhaustion (code named 'Salmons') but perhaps his greatest contribution to the literature on this area of Canadian operational research was the provision of complete footnotes which provide a priceless resource for further archival research.²⁰

Chapter 1- The Nature of Airborne Anti-Submarine Warfare

In order to understand more fully the origins of the Eastern Air Command Operational Research Section and the investigations which it undertook, we need to examine the evolution of airborne anti-submarine warfare and the tremendous increase in sophistication in the methods used to hunt submarines from the air. The early British explorations into the suitability of aircraft as sub hunters during the great period of aeronautical experimentation in the decade between the Wright Brothers first powered flight in 1903 and the outbreak of the First World War gave the island nation an early lead in devising an airborne counter to a weapon which in certain circles, was viewed as a threat to British sea communications.

However, as would be the case over most of the next quarter century, the technology of the aircraft simply was not up to the rigors of increasingly lengthy open-ocean patrols. During the First World War, all of the major combatant nations used aircraft (and in some cases, dirigibles) to varying degrees of success against submarines, although the potential of the aircraft seemed ultimately to outstrip its real capabilities. The postwar era witnessed rapid development in aircraft technology, with designers in Great Britain, the United States, Italy, and latter, Germany, competing to develop longer ranged and faster aircraft which would have equal application as civilian passenger aircraft and as bomber and maritime patrol aircraft.

The development of the latter was largely confined to the nation most at risk from submarine attacks upon its shipping, Great Britain. The interwar period marked the nadir of British airborne anti-submarine expertise as many of the developments and lessons of the First World War were cast aside due to the impact of crippling budgetary restrictions

and a lack of clarity regarding the wartime role of Britain's maritime aircraft, whose operational organization was clouded by jurisdictional disputes between the Admiralty and the Air Ministry which were resolved only in 1936 when Royal Air Force Coastal Command was formed. The emphasis on the value of surface ships equipped with Asdic to the virtual exclusion of airborne anti-submarine efforts ensured that in September 1939, Coastal Command was the poor cousin in the British war effort, lacking proper equipment and suffering from an ill-defined mission. The Royal Canadian Air Force was even in more dire straits upon the outbreak of the Second World War, lacking almost all of the essentials in airborne anti-submarine warfare: aircraft, trained personnel, airbases, effective tactics tailored to the unique Canadian area of operations and a properly defined role and mission. These crippling limitations persisted in both the RAF and RCAF through the first three years of the war, ensuring that airborne anti-submarine warfare remained much as it was in the First World War: a haphazard affair based largely on intangibles such as skill, daring and a bit of luck.

I

During the first months of 1912, at the behest of a British Admiralty committee, a British submarine lieutenant, Hugh Williamson, drafted what became the first in-depth exploration of the possibilities for the use of aircraft in anti-submarine warfare.¹ The level of detail and complexity in Williamson's analysis is quite remarkable when one considers that the submarine was at best seen in naval circles as a quaint, often unreliable auxiliary to the main battle fleet. Indeed, as historian Alfred Price observes in Aircraft Versus Submarine, "the unreliability of the internal combustion engine meant that any but the shortest overseas reconnaissance was a matter of some risk; just two years earlier [1909]

Louis Bleriot's twenty-five mile flight across the English Channel had been considered worthy of a £4,000 cash prize."² Yet Lieutenant Williamson, as Price notes, "was almost uniquely fitted for the role of poacher turned gamekeeper: only one other submarine officer in the Royal Navy had qualified as a pilot, and there can have been few in other navies with both of these still-unusual skills."³ Williamson's paper, entitled "The Aeroplane in use against Submarines," described many of the concepts which have become the first principles in airborne anti-submarine warfare. Envisioning a monoplane capable of flying for five hours with a bombload of three hundred pounds and a crew of two (which was almost beyond the realm of possibilities given the state of aircraft design in 1912), Williamson hit upon "precisely the manner in which the aircraft was to exert its greatest pressure on the submarine during the two world wars which were to follow: by forcing a boat to submerge, in other words by denying it free use of the surface, the submarine could temporarily be neutralised."⁴

Williamson did not view aircraft as being capable of land-based operations against submarines. Instead, his vision involved a primitive aircraft carrier, a converted obsolescent *Monmouth* Class armoured cruiser fitted with a flight deck aft which would serve not only as a mobile base for its aircraft but would also force a sighted submarine to dive with its gunfire in order to allow the aircraft to attack with depth-fuzed bombs without risk of return fire from the submarine.⁵ For his effort, Williamson "received a letter from the Lords Commissioners of the Admiralty signifying 'an expression of their appreciation'. Also, as a special case, Williamson was later permitted to qualify in both the submarine and the aviation branches of the Royal Navy."⁶

By the outbreak of the First World War, only the British and Germans possessed sizeable naval air arms with the Royal Navy having “fifty-two seaplanes, and seven non-rigid airships of which three were capable of oversea patrols” while “the Imperial German Navy had thirty-six seaplanes, and one rigid airship.”⁷ In contrast, most of the major naval powers possessed large forces of submarines, or more accurately, submersibles as their low battery capacity combined with low underwater speed made lengthy periods underwater impractical.⁸ As a result, the battleground between aircraft and submarine throughout both world wars was to be on the surface or, if an aircraft caught a submarine in the process of diving, just below the waves.

The submarine war began soon after the first shots were fired in August 1914. Initially, both British and German submariners operated with relative impunity, with the former sinking “the German cruiser *Hela*, the destroyer *S-116*, and the Turkish battleship *Messoudieh*” while U-boats scored several successes including the British battleship *Formidable* and *U-9*’s remarkable feat given the technology of the day of sinking “in a space of just under an hour... the British cruisers *Cressy*, *Aboukir* and *Hogue* off the Dutch coast.”⁹ The airborne response of both the British and German navies to the submarine threat, although intensive, did not yield any sinkings. The Germans, with their fleet of long range Zeppelins, made the first airborne attack on a submarine when “on Christmas Day 1914 the Zeppelin *L-5*... came upon the British submarine *E-11* (Nasmith); the latter was able to dive before the attack could develop, and the two bombs released by the airship exploded harmlessly on the surface.”¹⁰ Neither British nor German aviators scored any confirmed success against a submarine during the first two years of the war.

The honour of the first sinking of a submarine by an aircraft was claimed by the Imperial Austro-Hungarian Navy. Following the outbreak of hostilities, the dual monarchy's navy created its own naval air arm equipped primarily with Lohner flying boats to operate against Allied submarines and surface vessels in the Adriatic Sea.¹¹ As in the British and German experience, much of the Austrian naval air arm's flying was devoted to fruitless patrols during which the crew strained to catch a glimpse of anything resembling a submarine. However, on the 15th of September 1916, the naval airmen were rewarded with the report by one of their fellows of "an unidentified submarine on the surface near the Austrian naval base at Cattaro (now Kotor [in Croatia]) in the southern Adriatic."¹² Two Lohner flying-boats were dispatched to the location reported by the pilot but the crews found nothing and resolved to search the area. As Price remarks, "Forty minutes later their persistence brought its reward: Fregatten-Leutnant Baron von Klimburg, the observer in one of the aircraft, suddenly nudged his pilot and pointed to the unmistakable cigar-outline of a submarine beneath the glass-clear waters."¹³ Both flying boats dove to the attack and dropped four bombs on what they later discovered to be the French submarine *Foucault*. Three of the four bombs struck home, causing the submarine to dive out of control and only after a long struggle was the crew able to coax their crippled submarine to the surface, where after further airborne attacks, the commander ordered the stricken boat abandoned.¹⁴ Alfred Price concludes that "For the first time ever, attacking aircraft had inflicted lethal damage on a submarine in open water. From now on the notion of an aircraft to hunt and destroy submarines was no longer confined to the realms of theoretical possibility: it was an accomplished fact."¹⁵

On February 1, 1917, with over one hundred modern U-boats in service, the German government announced that its submarines would begin unrestricted attacks upon all shipping sailing in the seas surrounding the British Isles.¹⁶ The threat of this undersea blockade soon became apparent forcing the introduction of the convoy system.¹⁷ To assist in the protection of the convoys, the Royal Naval Air Service (RNAS) undertook a rapid expansion with new airships and American-built Curtiss Large America flying boats entering service during the first half of 1917. Canadians were to figure prominently in the RNAS's airborne anti-submarine operations, prompting official historian Sid Wise to observe that "whether through accident of posting, timing of arrival, or design (though there is no evidence for the latter), certain RNAS units eventually became heavily or even predominantly Canadian."¹⁸ A Canadian, Commander T.D. Hallam, commanded the Felixstowe 'War Flight' of Large America and Felixstowe F-2A flying boats which conducted the 'Spider Web' patrols in the North Sea during the final two years of the war resulting in several attacks on U-boats (but no confirmed sinkings).¹⁹ Two Canadians, Flight Sub-Lieutenants N.A. Magor and C.E.S. Lusk, achieved the single British aircraft-only kill of a submarine during the First World War. On 22 September 1917, Magor, Lusk and their two crewmen, operating their Large America out of the Royal Naval Air Station at Dunkirk on a protective patrol for the monitor *Terror* off Ostend, Belgium sighted an enemy submarine on the surface.²⁰ Magor and Lusk dropped two 230-lb bombs on what was later identified as *UB-32* which immediately heeled over and sank from the two direct hits.²¹ Wise comments that "to score two direct hits on such a narrow target from a height of 800 feet with the primitive aiming device of the time was a matter of good luck rather than good judgment."²² In any case, the aircraft had proved its

potential in anti-submarine warfare, as both a killer and deterrent but further development was needed to transform the fragile aircraft of 1914-1918 into long-range threats to submarines wherever they were located.

In an attempt to improve the lethality of the early anti-submarine aircraft, scientific assistance to the airmen began to be provided during the First World War, setting a pattern which would reach a sophisticated peak during the Second World War. Price recounts experiments undertaken by British researchers in 1915 to fit hydrophones to flying boats in an attempt to provide a more effective sighting system than the crews eyesight. He concludes that “in the event operational hydrophone searches were few and far between, and invariably unsuccessful; unless the U-boat commander was careless and made a lot of noise, the device rarely had a range greater than a few hundred yards.”²³ More sophisticated sensors to locate surfaced and submerged submarines would not be developed until the Second World War, but the introduction of scientists to the search for increased airborne anti-submarine effectiveness began in earnest during the First World War.

II

Unfortunately, many of the advances made by Britain not only in the area of airborne anti-submarine warfare but in air warfare generally were undone in the wave of drastic defence spending cuts undertaken in the wake of the Treaty of Versailles. By November 1918, the newly formed Royal Air Force possessed the most advanced airborne anti-submarine force in the world with several squadrons equipped with the Felixstowe F-2A flying boat. Of note is one RAF squadron, No. 246 , which was re-equipped in May 1918 with the Blackburn Kangaroo, a converted twin-engined land-based bomber which

demonstrated the utility of landplanes as maritime patrol aircraft with its 8 hour endurance and 920lb bombload carried internally (a novelty in 1918).²⁴ However, these revolutionary anti-submarine aircraft were quickly retired to serve as civilian transports as retrenchment took hold in the British armed services while the RAF, under the sway of Air Marshal Hugh Trenchard, embraced his vision of the supremacy of strategic bombing in an attempt to stave off moves by the other two services to reclaim their air arms sacrificed to the junior service in 1918. As John Terraine notes in The Right of the Line: the Royal Air Force in the European War 1939-1945, to appease the military cost-cutters such as Winston Churchill, “Trenchard was able to demonstrate that an air force could be (comparatively) cheap,” thereby saving the nascent service from an early demise.²⁵ The dominance of Trenchard and his circle of bombing advocates ensured that the majority of the RAF’s dwindling resources would be devoted to the bomber force, at the expense of the fighter and maritime co-operation squadrons.

Two factors made cuts to the RAF ‘Coastal Area’ (which controlled the dwindling number of maritime aircraft and airships) particularly appealing to both the RAF leadership and politicians searching for ways to reduce the defence budgets. As a component of the Peace of Versailles, Germany was forbidden in the naval peace treaty from constructing submarines.²⁶ The elimination of the largest undersea threat to Britain’s survival quickly ensured that, as Alfred Price observes, “with no visible threat to justify their retention, the vast sea and air anti-submarine forces diminished to a shadow of what they previously had been.”²⁷ Not satisfied with that step, the coalition government of David Lloyd George attempted to secure, albeit unsuccessfully, the complete abolition of the submarine as a naval weapon of war at the Washington Conference of 1921.²⁸

Dismayed by the failure to abolish the submarine, the British Admiralty began work on refining the submarine detection device for surface ships developed in 1917 by the Allied Submarine Detection Investigation Committee: Asdic.²⁹ As Price notes, "In the early 1930s the device entered service in the Royal Navy in quantity, and with skilled operators it performed impressively," adding that "in Britain the belief grew that the Royal Navy had found 'the answer' to the submarine."³⁰ These factors produced an atmosphere of complacency in Britain regarding undersea warfare, to the extent that the Royal Navy's Asdic-equipped destroyer flotillas appeared to many to not only have eliminated the submarine threat but also made the airborne anti-submarine aircraft obsolete.

As a result RAF Coastal Area drifted slowly but seemingly inexorably into oblivion during the late 1920s and 1930s only kept barely in existence by the Navy's requirement for maritime reconnaissance aircraft of longer range than their own carrier-based force. These aircraft were to be used in a reconnaissance and strike role against enemy surface raiders in the event of war, but little consideration was given to the use of aircraft in any meaningful way to assist Asdic-equipped destroyers in the anti-submarine role.³¹

In July 1936, in response to German rearmament, the Royal Air Force reorganized its squadrons into functional commands, bringing Fighter, Bomber and Coastal Commands into existence. The first commander of Coastal Command, Air Vice Marshal Sir Arthur Longmore, was faced with a most difficult situation. The smallest of the three front-line Commands, Coastal Command's strength in 1936 was barely adequate to undertake even the limited peacetime routine, consisting of only four flying-boat squadrons, two squadrons of land-based Avro Ansons and a squadron of decrepit Vickers Vildebeest biplane torpedo bombers.³² As part of the rapid rearmament programme undertaken over

the next three years, Coastal Command's strength would be built up with the formation of additional squadrons of Ansons, whose utility in the forthcoming conflict given a cruising speed and bombload inferior to the Blackburn Kangaroo of 1918 was questionable at best, and the addition of handfuls of long-range Short Sunderland flying boats and American-made Lockheed Hudson land-based patrol aircraft.³³ Indeed, the Anson, with its poor armament (2 .303 machine guns and four 100-lb bombs) and lack of performance was unsuitable for any duty other than uncontested reconnaissance; in fact its crews were instructed that "The Anson is a civil type of aircraft adapted for service purposes and is therefore restricted to the type of flying allowed within the normal civil category."³⁴

Yet when war was declared on September 3, 1939, the 'Faithful Annie', as the Anson's crews lovingly called their sedate mounts, was Great Britain's first line of defence against German U-boats. The Royal Navy, wishing to prevent avoidable shipping losses to marauding submarines, immediately implemented the convoy system whose demand for air escort strained Coastal Command's thin resources.³⁵ The first Coastal Command attack on a submarine occurred on the 5th of September by an Anson of No. 233 Squadron which was destroyed by shrapnel from its own bombs while the submarine, later found to have been British, escaped unharmed.³⁶ Indeed, 1939 was disappointing for Coastal Command, with a record of 57 sightings of German submarines but no kills or even assisted kills.³⁷

This poor performance was rooted in several factors. The limited resources of Coastal Command and its largely unsuitable aircraft certainly played a part. In particular, as John Terraine notes, many German submarines escaped detection as Coastal Command's primary weapon, the Anson, suffered from "limited range [which] prevented it from

spanning the North Sea which it was to patrol; a gap of about 50 miles existed between the Anson's extreme flight limit and the Norwegian coast."³⁸ Terraine suggests that the nature of Coastal Command's task had much to do with its initial lack of success. Citing structural factors such as the "continuing paucity both of aircraft and of trained crews," he observes that "the command had operated from the very first at full intensity" in increasingly poor weather as the winter of 1939-40 took hold.³⁹

Both John Terraine and Alfred Price agree that the primary factor limiting Coastal Command's effectiveness in killing U-boats was the lack of proper weaponry to destroy their targets. The limitations of Asdic had forced aircraft to almost immediately take a larger role in the anti-submarine campaign but the years of neglect during the 1920s and 1930s had left Coastal Command without a reliable anti-submarine bomb. Coastal Command entered the war with three varieties of anti-submarine bombs: 100lb (the only one which could be carried by the Anson-equipped squadrons), 250lb and 500lb.⁴⁰ Terraine questions the decision made in 1934 to develop these three sizes of bombs given that "by the end of 1917 it was the considered opinion of those concerned that the best weapon for air attack on a submarine was a bomb containing at least 300 lb of high explosive; with the casing this would give it a total weight of 520 lb, and it should be fitted with an impact fuse or a delay fuse to detonate at about 40 feet below the sea surface."⁴¹ Terraine attributes the 1934 decision to "the general view that nothing that had happened in the First World War could be of any interest," a mindset which may also provide clues as to why the Anson, a less effective replacement for the Kangaroo of 1918, could serve as the primary equipment of Coastal Command in 1939.⁴² In any case, the anti-submarine bombs equipping both Coastal Command and the Fleet Air Arm in the

first months of the Second World War were often more dangerous to their users than to their intended victims for as Alfred Price comments, “the shrapnel from the bomb, exploding after glancing off the surface, was more effective against the dropping aircraft than its blast effect ever was against a U-boat.”⁴³ Price and Terraine agree that the lack of proper bombsight for attacking submarines placed British aircrews in the unenviable position of either missing their target by attacking from a safe height or, if they attacked at a low level to drop their ordnance visually, they risked being destroyed themselves.⁴⁴

Coastal Command could take heart in two areas during the first disappointing months of its anti-submarine campaign, which had officially begun on 13 November 1939 with Coastal Command Headquarters’ order that anti-submarine operations be given equal priority to its original primary role of maritime reconnaissance.⁴⁵ First was, as Price notes, the fact that “the Royal Air Force... were to enter the war in 1939 with aircraft to counter the submarine better than those of any of the other belligerents. But this was only because other nations had devoted even less effort to the problem of combating the submarine from the air.”⁴⁶ More significantly, W.A.B. Douglas comments that Coastal Command benefited from “the excellent organization for the command and control of naval and maritime air forces that had been established in 1937-8.”⁴⁷ This system included group commands (initially three) which were responsible for a sector of the waters surrounding the British Isles and “more importantly... were located with the corresponding naval headquarters to form three (later four) Area Combined Headquarters [ACHQ], where the staffs of the two services shared a common operations room.”⁴⁸ The flexibility and co-operation which this system fostered combined with Coastal Command’s access to information such as U-boat signal intercepts which fed the Admiralty’s Submarine

Tracking Room ensured that when Coastal Command obtained the weapons, sensors and aircraft to fulfil its anti-submarine mission properly, the command and control organization needed to obtain the maximum potential out of the front-line squadrons was in place.⁴⁹

The low point of Coastal Command's fortunes in anti-submarine warfare was reached on 11 March 1940 when the first U-boat was sunk by a British aircraft during the Second World War. Unfortunately for Coastal Command, the attack and sinking of U-31 in the Heligoland Bight (off Denmark) was not made by one of the Command's aircraft; instead the honour went to a Bomber Command Blenheim of No. 82 Squadron piloted by Squadron Leader Miles Delap, who sank the U-boat not with the specialist anti-submarine bombs but with conventional 250 lb general-purpose bombs.⁵⁰ Coastal Command had little time to rue its ill-luck as the task of anti-submarine warfare became increasingly difficult (and desperate) by the summer of 1940. As German U-boats commenced operations from bases in occupied France, they operated far out in the Atlantic Ocean while avoiding the North Sea chokepoint, thereby immediately removing Coastal Command's short and medium range Ansons and Hudsons from any position of influence in future battles.

Three developments, however, were underway during 1940 which would enable the Command to increase dramatically its lethality against the U-boat. The fitting of ASV radar to several Coastal Command aircraft, the provision of effective airborne depth charges to replace the dangerous and almost useless anti-submarine bombs, and the development of the Leigh light all served to increase both the search and attack effectiveness of Coastal Command's steadily growing number of long-range aircraft and

marked a renewal of the relationship between scientists and those involved in airborne anti-submarine warfare which had been forged during the First World War.

The development of radar, in particular, was inexorably tied to the search for efficiency in airborne anti-submarine warfare as many of the same scientists who assisted in the early development of radar were also involved in the development of operational research techniques. The British experiments in radar of the 1930s, which would prove to have vital importance during the Battle of Britain during the summer of 1940, also spawned studies into the feasibility of airborne radar sets to detect other aircraft at night or vessels operating on the surface. By 1937, a team led by Dr. Edward Bowen had developed an airborne radar set capable of detecting ships at distances approaching 10 miles.⁵¹ This set, the ASV Mark I, was rushed into service in November 1939, a fact which led to severe serviceability difficulties which compounded the bulk and limited detection ability of the first sets.⁵² The development during 1940 of an improved version, ASV Mark II, as well as a new device which operated at wavelengths of 10 centimetres instead of the previous 1.5 metres (which improved detection ability of small objects in surface clutter such as submarine conning towers) promised to be potential solutions to the persistent problem of improving the aircraft's detection ability, particularly in low visibility or darkness.⁵³ However, as Alfred Price comments, the demands of the night fighter and bomber force took priority over the needs of Coastal Command with the result that "while Coastal Command radar experts cast covetous eyes at the new device[s]... that was all they were able to do for the time being."⁵⁴

While ASV was slowly being fitted to Coastal Command aircraft, a series of trials was underway during the winter of 1939-1940 to prove the concept of dropping naval depth

charges from aircraft.⁵⁵ The tests illustrated that it was possible, provided the depth charge was not dropped at too great a speed or height (i.e. above 115mph and 100 feet altitude).⁵⁶ The depth charges' advantages outweighed its disadvantages, particularly in its reliability, greater lethality against partially submerged or submerged targets and its safety for the attacking aircraft (as it would not bounce back into the air on contact with the ocean).⁵⁷ Both a 500lb and a 250lb airborne depth charge (equipped with a streamlined nose and tail fins to improve stability upon release, thus aiding accuracy) were developed, quickly becoming the mainstay of the Coastal Command and indeed, the Allied, airborne anti-submarine arsenal.⁵⁸

The final technological innovation of 1940 removed the submarine's last remaining 'aircraft-proof' cover: darkness. The effectiveness of aircraft as submarine-hunters in good to poor daylight visibility was enhanced by the fitting of ASV but even though ASV-equipped aircraft could detect surfaced submarines (i.e. recharging their batteries) at night, there was no way to launch an effective attack as there was not sufficient light for either a visual or bombsight attack on the target submarine. In September 1940, the Air Officer-in-Command (AOC) of Coastal Command, Air Chief Marshal Frederick Bowhill, requested that all members of his Command submit any ideas regarding night attacks on U-boats.⁵⁹ One officer at Coastal Command Headquarters, Squadron Leader Humphrey de Verde Leigh, submitted a proposal on 23 October 1940 to fit a powerful searchlight to an aircraft which would allow for the illumination of the target during the crucial moments of the attack run.⁶⁰ After overcoming a series of developmental problems, particularly the weight of the searchlight and its power supply (Leigh

eventually settled on battery accumulators charged by a generator working off the aircraft's engines), the Leigh light began to enter squadron service in the fall of 1941.⁶¹

By this point, the war was two years old. Coastal Command had struggled valiantly against a variety of crippling handicaps but now the tide was beginning to turn in its favour. New technological developments combined with an increase in the overall effectiveness (if not size- still 400 aircraft) of Coastal Command's anti-submarine force marked the arrival of a truly deadly threat to the submarine. The replacement of the Ansons with more Hudsons as well as the addition of long range Whitley, Wellington and in late 1941, very long range Liberator landplanes and Sunderland and Catalina flying boats "forced the U-boats to operate farther out into the Atlantic, thus reducing the amount of time they spent on active patrol, and hence the amount of time available to attack convoys" while also increasing the length of time convoys could have air escort.⁶² Coastal Command's increased coverage, by the end of 1941, had had an unintended effect. W.A.B. Douglas asserts that Coastal Command's 'revolution' as he terms it contributed to the U-boats' arrival in North American coastal waters during 1942, with disastrous results as Royal Canadian Air Force Eastern Air Command (EAC) was forced "suddenly to adapt to a new form of warfare, whose weapons and tactics changed rapidly, always in the direction of more sophisticated technology and more rigorous demands on groundcrew and aircrew alike."⁶³

III

The Royal Canadian Air Force historian F.H. Hitchens remarked that "relatively little is known of the work of the Royal Canadian Air Force at home during the Second World War... even within the Force there are few who realize that there were, during the war,

over 40 squadrons engaged on operations in the Home Theatre- a number not far below the total [number] of squadrons that served overseas (47)... if their battle honours are fewer, the hardships they had to endure and the difficulties they had to overcome were, in many respects, greater.”⁶⁴ The task of defending Canada’s East Coast and, in particular, providing airborne anti-submarine escort to the embattled convoys en route from North America to Great Britain, was assigned to Eastern Air Command.

Like RAF Coastal Command, Eastern Air Command entered the Second World War ill-prepared for the tasks which it would be assigned. Historian Carl Vincent explains that “in the inter-war years the Atlantic was relegated to secondary importance by those planning Canada’s air defences” with the result that when the focus shifted to Eastern Air Command on the outbreak of war in September 1939 and its roles of convoy escort and anti-submarine patrols, “the squadrons on the east coast had at first to rely on an inadequate supply of outdated aircraft, because of the stringent financial restrictions imposed by the government in the years before the war.”⁶⁵ The RCAF, on the outbreak of hostilities, was unprepared for its assigned Home Defence tasks, namely air and seaward defence of Canada, naval co-operation and coastal artillery co-operation.⁶⁶ Leslie Roberts, in There Shall Be Wings, comments that “few knew that except for nineteen Hurricanes, eleven Blackburn Sharks and a few coastal patrol machines, such as the Stranraer, aircraft listed as service planes were obsolete for purposes of modern air warfare.”⁶⁷

First among Eastern Air Command’s difficulties was the sheer scope of its operational area. It stretched, as W.A.B. Douglas notes, “from eastern Quebec to the seas beyond Newfoundland- and there were no obvious transit routes [or choke-points] for enemy ships and submarines comparable to the Shetlands-Iceland gap or the Bay of Biscay in the

northeastern Atlantic.”⁶⁸ To patrol this inhospitable area plagued with violent weather, cold and ill-provided with airfields, Eastern Air Command was forced to rely upon only four squadrons of obsolete maritime reconnaissance aircraft. On the outbreak of war, No. 5 Squadron, based at Dartmouth, Nova Scotia, was perhaps the best equipped, if only because its Supermarine Stranraer flying boats were “the few available examples of the only aircraft designed for the job” of maritime reconnaissance.⁶⁹ On the other hand, No. 8 Squadron was forced to undertake its patrol duties with Northrop Deltas, a wholly unsuitable civilian passenger aircraft.⁷⁰ No. 3 (which in October 1939 was split to become 10 and No. 11 Squadrons) Squadron was equipped with the Westland Wapiti biplane light bomber which had entered service with the RAF in 1928.⁷¹ As Air Marshal Clare Annis recalls, “the Wapiti was really a De Havilland D.H. 9A biplane of WW I ancestry which the UK had modernized by rebuilding[sic] in metal instead of wood” adding that “even by mid-1930s standard, when the RCAF acquired 18 of them second-hand from the RAF, they were antiquated.”⁷²

By November 1939, certain EAC squadrons began to receive ‘new’ equipment as the RCAF expanded and the roles of EAC increased in scope and number as well. No. 11 Squadron began to convert to Lockheed Hudsons while No. 8 Squadron received its first Bolingbroke I bombers (Canadian-made versions of the Bristol Blenheim).⁷³ More significant was the conversion of No. 10 Squadron to the Douglas B-18 Digby, 20 of which had been ordered by the RCAF in 1937-8.⁷⁴ Air Marshal Annis remarks that “the Digby was at that time quite the longest range aircraft the RCAF possessed” and “with its bomb bay tanks full, it could hang in there for about 17 hours.”⁷⁵ The Digbys represented the RCAF’s only long range strike force, and the small numbers available not only

limited the long range maritime patrol capabilities of EAC but due to their dual maritime reconnaissance and bomber role, also now necessitated the “uniquely Canadian designation ‘Bomber Reconnaissance’ or ‘BR,’ which more accurately described the various tasks carried out by each of the RCAF’s small number of maritime squadrons.”⁷⁶

In May 1941, a new aircraft type joined No. 5 (BR) Squadron in EAC in a joint Anglo-Canadian attempt to bolster EAC’s long range anti-submarine capabilities. Nine Consolidated Catalina flying boats began flying first with 5(BR) and then in July with 116(BR) from Dartmouth and Botwood, Newfoundland.⁷⁷ The Catalinas provided a desperately needed long range addition to the EAC arsenal against the U-boat but it was severely underpowered which in practice meant that “they could only perform convoy escorts to a 450-mile radius, and anti-submarine sweeps to a 750-mile radius, with no provisions for a worthwhile “loiter” time.”⁷⁸ In a January 1943 report, then Wing Commander Annis commented that the Catalina suffered from a low cruising speed, a dangerously large silhouette (which made it an easy target for U-boat anti-aircraft gunners), a hull shape which limited visibility for visual attack runs, chronic wing icing due to a low service ceiling and a low bombload [1000lbs] all of which limited the aircraft’s value as a sub-hunter.⁷⁹ However, through most of 1942 and 1943, 5(BR)’s Canadian-made Canso (amphibious variants of the Catalina) provided the only long-ranged EAC air coverage over the Northwest Atlantic as 10(BR) was based at Dartmouth impatiently awaiting the outcome of protracted negotiations with both the British and American governments to secure a supply of very long range Consolidated B-24 Liberator bombers.⁸⁰

Eastern Air Command's difficulties were compounded by the severe weather of the North Atlantic. Air Marshal Annis remembers that "we found the prevailing winds over the North Atlantic to be so commonly westerly and so strong that aircraft such as the Digbys, Catalinas and Cansos, having low cruising speeds even with great endurance, were not very effective. If our cruising speed were, say, 140 MPH and the common westerly wind was 45 MPH and we wanted to work 800 miles out to sea, our ground speed coming home would be only 95 MPH and it would take 8 ½ hours. This factor left a big gap in the middle of the Atlantic where neither we nor U.K.-based aircraft could reach."⁸¹ W.A.B. Douglas notes that the prevailing winds had a large impact on the operational radius (i.e. The distance an aircraft could transit, patrol and return safely on its fuel load) of EAC aircraft with "the effective range... [being] roughly a third-frequently much less- of the total distance the aircraft could fly without refuelling."⁸² He adds that as the war progressed, "the weight of armament and equipment and number of crew members significantly altered aircraft performance, while the difficult weather conditions on the Canadian coasts often greatly reduced operational ranges."⁸³

Technology depends upon a trained human operator to use it to its maximum potential. The first three years of the war found EAC scrambling to secure adequate numbers of trained personnel and the bases from which to operate their aircraft. Annis remarks that in the early days of the war:

We still had a lot to learn about air warfare. For instance pilots knew practically nothing about enemy aircraft recognition. It is interesting to recall that when we landed at Dartmouth [on 1 September 1939] we placed the aircraft in the usual straight line and then dismissed the airmen. But Group Captain [later Air Vice Marshal and Commander of No. 6 Group, Bomber Command] Brookes... Rushed out and ordered them to be staggered... The squadrons on the East Coast were

really starting from scratch and were largely unaware of the techniques of flying over water.⁸⁴

The rapid expansion of the RCAF, by means of the British Commonwealth Air Training Plan (BCATP), both for overseas and home service, forced the service to adapt and attempt to learn on the job and from the example of the Royal Air Force. In Eastern Air Command, given its dangerous operational environment and the importance of protecting the precious convoys, the strain was immense. As Annis notes, “we had to learn not only how to fly our aircraft to near the limits of their endurance in all the rotten weather the North Atlantic would throw at us, but also how to destroy submarines whenever the fleeting chances occurred,” adding that “in retrospect it is astonishing how much the Home War Establishment... Had to do and learn in so short a time and how fortunate we were the Germans did not start operating in the Western Atlantic and our North American coastal waters until... the autumn of 1941.”⁸⁵ Douglas points to the insufficient training level of Eastern Air Command crews as late as 1942 due to the lack of dedicated operational training squadrons (resulting from a lack of aircraft) as having “undoubtedly played a large part in the failure of aircraft to give U-boats the coup de grace.”⁸⁶ Ultimately, Annis reflects that “I think you could say that by the end of 1942 we were learning ways of dealing with monotony and boredom so that with improved training and better equipment at their disposal our crews were becoming more efficient.”⁸⁷

As with Coastal Command, Eastern Air Command crews struggled with unreliable armament during the first three years of the war. Annis remembers that “in the Digbys we had the American 600-lb bomb which wasn’t very satisfactory. One had to be flying very low for release so that the submarine had plenty of time to dive. It was also unreliable in

detonation.”⁸⁸ Eastern Air Command’s dilemma was compounded by the low priority accorded to home-based Canadian squadrons by the British and Americans for new weapons and equipment which made it difficult for the Command to improve its effectiveness against the U-boat.⁸⁹ Annis recalls that it was not until the arrival of the first nine Catalinas in June 1941 that Canadian aircraft began to be armed with depth charges, over a year after Coastal Command began their widespread use and it was not until November 1941 that most Eastern Air Command units had a supply of depth charges.⁹⁰ Similarly, despite the pressing need for very long range aircraft such as the Liberator, Eastern Air Command did not receive any such aircraft until the late spring of 1943 whereas the RAF and USAAF had had them in service since 1941.

The availability of sensors and the dissemination of search and attack tactics were also delayed in their transmission from Coastal Command to Eastern Air Command. Carl Vincent notes that the first ASV units in Eastern Air Command were fitted in some of No. 10 Squadron’s Digbys in October 1941, two years after its introduction in the RAF.⁹¹ Certainly the secretive nature of the British radar development may explain in part the delay in its dissemination to Canada but its value in operations conducted in poor visibility and especially as a navigational tool ultimately outweighed any concerns about security in favour of an increase in Eastern Air Command’s effectiveness.⁹² F.H. Hitchens relates one account of the value of ASV to Eastern Air Command noting that “on 26 July [1942] when five Digbys went out over the Atlantic, three to patrol and sweep and two to escort a convoy. One of the latter aircraft did not carry ASV and, with a low ceiling over the sea, was unable to locate the convoy. The second aircraft, however, had ASV and

thanks to this equipment experienced no difficulty in picking up the ships and carried out its mission.”⁹³

Ultimately, effective detection equipment, weaponry, aircraft and aircrew are of little use if there are few submarines to hunt. Eastern Air Command faced a situation during the first three years of the war in which very few U-boats made the journey to the Northwest Atlantic. As noted above, the growing effectiveness of Coastal Command gradually forced the U-boats further out into the Atlantic, for as Annis posited in 1943, “It is reasonable to suppose, from an analysis of past operations that this is because air power has been very effective as a countermeasure whenever adequate air coverage can be given.”⁹⁴ The entry of the United States into the war in December 1941 and the subsequent dispatch of U-boats to the largely unprotected shipping lanes off the American Eastern Seaboard as well as the Gulf of St. Lawrence strained Eastern Air Command severely and forced another rapid expansion both quantitatively and qualitatively as well as an emulation of Coastal Command by soliciting the assistance of Canada’s scientists to aid in the hunt for German U-boats.⁹⁵

Chapter 2- Blackett and the Origins of Operational Research

The structure and intellectual foundations of Eastern Air Command's ORS were based largely upon the pioneering experience of the British Royal Air Force with modifications to suit the peculiarities of the Canadian situation. Although the history of operational research may be traced to the First World War, the development of the basic techniques began in earnest in 1934 with the British experiments into radar led by the Tizard Committee. A key member of this committee was Professor P.M.S. Blackett, a future Nobel Prize winning physicist who would be inexorably linked with the development of operational research as a recognized and valued source of information at the command level of the military. Professor Blackett's work for the Tizard Committee and upon the outbreak of war in 1939, Anti-Aircraft Command, RAF Coastal Command and the Admiralty, transformed operational research from being the vague application of the scientific method to the integration of new technologies in the military context into a distinct branch of scientific inquiry, with its own techniques, methods and eventually, academic paraphernalia. In order to trace the early development of operational research, we must examine the pre-war radar experiments which served as the first testing ground of early OR methods. As well, the state of OR upon the outbreak of hostilities and Professor Blackett's involvement in expanding its use (and refining its methods) to Anti-Aircraft Command will be discussed. Finally, Blackett's key role in the creation and early methodological and organizational efforts of the Coastal Command ORS will be examined in the context of his December 1941 paper, "Scientists at the Operational Level" which, with its clear, detailed commentary on the purposes and methods of OR, articulated the basic principles of OR which provided the foundations for Eastern Air

Command's Operational Research Section and ultimately, for postwar civilian applications.

I

The 'technological killing' of the First World War prompted a turn in Great Britain (and to a lesser extent, in the United States), to apply science to the improvement of the utility and effectiveness of weaponry. Of particular concern was the submarine and, in an attempt to counter the latter, the United States Navy Consulting Board headed by the renowned inventor Thomas Edison. created a statistical model for the evasion of submarines by surface ships. This application of scientific techniques was similar to later Coastal Command ORS work regarding density theory, the only difference being that Edison was looking for a means by which to avoid submarines and Coastal Command was desperately attempting to improve its chances of locating submarines.¹ Similarly, the experimental section of the British Army Munitions Invention Department under A.V. Hill explored the problems of anti-aircraft gunnery in an attempt to limit the effectiveness of bomber aircraft.² Indeed, Hill and several of his colleagues would play major roles in the development of operational research techniques during the mid-1930s.³ However, as OR historian Joseph McCloskey notes, much of this early work was allowed to languish as

During the interwar years, nothing of significance to the history of operations research was done in these areas... and this despite continued progress in the development of aircraft and submarines, surface vessels, tanks and other vehicles of land warfare, and radio and telephone. The designers led, the tactics lagged, and effective counter-measures were virtually non-existent.⁴

Both the Americans and British, suffering from severe war-weariness, showed little interest in military spending of any sort during the 1920s and 1930s and scarce budgets left little room for research of any kind. Indeed, the majority of British military research was devoted to the development of Asdic, which many in the Admiralty saw as a virtually infallible counter to the submarine menace. However, as McCloskey notes, there were calls in Britain by certain influential personalities, such as Winston Churchill and his friend Professor Frederick Lindemann, for increased research in other areas of military concern, particularly regarding the increasingly worrisome potential of the bomber.⁵ These calls influenced H.E. Wimperis, the Director of Scientific Research in the Air Ministry to recommend in November 1934 the creation of “a Committee for the Scientific Study of Air Defence” [C.S.S.A.D.] with the mandate “to “consider how far recent advances in technical knowledge can be used to strengthen the present methods of defence against hostile aircraft”.⁶ The Committee, which first met in January 1935, was composed of the chemist Henry Tizard (chair), Nobel Prize winning physiologist Professor A.V. Hill, physicist Professor P.M.S. Blackett, Wimperis (an engineer and inventor in his own right) and A.P. Rowe, who served as secretary and as superintendent of the Telecommunications Research Establishment during the Second World War.⁷

The Committee’s original focus was on a means of destroying bombers. In early 1935, Wimperis inquired with the head of the Radio Department of the National Physical Laboratory, Robert Watson-Watt as to “the feasibility of “death rays,” which, as McCloskey remarks, were “a perennial favourite of amateur inventors.”⁸ Instead, Watson-Watt convinced the Tizard Committee that radio waves could be more effective not as a weapon but as a sensor to detect bombers in order to dispatch fighters to destroy

them. The Tizard Committee's enthusiastic embrace of Watson-Watt's 'radio direction finding' ensured its development in the bureaucratic maze of 1930s Whitehall. By the 1938 Fighter Command exercises, a chain of five radar stations had been established in south-east England.⁹ Rowe had now been appointed superintendent of the Bawdsley Research Station (a combined 'chain' station and RDF research establishment) and it was under his direction that the first activities known with the description 'operational research' began.¹⁰ A team under E.J. Williams was ordered to investigate the problem of filtering and prioritizing the radar information, tasks which the Air Ministry's Official History of Operational Research in the R.A.F. asserts "were in essence the development of the Filter Room system under operational conditions, [and] must therefore rank... as being [one of] the earliest applications of the science of operational research."¹¹

The outbreak of war in September 1939 witnessed a rapid expansion of OR activities in the British armed services, most notably in the Royal Air Force. Not only did the approximately 80 scientists at Bawdsley remain on duty but other commands, such as Fighter Command, quickly formed similar research sections to study problems specifically related to their operations.¹² However, the nascent science of OR still remained firmly within the realm of air-related activities. Indeed, the first crossing of service lines occurred during the Summer of 1940 when the Army's Anti-Aircraft Command (General Frederick Pile) on the recommendations of Tizard and Rowe, formed its own unofficial OR section under Pile's scientific advisor Professor Blackett.¹³ The formation of the Antiaircraft Command Research Group was a logical extension of OR given the growing need and desire to integrate radar into the Command's operations. 'Blackett's Circus,' as it quickly became known, explored all aspects of the problems of

ground anti-aircraft defences, from the flow of information from the sensors to the various batteries (a study similar to Williams' pioneering work during 1938 on filter rooms) to the most effective number of guns per battery given the lack of adequate numbers of gun-laying radars during the summer and early fall of 1940.¹⁴ These studies were desperately needed by Anti-Aircraft Command as it was the primary defence against the German night Blitz of the fall and winter of 1940-41. However, the move by the Luftwaffe away from massed night raids by the spring of 1941 allowed Blackett to transfer to RAF Coastal Command to assist in the creation of an ORS to support the increasingly desperate fight against the U-boat. As Blackett's biographer Sir Bernard Lovell comments, "Blackett was with A.A. Command as Scientific Advisor to Pile at the H.Q. Of A.A. Command at Stanmore for only seven months- until March 1941- but during that short time he made a great impression, both on Pile and on the operations of the Command."¹⁵

II

The lack of success in operations against the U-boat by RAF Coastal Command was a cause for concern not only at Coastal Command HQ but also at the Admiralty and Whitehall. The search for an effective counter to the damaging U-boat attacks on convoys ostensibly securely guarded by Asdic-equipped destroyers, and the inadequacy of Coastal Command's resources to support these escort tasks, reached a head in early 1941. The Commander in Chief of Coastal Command, Air Marshal Sir Frederick Bowhill, secured Professor Blackett's transfer from Anti-Aircraft Command to Coastal Command as head of the planned Operational Research Section and as his scientific advisor.¹⁶ Blackett was accompanied by the reputation his work for Frederick Pile had created as well as his

growing sense of the purpose of OR. His biographer Sir Bernard Lovell observes that “his experience with A.A. Command had given him clear ideas about the organization of such an operational group. He had learnt to avoid responsibility for technical problems with equipment or any daily routine work, so that the group could be free for non-routine investigations and researches.”¹⁷ In particular, Blackett was adamant that his newly formed Coastal Command ORS would report to the Commander in Chief and not the Air Ministry, thus keeping criticisms within the Command, where they could be acted upon and remedied by the operational units and not transformed into politicized weapons to be used by ‘outsiders’ in attacks on Coastal Command’s record against the U-boat.¹⁸

Upon his arrival in June 1941, Air Marshal Sir Philip Joubert de la Ferte inherited the small ORS created by his outgoing predecessor. Under his command and that of his successor Air Marshal Sir John Slessor, the Coastal Command ORS became a model of the influence which effective operational research could have on the course of a force’s operations. However, during the first months of the ORS’s existence, Blackett was preoccupied with defining its role and purpose in order to maximize its effectiveness in producing meaningful and useful findings which could be immediately applied to Coastal Command’s operations, particularly its airborne anti-submarine effort. The result of these ruminations was a short discussion paper which Blackett produced in December 1941. Although Blackett himself described “Scientists at the Operational Level” as “hurriedly and somewhat flippantly written,” it had a great influence on the development of future operational research sections for as Terry Copp notes, the paper “was circulated in all three British services and in the United States.”¹⁹

“Scientists at the Operational Level” is only four pages long, but its arguments possess a clarity and logic which made it the seminal statement of the first principles of operational research. Blackett begins by observing that the integration of scientists into the operational command level was essential in order “to enable operational staffs to obtain scientific advice on those matters which are not handled by the Service technical establishments.”²⁰ This was a reciprocal relationship for the “operational staffs provide the scientists with the operational outlook and data” which they required in order to “apply scientific methods of analysis to these data and... thus... give useful advice.”²¹

The logic of placing operational researchers at Command Headquarters was clear to Blackett. First, the presence in the Command operation room of the required primary material, such as “all signals, track charts, combat reports, meteorological information, etc.” on which to base the analyses prompted Blackett to make the essential observation that “such scientific analysis, if done at all, must be done in or near [these] operations rooms.”²² This requirement also made it critical that “an Operational Research Section should be an integral part of a Command and should work in the closest collaboration with the various departments at the Command.”²³ Above all, Blackett asserted that “the head of the Operational Research Section should be directly responsible to the Commander-in-Chief and may with advantage be appointed as his scientific advisor” in order to retain the independence necessary for objective research.²⁴

Blackett added a series of provisos to the above vision. First, in order to create the necessary high quality scientific atmosphere, Blackett commented that “a considerable fraction of the staff of an Operational Research Section should be of the very highest standing in science, and many of them should be drawn from those who have had

experience at the Service technical establishments.”²⁵ Although intellectual achievements were key, he also added that operational research could only be effective when the researchers had a measure of knowledge of the nature of the problems they were to study (which could be obtained through interaction with operational personnel).²⁶

These factors, if implemented, would allow an ORS to fulfil its duties, the general nature of which Blackett discussed. The need for an ORS, as Blackett argued, was clear as “very many war operations involve considerations with which scientists are specially trained to compete [sic], and in which serving officers are in general not trained.”²⁷ In general, the majority of an ORS’s studies were to be composed of detailed statistical investigations into the results of operations which would then be “‘explained’ in the scientific sense, i.e. brought into numerical relation with other operational facts and the known performance of the weapons used,” with the results prompting “consideration... [of] possible modification of the tactics to improve the operational result.”²⁸ The other aspect of the ORS’s work involved operational experiments with new weapons and sensors, in which case it acted as “a liaison... between the operational staff, the technical department which produced the device, and the development unit which tested it.”²⁹ These studies involved either reports on the results of tests or actual service use of a specific device or may explore the value of various tactical uses of a given device by means of mathematical calculation.³⁰ Indeed, as Blackett pointed out, not only may an ORS be used to assist in the testing of a new device but it could have also been of assistance to the Command in formulating requirements for new devices “by interpreting (a) the operational facts of life to the technical establishments, and (b) the technical possibilities to the operational staffs.”³¹ The ORS’ role as intermediary, according to

Blackett, was extremely valuable as “a considerable wastage of war effort has occurred through lack of this joint discussion.”³² Ultimately however, the ORS’s prime function was to disseminate scientifically-based assessments of a Command’s operations. To facilitate this, Blackett emphasized the need for the production of reports on the findings of the various studies. He added that “these should be given a wide circulation, e.g., in the Air Force to squadrons to be read by the aircrews. In this way, the tactical education of the men on the job can be raised.”³³

“Scientists at the Operational Level” not only provided a clear vision of the purpose, roles and relationship with military structure of an ORS but in conjunction with its inspiration, Coastal Command ORS, served as a model for future Allied OR institutions. Operational Research Sections, were, as Professor Waddington observes, “completely new elements in the military organization” and as such, might have been expected to create a measure of difficulty regarding the chain of command, but this was not the case.³⁴ Indeed, Waddington asserts that “the scientists took considerable pride in the fact that they were, although civilians, accepted as full members of the Command team.”³⁵ This may be explained by several factors. First, Coastal Command ORS was quite a small organization, numbering fewer than 25 members at any given point, therefore limiting the potential disruptiveness of their presence at Command Headquarters.³⁶ These individuals, a mix of civilian researchers and service personnel were led by a succession of strong directors such as Blackett and Waddington who cared passionately about OR and understood and imparted to their staff that their duties were of the utmost importance to Coastal Command’s efforts to preserve Britain’s Atlantic lifeline. This task of

management was aided to a certain extent by the nature of the staff itself. Professor Waddington observes that:

The anti-U-boat O.R. effort can claim that some rather high powered scientists contributed to it. In the staff of the section there were two Nobel Prize winners (Blackett and Kendrew), five fellows of the Royal Society (Blackett, Kendrew, Williams, Waddington, Robertson) and a Fellow of the National Academy of Sciences of Australia (Rendel), and several of the others reached Professorial rank.³⁷

Not only was the staff extraordinarily competent to perform their duties but they were also well-equipped to perform these tasks under a measure of pressure and do so innovatively because of their youth. Waddington adds that “the oldest of the influential O.R.S. Workers at Coastal was Blackett, who was about 45 at that time; most of the rest were in their thirties or even twenties.”³⁸

Certainly the youth and high-powered credentials of the staff of Coastal Command ORS was put to the test by the multitude of requests for their services during the last four years of the war by Coastal Command Headquarters. A detailed account of the activities of the section is beyond the scope of this thesis, an exceptional discussion being provided by Professor Waddington in OR in World War 2: Operational Research against the U-boat. However, a short examination of the general areas of study is essential in order to understand the basis of knowledge from which RCAF Eastern Air Command ORS would operate from 1943 to 1945.

Coastal Command’s areas of responsibility stretched far beyond airborne anti-submarine warfare to include ocean reconnaissance, anti-shipping strike, long-range ocean fighter escort and air-sea rescue.³⁹ Joseph McCloskey explains that “because of the nature of its tasks, primarily anti-submarine operations and convoy protection, plus

attacks on enemy shipping, Coastal Command offered a much wider scope for operations research than did Fighter Command.”⁴⁰ He adds that “Coastal Command operations were inherently more complex. Each operation involved problems in navigation, search, identification, bombing accuracy, verification of result, and, not least, given Britain’s weather, return to base.”⁴¹ In the main, the Coastal Command ORS’s studies fell into four categories, namely anti-shipping operations (including photographic reconnaissance and weapons), anti-U-boat operations, planned flying and maintenance, and weather and navigation.⁴² Only the latter three areas are applicable to this discussion, but each produced a wealth of knowledge which not only increased the effectiveness of airborne anti-submarine operations in the Atlantic theatre but also provided critical information and models upon which EAC ORS could build.

The area of anti-U-boat studies encompassed a variety of operational elements, from weaponry, tactics and sensors through search techniques and even aircraft colour. At the centre of a series of seminal studies was E.J. Williams, who assumed the leadership of the ORS in December 1941 after Professor Blackett departed for the Admiralty.⁴³ The first major study undertaken by the ORS in late 1941 was Williams’ exploration of the lack of effectiveness of Coastal Command’s airborne depth charges. This study, which Joseph McCloskey terms “the classic OR study of World War II,” discovered that the failures of the depth charge attacks of 1940-41 were not the result of an inherent flaw in the design of the weapon but instead were the product of the standard 100 foot depth setting which was wholly unsuitable for attacks on surfaced or semi-surfaced submarines (as the depth charge would sink to a depth where it would no longer be lethal to a submarine operating at or near the surface).⁴⁴ Instead, Williams recommended that the

setting of depth charge fuses be modified to explode at 25 feet in order to capture the vast majority of Coastal Command U-boat targets in the weapon's lethal radius.⁴⁵ Similarly, the ORS undertook major studies of aiming methods, depth charge spacing and even the proper colour of aircraft (white to limit their detectability) all of which had an influence on increasing Coastal Command's efficiency not through the introduction of new weapons but by maximizing the potential of existing ones.

Williams was also at the centre of two interrelated theoretical studies which would have a much broader impact on the general nature of Coastal Command's airborne anti-submarine operations. In a series of 1942 reports, Williams developed the concept of the 'density method,' which, after considering the number of submarines known or believed to be present in a given area, the proportion on the surface at any given moment and the aircraft type on patrol, used finite mathematics to determine "the probabilities of success in detecting, attacking, and killing..."⁴⁶ As McCloskey observes, "whenever results dropped below expectation, the density method facilitated analyses to ferret out probable causes and the effects that changes in methods might have."⁴⁷ The density method had a key influence in prompting Williams' final study for the ORS in late 1942: planned flying and maintenance. This study, dated 15 November 1942 and begun by Williams and then expanded after his departure into a team investigation under C.E. Gordon, tackled the essential problem that Coastal Command's lack of aircraft which was exacerbated by the RAF standard of basing aircraft use on availability and not the missions needed to be flown.⁴⁸ Joseph McCloskey comments that "the ORS studies... showed that scheduled missions could be flown if serviceability dropped below 50% [instead of the previous RAF minimum standard of 70-75%]" with the result that "[flying

and maintenance] schedules came to be based on the missions to be flown. Service crews were reduced, more flying was achieved, and more efficient use of ground personnel resulted.”⁴⁹ This system of planned maintenance not only enhanced the operational efficiency of Coastal Command’s squadrons but also set a pattern used by civilian and military air fleets to this day, namely, the primary mission must take priority over all but emergency maintenance.

As a pioneer in the field of operational research, the Coastal Command ORS not only had to carve for itself a unique niche as a largely civilian establishment in the command structure but had to do so under the pressure of the search for remedies to the Command’s rather dismal record of success against their primary enemy. Professor P.M.S. Blackett, whose “Scientists at the Operational Level” provided the blueprint for operational research in the military context, guided members of the Coastal Command ORS such as E.J. Williams in the production of a series of studies during the first two years of the section’s existence. These dramatically improved the Command’s effectiveness, efficiency and lethality largely by using the scientific method to illustrate that minor modifications to practices could yield immediately tangible results. Coastal Command ORS’s efforts during 1941-43 created a body of methodological and technical knowledge which formed the core of the rapidly developing techniques of OR. Ultimately, when it was formed in November 1942, Eastern Air Command Operational Research Section would greatly benefit from this knowledge as the staff, once they were trained by their counterparts at Coastal Command ORS, could tackle a variety of problems of interest to the RCAF without having to devote time to formulating a body of general theory.

Chapter 3- The Creation of Eastern Air Command ORS

By early 1942, the leadership of the Royal Canadian Air Force, particularly the new commander of Eastern Air Command, Air Vice-Marshal A.A.L. Cuffe, were growing painfully aware of the deficiencies in Canadian airborne anti-submarine operations. The lack of U-boat kills was the most apparent problem. A series of innovations pioneered by RAF Coastal Command began to trickle into Eastern Air Command, ranging from weapons, sensors and tactics to new aircraft and command structures. A key part of the latter was the organization of an operational research section based on the successful model pioneered during 1941 at Coastal Command headquarters under Professor P.M.S. Blackett. Following a series of discussions and survey visits by Coastal Command officers to Eastern Air Command during the first half of 1942, the decision was made by the Air Staff during the summer of 1942 to organize Canadian operational research sections at RCAFHQ in Ottawa, Western Air Command Headquarters in Vancouver and Eastern Air Command Headquarters in Halifax. This decision introduced the science of operational research to Canada, enabled a body of researchers to be trained by the leaders in this area and therefore provided the foundations not only for future Canadian-oriented airborne anti-submarine warfare research but also for the continuation and development of Canadian OR in the postwar era.

I

The period 1939-41 was characterized by the frantic expansion and training of Eastern Air Command for its primary role of airborne anti-submarine warfare. Not surprisingly, it depended on the knowledge and skill of RAF Coastal Command. However, Coastal Command was preoccupied with its own difficulties in combating the U-boat menace and

thus Eastern Air Command was forced to adapt as best it could, mixing British methods, weapons and tactics with a hodgepodge of aircraft types (none of which were entirely satisfactory) operated by inexperienced aircrew.

There is a measure of disagreement in the historical record regarding the level of assistance offered by Coastal Command to Eastern Air Command during the first two years of the war. The official historian of the RCAF, W.A.B. Douglas, notes that during this period “the sharing of knowledge on technical developments- as evidenced by Canadian production and adoption of the British aerial depth charge- was part of a growing understanding between the two commands.”¹ Indeed, Douglas cites the Air Officer Commanding Eastern Air Command during much of the first three years of the war. Air Vice-Marshal N.R. Anderson, who remarked on the importance of this relationship in an internal memorandum dated 21 November 1940:

Long experience, training and scientific investigation of Coastal Command in maritime air operations... Has evolved a sound operational policy and procedure which is being continuously advanced to keep ahead of enemy methods. Any information for guidance which Coastal Command can give Eastern Air Command on advances in operational methods, equipment or procedure will be treated with the degree of secrecy desired and used in the manner most likely to ensure pursuit of a common operational doctrine in the Battle of the Atlantic.²

Anderson’s desire to establish doctrinal and operational links with Coastal Command began to take shape during the summer of 1941 when he and the Air Officer Commanding Coastal Command, Air Chief Marshal Phillip Joubert de la Ferte, commenced a trans-Atlantic correspondence on issues of concern to both Commands.³ However, this interaction suffered on two key scores. First, as Douglas observes, “time for such discussion was fast running out” as the attack on Pearl Harbor prompted a shift of the Kriegsmarine’s U-boats to the Western Atlantic.⁴ Not only did this mean that

Eastern Air Command would be responsible in the coming months for an active battleground but would also have to respond to not only the attacks of U-boats operating inshore in the Gulf of St. Lawrence during the summer of 1942 while struggling to do so with a reduced force following the diversion of already scarce resources to the West Coast to bolster Western Air Command's meagre force against an apprehended Japanese assault.⁵

More importantly, the correspondence between Anderson and Joubert de la Ferte occurred at the highest executive level, meaning that little of any immediate impact to the operational squadrons was discussed. In a 1979 interview, Air Marshal C.L. Annis asserts that during the first two years of the war, there was little interchange of information between Eastern Air Command and Coastal Command, although "there was a general following of Coastal Command tactics."⁶ For example, Annis remembers that the first EAC U-boat kill (31 July 1942) involved the pilot, Squadron Leader Small of 113(BR) Squadron "drawing on the experience of Coastal's ace- Tom...? (Squadron Leader T. Bullock who had a Canadian navigator F/L M.S. Layton?) [Kealy's parenthesis]" flying at a greater height than usual in Eastern Air Command, thereby increasing the visual sighting range of the crew while reducing the chance that the aircraft would be sighted by the target.⁷ Annis concludes that the low level of interchange at the operational level was in large part due to the conditions encountered by Eastern Air Command as "until the Germans arrived over this side in 1942 we had little to contribute... and milked them [Coastal Command representatives] for all they were worth. While Coastal Command was getting a lot of operational experience ours was mainly in dealing with the climatic conditions peculiar to our side of the Atlantic."⁸

In any case, the situation in Eastern Air Command by early 1942 was such that only dramatic action and not discussions could solve its many difficulties. When AVM Cuffe arrived in February 1942 to take command, he found a force struggling with inadequate numbers of obsolescent aircraft equipped with often ineffective weapons and sensors, manned by inexperienced crews and controlled by a haphazard and unsophisticated command structure, all the while combating an elusive enemy in miserable operational conditions. He and his staff began a series of reforms based on those undertaken previously by Coastal Command that were aimed at improving the efficiency of Eastern Air Command within the limits of the resources available to them. The first moves were aimed at rationalizing and improving the Command's grasp of the tactical 'picture' of operations in its sector in the Northwest Atlantic. The adoption in April 1942 of Coastal Command's Manual of Coastal Command Operational Control and the creation of a new joint operations room in Halifax transformed Eastern Air Command Headquarters into a rough copy of Coastal Command's headquarters model at Command and Group level.⁹ However, as W.A.B. Douglas observes, the latter was unfortunately "imperfectly modelled on its British counterpart... Having military and naval liaison officers but inadequate naval input."¹⁰ This was a product of interservice squabbling between the RCAF and the Royal Canadian Navy (RCN), both of which were jealously guarding operational control over their own forces, an issue made even more significant by the entry of the United States' into the war which spelled the end of largely autonomous Canadian operations in the Western Atlantic.

By the time of Cuffe's arrival, the need to improve the training of the Command's aircrew and the aircraft's weaponry and sensors was well understood. Modifications in

these areas had previously been undertaken in Coastal Command with good results. However, the lack of resources under Eastern Air Command control worked against these efforts from the beginning. This was most noticeable in regard to aircrew training. Douglas observes that the fact that “there was still no operational training unit specifically established for the command’s maritime reconnaissance squadrons in 1942... undoubtedly played a large part in the failure of aircraft to give U-boats the *coup de grace*.”¹¹ The lack of available frontline aircraft contributed to training problems as all Digbys, Hudsons and Catalinas were urgently required by the operational squadrons. Douglas points out that “the RCAF instituted a syllabus on armament at training establishments and introduced a policy of ‘on the job’ training in operational units, geared to an up-to-date instructional programme,” but adds that the majority of training occurred on operational missions, which was not ideal for obvious reasons.¹²

Inadequate equipment also limited the effectiveness of Eastern Air Command squadrons through 1942. Most squadrons still carried depth charges with deep (fifty-foot) settings, which had been proven to be ineffective by Coastal Command ORS the previous year.¹³ Eastern Air Command was aware of this research, which had been confirmed by its own limited experiences, as a supply of the Mark XIII detonator pistol was quickly ordered but did not begin to arrive until February 1942.¹⁴ Similarly, as Douglas comments, “the Amatol-filled 250-lb charges lacked killing power, as Coastal Command’s scoreless record in early 1942 also demonstrated.”¹⁵ Noting this example, the RCAF ordered a quantity of Torpex charges in May 1942 but these too were delayed as Coastal Command maintained priority in deliveries.¹⁶ In regard to sensors, EAC squadrons began to receive ASV Mark II radar in April 1942, but as Douglas notes,

“Eastern Air Command’s early experience with the equipment in detecting U-boats was as disappointing as Coastal Command’s had been.”¹⁷ One can imagine the frustration at all levels of Eastern Air Command, observing the modifications being undertaken at Coastal Command to improve the lethality of anti-submarine aircraft, yet being unable to implement the same changes due to the lower priority accorded to Canadian orders of weaponry. The lack of adequate manufacturing facilities in Canada, particularly for explosives, delayed implementation of home production of the torpex charges. This was the state of affairs under which all of the forces of the Canadian Home War Establishment had to suffer in order to provide adequate equipment for the forces in more ‘active’ war zones.

Given the slow pace of re-equipment in Eastern Air Command, senior RCAF officers began in late 1941 to call for the creation of an operational research section on the model of that created less than a year earlier at RAF Coastal Command. This action, they believed would assist in the effective utilization of the limited resources on hand. Air Marshal H. Edwards (Air Member for Personnel), Air Vice-Marshal Anderson (as Air Officer Commanding EAC and after February 1942, Air Member for Air Staff) and Air Vice-Marshal E.W. Stedman (Air Member for Aeronautical Engineering) all put forth proposals for the creation of a Canadian ORS to study problems of airborne combat with emphasis upon airborne anti-submarine warfare.¹⁸ The discussion took a more active course following a conference on 11 February 1942 between Anderson, Cuffe, Air Vice-Marshal G.R. Bromet of Coastal Command and Captain G.E. Creasy of the Royal Navy. This conference explored all of the major areas of concern at Eastern Air Command, including aircraft, training and weaponry and significantly, the door was

opened for the introduction of operational research techniques in Canada. The joint report which emerged from the conference rather meekly asked “if one of the Officers from the Operational Research Section at Coastal Command Headquarters in U.K. could be spared for a visit to E.A.C. Headquarters his experience might be extremely valuable, and such a visit would be much appreciated.”¹⁹

Strangely, given the lack of haste with which Canadian requests for additional equipment were handled in Britain, a member of Coastal Command ORS, Mr. J.P.T. Pearman visited Eastern Air Command in March 1942 to introduce the concept of operational research to Canadian officers and undertake some preliminary studies in areas of pressing concern.²⁰ Pearman created the foundation for later Canadian OR studies by introducing Coastal Command methods of statistical collection.²¹

Pearman also conducted a short, general OR analysis of the anti-submarine air effort during February 1942. “The method adopted [in formulating the report],” he wrote, “is similar to that used in the Monthly Summaries of A/S Air Effort issued by O.R.S. Coastal Command.”²² Pearman’s primary conclusion, “that the amount of A/S flying fell off considerably beyond 200 miles from base, while there appears to be a maximum U.B. density in the 400-600 mile region” highlighted the primary deficiency of Eastern Air Command: the lack of effective long-range aircraft in sufficient numbers to patrol the U-boat’s ‘favourite’ hunting area Southeast of Greenland and Southwest of Iceland.²³ Eastern Air Command had to wait for the arrival of the U-boats in the coastal shipping lanes, where the arrival would often be announced by the ‘flaming datum’ of a sinking merchant ship.

Less than four months passed before another RAF delegation visited Halifax, this time to review the state of the Command as a whole. As Douglas notes, the delegation included “Wing Commanders S.R. Gibbs and P.F. Canning of the RAF, who had recently spent eight months advising the USAAF on the organization of operational control, the creation of combined operations rooms, and the establishment of an anti-submarine command along the lines of RAF Coastal Command.”²⁴ Gibbs, in his final report of his visit, did not call explicitly for the creation of an ORS but did raise several issues regarding the efficiency of the Command. He observed that “the responsibility of E.A.C. for the total air defence of Eastern Canada...[ensures that] their full attention cannot be given to the A/S aspect, even though it is of paramount importance at the moment.”²⁵ He concluded that “a purely A/S staff [which, if based on the Coastal Command model, would include an ORS] would be able to give the time and thought to the research and development that is necessary to gain the maximum value from the A/S effort.”²⁶

The first of two areas of concern which Gibbs explored, “the usual shortage of aircraft,” a problem compounded by the fact that “a considerable percentage of the aircraft available at the moment will be at the end of their operational life in a few months” was of concern to both Coastal Command and Eastern Air Command.²⁷ In response to the shortage of aircraft, E.J. Williams of Coastal Command ORS embarked on his study which eventually yielded the system of planned maintenance and flying which revolutionized Coastal Command’s operations by making better use of a very scarce resource. Gibbs was also concerned about the lack of Torpex depth charges, noting that “several excellent attacks have been made recently with the ordinary Mk.VIII D.C. with, as yet, no definite result.”²⁸ Gibbs added that “I gather that the standard of

Operational Training of pilots on posting to squadrons could be improved,” a key issue which the Eastern Air Command ORS would tackle upon its formation.²⁹

At the same time as Wing Commanders Gibbs and Canning were touring Eastern Air Command, discussions at Air Force Headquarters (AFHQ) in Ottawa regarding the creation of a number of operational research sections for the Home War Establishment were ongoing. Emerging out of these meetings involving Anderson, Stedman, Squadron Leader L.W. Lloyd (Directorate of Personnel) and Dean C.J. Mackenzie (Acting President of the National Research Council) was an agreement in principle for the creation of a nucleus of an operational research establishment with the recruitment of six senior researchers.³⁰ The selection of personnel was the responsibility of the National Research Council, and by the end of July, Dean Mackenzie provided a list to the committee of potential candidates for the positions. With a speed almost unknown in Ottawa, Professor J.O. Wilhelm, Assistant Professor of Physics at the University of Toronto, was appointed as Head, Operational Research Centre Air Force Headquarters and began his duties on 14 August 1942, just over a month after the decision was made to introduce operational research techniques into the Home War Establishment.³¹

Wilhelm’s duties were liaison with the Air Member for Air Staff (Anderson to January 1944) and supervision of the Command-based Operational Research Sections of the RCAF.³² His first task, however, was to fill the various research positions at the planned operational research sections at Eastern Air Command, Western Air Command and the RCAF in Britain. As Wilhelm notes in a 1943 Progress Report, “this proceeded slowly as every effort was made to select the correct personnel and all of the people suggested were actively engaged in important war work.”³³ To assist in the selection

process, an Allied advisory delegation composed of Group Captain A.C. Menzies of the Operational Research Centre, Air Ministry and Major W.B. Leach of the United States Army Air Forces visited Ottawa during August 1942.³⁴ Wilhelm adds in his 1943 Report that Menzies offered the helpful advice “that great difficulty was being encountered in Britain in obtaining scientific personnel of the right calibre for Operational Research Work.”³⁵ The hidden agenda behind this comment, Wilhelm notes, was that Menzies “raised the question of the possibility of Canadian scientists being available to assist the R.A.F. Operational Research Sections if not permanently, at least for a reasonable period.”³⁶ The search for suitable candidates to fill the positions in Canadian ORS’ took priority during the summer of 1942 and Menzies’ request was placed aside for the moment.

Given the need for scientific assistance for the Command and its squadrons, the most urgent position to be filled was that of Head, Eastern Air Command ORS. Professor Colin Barnes, a mathematical physicist at the University of Toronto, was selected to head the EAC ORS, and, in accord with an agreement made by Wilhelm with Menzies during his visit, Barnes and Wilhelm visited Great Britain in September to tour the Operational Research Sections of the RAF.³⁷ The visit allowed Barnes and Wilhelm an opportunity to observe and explore a variety of issues relating to operational research. Although Wilhelm only remarks that “this tour was most helpful,” it certainly was much more than that as it laid the groundwork for future co-operation by facilitating the dispatch of six RCAF officers to RCAF Overseas in Great Britain to work in various OR sections and learn OR techniques.³⁸ Indeed, two of these researchers, Flight Lieutenant J.W. Abrams and Dr. A.G. Nickle, served with distinction on the staff of Coastal Command ORS

where, according to C.H. Waddington, they “carried out much of the detailed work on the technique of attacking U-boats.”³⁹ In any case, the visit by Barnes and Wilhelm, as operational researcher George Lindsey notes, simply confirmed that as with many aspects of the Canadian military experience during the Second World War “the procedures and tactics [to be used by the planned Canadian ORS’] were very much determined by the much larger and more experienced Royal Air Force.”⁴⁰

II

On 30 November 1942, Professor Barnes arrived at EAC Headquarters in Halifax to begin the process of making the first Canadian Command-level Operational Research Section a reality. It would be, however, seven months before the section’s establishment of three civilian scientists was complete. Dr. J.W. Hopkins, an applied scientist at the National Research Council, joined the section in January 1943 while in June of that year, Dr. E. Chalmers Smith, a Harvard-educated botanist and geneticist completed the staff, which included both civilian researchers and attached RCAF personnel as assistants and supernumeraries.⁴¹ As Wilhelm notes, for the first year of its existence while the staff learned their trade and other RCAF personnel were being trained in Great Britain, “the details of the establishment were left in an indefinite state since it was felt best to let the Section grow and take thought for changing the establishment as the necessity arose.”⁴²

An early problem (that was never satisfactorily resolved) regarding the organization occurred in the area of the rank structure of civilians and military personnel within the ORS. In a memorandum to the Air Officer Commanding-in-Chief (AOC-in-C) of Eastern Air Command, Air Vice-Marshal G.O. Johnson, dated 31 August 1943, Professor Barnes expressed concern about the proposal by Dr. C.W. Leggatt, Head, Western Air Command

ORS to grant honorary commissions to two of his civilian operational researchers.⁴³ Barnes observes that the RAF system of largely civilian ORS organizations allowed for “free scientific, often acrimonious, discussion [which] is less hampered where no inhibitions based on relative rank are present.”⁴⁴ He warned that “naturally the introduction of ORS civilians into the RCAF establishments must have been viewed with some misgivings, at least until the novelty wore off” and concluded that “the cooperation of the service personnel with the ORS at EAC HQ is quite generally satisfactory, and I feel that a change of status such as that contemplated would be embarrassing to everybody.”⁴⁵ This desire to avoid offending the sensibilities of any party involved is the crux of Barnes’ argument as he presciently observed that “I can appreciate the ornamental value of an honorary commission but fail to see that its possession will not be a handicap rather than an asset in our work here.”⁴⁶ Indeed, he implies that Western Air Command was taking the path of least immediate resistance but which was strewn with thorns, remarking that “apparently Air Vice-Marshal M Stevenson [AOC-in-C WAC] and his ORS feel that the possession of an Air Force uniform is necessary to overcome [the difficulties of civilian-military relations at the ORS].”⁴⁷ In a handwritten margin note, Air Vice-Marshal Johnson concurred with Barnes’ unsolicited assessment, putting to rest temporarily an issue which presented a dilemma for the RCAF as the need to integrate researchers and military personnel with operational experience was a key component of the success of British OR. The correspondence between Barnes and Johnson also illustrates another essential element in the place of the ORS in the command structure, namely that the ORS reported to the AOC-in-C, thereby avoiding difficulties regarding the placement of a largely civilian body into the broader military hierarchy.

However, the problem of rank structure within an ORS spread to EAC ORS despite Barnes' firm stance. In a letter dated 6 November 1944, Flight Lieutenant J.L. Morton, a military member of the ORS complained to Professor Wilhelm "that the relative status of civilians on the establishment is considered to be that of Squadron Leader," adding that he is "eligible for promotion to the rank of Squadron Leader whenever I am filling a position on establishment calling for that rank."⁴⁸ This letter is remarkable in several ways. First, it illustrates that a degree of civilian-military tension persisted well after the initial formation of the ORS' sparked in large part due to the vague organizational structure decided upon by Professor Wilhelm in August 1942. More intriguingly, there is no response on the part of Professor Wilhelm in the file nor any margin notes, which, given his reluctance to solidify the organizational structure of the ORS', may be interpreted to mean that he took no action on this matter, leaving Morton (and perhaps others') complaints unresolved.

In any case, the organization of the Eastern Air Command ORS was intentionally quite fluid as was the case in the British model. AVM Anderson, in a series of memoranda produced during the summer of 1942, outlined the shape of the proposed Canadian operational research sections. Addressing the question of civilians in the ORS' and basing his analysis almost verbatim on Professor Blackett's "Scientists at the Operational Level," Anderson wrote in June 1942 that "Operational Research Sections are staffed by officers (civilian) of the highest standing in Science and, at the same time, temperamentally suited to close co-operation with the Services."⁴⁹ Although Anderson agreed with Blackett noting that "an O.R.S. should be responsible to the Air Officer Commanding alone and should report in the first instance directly to him or his deputy"

he also asserted that “O.R.S. personnel should have complete freedom of movement,” both of which necessarily separate ORS personnel from the remainder of the Command.⁵⁰ However, Anderson did not explore how this new organization with its civilian personnel and atypical command relationship would be integrated into the larger Command, which was a necessity if its work was to be accepted (or even informed) by the operational units. Instead, in his memorandum of 8 September 1942, Anderson simply informed the AOC-in-C’s of Eastern and Western Air Commands that “operational research officers will in no sense disturb the present chain of command but will serve as specialist advisers on A.O.C.’s staff.”⁵¹ Unfortunately, there is no record of the response of Air Vice-Marshals Johnson or Stevenson to Anderson’s rather vague description of the place of these new civilian organizations in the structure of their commands, although certainly their excellent reputation in Great Britain likely would have produced little concern.

The purpose of the Eastern Air Command ORS was explored by Professor Barnes in two memoranda to Air Vice-Marshal Johnson dated March and July 1943. Barnes reiterates Anderson’s view of the position of the ORS, noting that “the O.R.S. should be responsible to the A.O.C. alone and should report directly to him (or his deputy), while maintaining the complete freedom of movement necessary for close liaison with technical development and research.”⁵² However, he also expressed concern about the laissez-faire organizational structure promulgated by Anderson and Wilhelm: “as far as is known. no definite directive has been issued regarding the details of the O.R.S. establishment to be maintained at E.A.C., and while the service personnel attempt to help in every way, they are handicapped by lack of precise knowledge of where O.R.S. fits into the administrative picture.”⁵³ The purpose of the Eastern Air Command ORS was clearer, being described

by Barnes as “to provide a number of scientists to act in an advisory capacity for the A.O.C.-in-C.,” with particular emphasis being placed on statistical analyses of Eastern Air Command’s primary roles of anti-submarine operations and fighter operations.⁵⁴

In order to obtain the data to fuel these statistical analyses, the Eastern Air Command ORS was dependent, like Coastal Command ORS, on effective liaison not only with the operational squadrons within the Command but also with each nation’s naval forces. The relationship with the Royal Canadian Navy was a cause for concern in many circles in the RCAF, some of it prompted by a parochial desire to retain operational control of anti-submarine aircraft while others, such as Eastern Air Command ORS required the co-operation of the RCN to fulfil their duties. During the first six months of the latter’s existence, Professor Wilhelm admitted in a summary of that period that external “contacts that were made... were very scattered,” noting that “there have been exchanges of information with the Canadian Army, Canadian Navy and the National Research Council.”⁵⁵ However, as noted above, as late as the summer of 1942 several contemporary visitors to Eastern Air Command Headquarters noted the lack of integration at the executive level of the Command and its Naval counterparts, a situation which existed in stark contrast to the British system. In March 1941, Coastal Command had been placed under the operational control of the Royal Navy, thus putting an end to the destructive infighting that also plagued the Canadian maritime forces through the first four years of the war.⁵⁶ W.A.B. Douglas concludes that “the RCAF was most reluctant to accept the fundamental principle of British anti-submarine practice- that air forces should operate under the appropriate naval direction.”⁵⁷ This rivalry was put aside to a degree in February 1943, when the RCAF dropped its objections to RCN operational control in

order to enable its sister service to win its demand from the Atlantic allies for control of the defence of the Northwest Atlantic shipping routes.⁵⁸

This strike in favour of unified maritime operations did not, however, have any great impact on the relationship of Eastern Air Command ORS with the RCN. As was the case in Britain, both the RCAF and RCN created operational research sections, with the latter's becoming operational in July 1943, approximately eight months after that of Eastern Air Command. In an attempt to foster cooperation between the two largely anti-submarine warfare-oriented operational research sections, the Air Member for Training, Air Vice-Marshal M R. Leckie, wrote the Chief of the Naval Staff, Admiral Percy Nelles on behalf of the Chief of the Air Staff in late April 1943. Leckie stressed the importance of naval data such as convoy routing and escort strength to effective ASW analyses by Eastern Air Command ORS but noted that "the operational research sections of the RCAF obtain information on request from the U.S. Navy through the Anti-submarine Warfare Operations Research Group, Washington, but to date no similar arrangement has been set up between the RCAF and the RCN."⁵⁹ As a result, Leckie suggested that the RCN allow RCAF OR personnel to consult directly with their personnel in order to obtain "data necessary to effect the complete analysis of RCAF operations."⁶⁰ There is no record in the RCAF files of Nelles' response to Leckie's request, although as will be seen in Chapter 5, the analyses conducted by Eastern Air Command ORS included a mass of information regarding convoys that could only have been obtained through the RCN, which confirms that there was at least a measure of cooperation between the services to facilitate OR activities. However, as in the British experience with Coastal Command and Admiralty ORS', there is no evidence of any

official cooperation in areas of study common to both the Eastern Air Command and Royal Canadian Navy ORS'. In fact, during the winter and spring of 1944, there was a duplication of studies regarding the effectiveness of submarine hunts to exhaustion ('Salmons') which were produced separately (save for exchanges of data) and simultaneously.⁶¹

This lack of official cooperation between Eastern Air Command ORS and its Naval equivalent did not affect the former's operations to any major degree as the key area of information sharing was agreed upon as being of mutual benefit. However, the collection of this data would not become crucial until late in 1943 and beyond, once the staff of Eastern Air Command ORS had implemented a data collection method within the Command itself. The method chosen was based heavily on that used by Mr. Pearman in his analysis of the Command's anti-submarine air effort which he conducted during his visit in March 1942. As early as April 1942, a memorandum circulated from Eastern Air Command Headquarters to the Department of National Defence for Air shows that AVM Cuffe ordered that a daily chart be maintained at Eastern Air Command Headquarters containing the following information:

- (a) Convoy and independent m/v [motor vessel] tracks (24 hours)
- (b) Air escort, showing clearly the number of aircraft involved and the part of the convoy route covered with times between meeting and leaving.
- (c) Sweeps, showing the area covered, the number of aircraft engaged and the times spent on patrol by each aircraft.
- (d) U/boat positions, differentiating between D/F's etc. and sightings.
- (e) Convoy or ship sighting reports from U/boats, showing the position of the convoy or ship at the time of the report.
- (f) Ships sunk or attacked, showing time, position and tonnage.⁶²

These categories formed the basis of Eastern Air Command ORS' monthly operational analyses, as will be seen in Chapter 5. Certain additional categories of information

garnered from the weekly and monthly reports submitted to Eastern Air Command Headquarters from the operational squadrons such as flying hours, aircraft serviceability, weather, U-boat sightings and attacks were also of great value to Eastern Air Command ORS and were carefully collected after November 1942.⁶³ As Professor Wilhelm commented postwar, “presenting this material in a clear manner resulted in the reorganization of certain operational forms, examination of serviceability, relative efficiency of squadrons, etc.” all of which aided the operational effectiveness of the squadrons, which was ample compensation for the annoyance of having to submit detailed reports to Eastern Air Command ORS.⁶⁴ This data collection system, Wilhelm asserted in August 1943, “makes possible a complete monthly summary and analysis which is distributed within two weeks of the close of the month,” whose value to Eastern Air Command Headquarters, as will be seen in Chapter 5, should not be underestimated.⁶⁵

In addition to the collection of data to facilitate monthly analyses, the first six months of Eastern Air Command ORS’ existence was devoted to certain preliminary explorations of special problems as requested by Command Headquarters. These included technical surveys such as windshield de-icing to operational considerations involving the best offensive tactics to use against U-boats, bombing accuracy and its effect on tactical decisions and the impact of implementing hunts to exhaustion in the Command’s operations.⁶⁶ As Wilhelm notes, these early studies were “investigated, some superficially in an exploratory way with a view to determining whether or not they deserved full attention and whether the facilities existed for giving them full study.”⁶⁷ Out of these early investigations would emerge, as will be seen in the next chapter, the exploratory

programme of research undertaken by Eastern Air Command ORS during the final three years of the Second World War.

Eastern Air Command's Operational Research Section emerged out of the efforts of certain senior RCAF officers such as Air Vice-Marshal Anderson and Cuffe who, having encountered the RAF Operational Research Sections on visits to Great Britain and in visits of delegations to Canada, pushed for the creation of examples to assist the Home War Establishment in its duties, particularly in airborne anti-submarine warfare. The implementation of this vision was not linear, as those in favour had to overcome the fact that, as W.A.B. Douglas delicately quips, "the RCAF was not yet attuned to mathematical analysis" as a valuable source of information for commanders.⁶⁸ Once this rather weak suspicion was overcome in the summer of 1942, an additional difficulty arose in the search for suitable candidates to staff the Operational Research Sections as many of the best scientific minds in Canada were already employed in key roles by the National Research Council. This delayed the creation of the Sections only slightly, given that a delay had been built into the planned creation in order to allow for the training of Canadian researchers by the British Operational Research Sections. This experience ensured not only that the Canadian Sections would be modelled heavily upon the British examples but that the studies produced by Eastern Air Command ORS would be complementary to those undertaken previously by Coastal Command ORS. As will be seen in the next chapters, British studies were adapted to explore the same questions but in the Canadian context while at the same time, studies of issues of importance solely to the Canadian airborne anti-submarine warfare establishment such as those investigating operations in the unique environment of the Northwest Atlantic would also be

undertaken. Ultimately, though, such studies operated within the model pioneered by Professor Blackett and his team in 1941, just as Canadian airborne anti-submarine warfare operations were heavily biased towards Coastal Command tactics, with Canadian content being introduced when necessary.

Chapter 4- Eastern Air Command ORS Operational Studies

The body of research undertaken by Eastern Air Command Operational Research Section during its period of activity (November 1942- August 1945) may, like the work undertaken by Coastal Command ORS, be divided into two distinct categories. The work of operational research sections involved the collection of statistics to facilitate monthly analyses of disparate trends such as the influence of weather and the average density of U-boats in a given area on the pace and results of the operational flying of the Command's squadrons.¹ However, Wilhelm adds that "concurrently with the collection of statistics other problems are investigated," at the request of the Command to seek a scientific solution to a persistent problem.² Unlike Coastal Command ORS, which devoted a great deal of effort to such studies, Eastern Air Command ORS, due to personnel constraints and the need to devote attention only to problems of specific interest to the Command, only produced a handful of operational studies. These studies were uniquely tailored to the needs of Eastern Air Command as they attempted to find solutions for problems unique to the Canadian operational environment such as the difficulties of searches for missing aircraft in the inhospitable Northwest Atlantic region, as well as for serious problems plaguing the Command's squadrons such as the persistent lack of bombing accuracy in attacks on U-boats.

Using a case study method, this chapter will explore five specific operational studies conducted by Eastern Air Command ORS in the period 1943-45. The first report produced by the section, Professor Barnes' February 1943 "Comments on Anti-Submarine Effort, 1941-42, E.A.C.," will provide the foundation for the subsequent discussion just as it did for the section's future studies as it identified the limitations and

failings of Eastern Air Command's airborne anti-submarine effort to the end of 1942. Emerging out of this report was the first operational study, which explored the key problem of the poor bombing accuracy of the Command's crews. This study had a measurable impact in that its recommendations were implemented and, in conjunction with equipment changes, contributed to the rise in the number of successful attacks on U-boats during the summer and fall of 1943.

The second and third reports are of note as they involve detailed, long-term studies of methods tailored to the unique operational conditions encountered by Canadian crews in the Northwest Atlantic. The question of prosecuting a submarine contact until it is lost or is confirmed as destroyed, known officially as 'submarine hunts to exhaustion' or, in Canadian parlance, 'Salmons,' were of particular interest. The low U-boat density in the Canadian area and the low probability of reacquiring a contact if it was lost (unlike the high density areas patrolled by Coastal Command such as the Bay of Biscay) meant this was an issue of considerable importance. Although opinion was mixed on their value in Coastal Command, Professor J.O. Wilhelm working in conjunction with Eastern Air Command ORS, implemented plans for the initiation of 'Salmons' given the presence of certain criteria. Later analyses of the 'Salmons' during the summer and fall of 1943 suggested that while this early move to offensive tactics did not bring about any successes, it did point the way ahead for the Command towards a balanced (offensive and defensive) approach to airborne anti-submarine warfare.

Additionally, Eastern Air Command ORS undertook a series of studies during 1944 that took into consideration the unique difficulties the Command's inhospitable and immense area of operations had upon searches for missing aircraft. Although, as with the

previous study, the Section worked from first principles put forth by Coastal Command ORS, they formulated their analysis and conclusions on the needs of Eastern Air Command. These studies were also highly original, involving an application of E.J. Williams' 'density method' for calculating search probabilities to a more peaceful task.

In the closing days of the European war, Eastern Air Command ORS produced an analysis of the relative effectiveness of various search techniques in locating schnorkeling U-boats and the dangerous new Type XXI U-boats that were more akin to the modern submarine than its submersible brethren. This analysis, although obviously of little operational use for the Command given its release date of 10 May 1945, is significant. It was based not upon research conducted by Coastal Command ORS but on that conducted by the United States Navy ASWORG, which, in my view, is yet another illustration of the late-Second World War and postwar shift of the Canadian military's reliance from Great Britain to the United States. As well, with the capture of the plans of the Type XXI by the Soviet Union with the collapse of Germany, this preliminary study would become particularly relevant when Eastern Air Command would be tasked during the 1950s with detecting the Soviet descendants of the Type XXI boats.

The last major Eastern Air Command ORS report of the war, an analysis of the Command's attacks on U-boats during the period October 1941 to June 1945, will be explored as it is a quite reflective document that assesses all aspects of EAC operations and draws some highly critical conclusions. It is a unique source that could only have been produced by a semi-independent establishment as its frank critiques provided an independent (although overly harsh given today's evidence) view of the performance of Eastern Air Command that could be used not only to draw lessons from the experience of

the war but also in the preparation of a Canadian anti-submarine warfare doctrine in the Cold War era.

I

The first two years of the Second World War were relatively quiet for Eastern Air Command. Only a handful of U-boats were encountered, all during the summer and fall of 1941 after the improvements implemented by RAF Coastal Command pushed the U-boats further west into the Atlantic south of Greenland. The availability of longer-ranged aircraft such as the Digby and Catalina allowed squadrons operating out of Newfoundland to reach (barely) the U-boats' new hunting grounds. However, this situation was dramatically transformed by the entrance of the United States into the war in December 1941. Almost immediately, Admiral Karl Doenitz implemented Operation *Paukenschlag*, dispatching five long-range Type IXB boats to strike “a tremendous and sudden blow’ against merchantmen of over 10,000 tons between the St. Lawrence and New York” beginning in early January.³ Compounding this threat, Doenitz also dispatched Group *Zeithen*, composed of seven Type VIIC boats which formed a patrol line stretching 250 miles south of Newfoundland.⁴

The Americans, adamant in their refusal to form their shipping into convoys and being wholly unprepared to counter the U-boat threat, attempted to defend their vulnerable shipping lanes against the marauding submarines. As a result of these ruinous attacks and the success of the Japanese advance in the Pacific, much of the defence of the Northwest Atlantic convoy routes fell to the already overstretched Canadians. However, as Douglas observes, “Operation *Paukenschlag*, would suddenly and graphically illustrate all the quantitative and qualitative weaknesses of Eastern Air Command.”⁵

Only five Canadian anti-submarine squadrons were available on the East Coast at the outset of the German attacks, with only three, Nos. 5 (BR) and 116 (BR) with Consolidated Catalinas/Cansos and No. 10 (BR) with Douglas Digbys, being equipped for long range patrols.⁶ These aircraft types were far from being the state of the art, for they suffered from low powered engines and slow speed (particularly in the case of the Catalinas) which reduced their operational radius and were hampered in the attack role by relatively ineffective depth charges.⁷ Perhaps more importantly, the rapid expansion of Eastern Air Command during the previous two years combined with the lack of aircraft, adequate operational experience and the demands on personnel by RCAF Overseas left the crews of the Command's squadrons inexperienced and inadequately trained in their primary anti-submarine role, one which would strain them severely over the forthcoming year.

The U-boat campaign of 1942 in American and Canadian coastal waters has been well described elsewhere, as has the response of the American and Canadian anti-submarine forces. However, most commentators largely ignore the lessons drawn, particularly in Eastern Air Command, from the initial inadequacies in their airborne response to Operation *Paukenschlag*. The first tentative inquiry, J.P.T. Pearman's operational research study of Eastern Air Command operations during February 1942 discussed in Chapter 3 was produced quite early in the 1942 campaign. Pearman did offer some keen insights based on statistical analysis that not only succeeded in convincing the Eastern Air Command leadership of the value of operational research but also highlighted the need for improved equipment. Pearman noted that the air effort during February was limited to a degree by weather but 299 hours (78 sorties) were spent on escort duty (with

77% of target convoys/independent ships being met) while 748 hours (180) sorties were flown on sweeps and patrols.⁸ Despite this effort, 15 merchant ships were sunk in the Command's area (north of 40N and west of 35W) by U-boats, 6 of which were in convoy.⁹ These losses were not unexpected given the remarkably high U-boat density in the Eastern Air Command area during the period in question. Pearman observed that "there were 283 "finds" of U.B.'s in the area during the month (mainly from Naval Sources)" and comments that "while, of course, this figure does not represent the absolute number of U.B.'s operating, it is not unreasonable that it is proportional and hence will give some idea of the distribution of the U.B.'s actually present."¹⁰ Despite this high U-boat density, Eastern Air Command aircraft only obtained one sighting and attack during the month, which if not concerning enough for the Command's leadership, was conducted not by aircraft from one of the five specialist Bomber-Reconnaissance squadrons but by a Westland Lysander artillery co-operation aircraft on emergency local patrol.¹¹

In an attempt to determine the statistical probability of U-boat "finds" by Eastern Air Command squadrons, Pearman divided the "finds" into zones based on distance from the Command's bases, discovering that 48 finds were 0-200 miles from EAC bases, 82 in the 200-400 mile zone, 106 between 400-600 miles and 47 were between 600-800 miles.¹² He observed that "the amount of A/S flying fell off considerably beyond 200' from base, while there appears to be a maximum U.B. density in the 400-600 mile region," adding that "about half the shipping losses occurred in this region also" marking a U-boat concentration astride the main convoy routes (Group *Zeithen*).¹³ Pearman hypothesized that "the very small number of U.B. sightings by a/c may be due either to superior

vigilance on the part of the enemy or to his knowledge of the standard sweeps (which have been flown regularly for some time) leading him to remain submerged for the greater part of the day when a/c are about.”¹⁴ He asserted that to improve the Command’s performance “more ASV fitted LR [Long-Range] a/c, and ASV beacons are urgently required together with white camouflage to decrease the chance of a/c being sighted first by U.B.’s.”¹⁵

The RCAF response to the submarine campaign and its losses proved to be successful out of all proportion. Toward the end of May, 113 (BR) Squadron equipped with medium-range Lockheed Hudsons began operations from Yarmouth, Nova Scotia while a detachment was based from late August at Chatham, New Brunswick.¹⁶ This squadron would, over the second half of 1942, amass a remarkable record of success against U-boats operating off the East Coast, for which Eastern Air Command staff were initially at a loss to explain. No. 113 (BR) Squadron attacked 11 U-boats during the period June-September 1942, which was more than all other Eastern Air Command squadrons combined for the whole year, and killed 1 (U-754, southeast of Cape Sable) on 31 July 1942.¹⁷ The commander of the squadron, Squadron Leader N.E. Small, was, according to W.A.B. Douglas, “Eastern Air Command’s outstanding pilot and its most conscientious student of maritime airpower” who was “described by senior officers as a ‘master pilot’ and ‘excellent tactician’ possessed of a ‘burning desire’ ‘to get on with the job’.”¹⁸

Two distinct factors contributed to 113 (BR)’s success under Small. First, upon taking command of the squadron in June 1942, Small ordered that the aircraft be painted white (as Pearman had encouraged Eastern Air Command Headquarters to order four months earlier), a novel innovation in the Command at the time.¹⁹ The question of the proper

colour for anti-submarine aircraft had been one of the first major areas of inquiry undertaken by Coastal Command ORS after its creation in March 1941. Preliminary research by this unit had discovered that in the North Atlantic, the almost perpetual overcast ensured, according to C.H. Waddington, that an aircraft's "underside is illuminated by light reflected from the sea, which is about 1/20th the intensity of the skylight" which meant that "even if the aircraft reflected 100% of the light falling on it, it would still appear dark against the background."²⁰ In response to this observation, Coastal Command ORS conducted a series of studies which determined that white camouflage on the sides and underside was most effective in dramatically reducing the silhouette of an aircraft against the clouds.²¹ Small's adoption of this scheme at a time when Eastern Air Command aircraft were painted with dark green/grey/brown camouflage and dark undersides marked a significant departure from Canadian doctrine and an embrace of Coastal Command methods in a search for increased effectiveness against the U-boat.

The second factor introduced by Small was more subtle. Indeed, a comparative analysis by Flying Officer E.C. Common, Intelligence Officer at Gander, Newfoundland, dated 16 January 1943, was required before the full import of Small's innovation was realized at Command Headquarters. Common, used the monthly anti-submarine reports filed by each squadron to Command Headquarters to analyse each U-boat sighting by an Eastern Air Command aircraft during the period June-September 1942. He noted the miles flown by each squadron during the period (and the average total per attack), the distance at which the U-boat was sighted and the height of the aircraft at the time of the sighting.²² This data is presented in chart form by Common, and it is quickly apparent that 113 (BR) was far more active than its sister squadrons during the period in question.

A close examination yields the variable that holds, in part, the answer. The average height in feet of the aircraft when the sighting of the U-boat occurred was 3250 for 113 (BR) while only 845 for the other five Eastern Air Command squadrons.²³ Common admitted that his analysis was quite rudimentary, ignoring variables such as aircraft type, duties (escort versus sweep), weather, etc., but concludes that operational personnel

Will notice, for what significance the facts may have, that the squadron showing the highest average altitude at the moment of sighting [113 (BR)]-

- (a) Showed the largest number of attacks per miles flown.
- (b) Made its sightings on the average at almost twice the distance averaged by the other squadrons.
- (c) Made its attacks when the submarines attacked were submerged on the average only 4.4 seconds as compared with an average of 12.3 seconds for the other squadrons. The greater speed of Hudson aircraft as compared with those [sic] of aircraft used in two of the five other squadrons would account in part, but in part only, for this difference...
- (d) Got in, on the average, more telling attacks than the others.²⁴

Small's U-boat sinking on 31 July 1942 not only marked the first victory for the Command but it also pointedly confirmed the need to adopt certain well-proven Coastal Command tactics, despite the different operational conditions. Interestingly, Coastal Command ORS did not discover the value in flying higher although it confirmed it in a 1943 study.²⁵ Instead, Small was drawing upon the tactics developed by Squadron Leader Terence Bulloch of RAF Coastal Command's 120 Squadron that flew long-range Liberators out of Nutts Corner, Northern Ireland and Iceland beginning in the summer of 1941. Air Marshal C.L. Annis credited Small in a 1979 interview with emulating Bulloch's tactics of flying at several thousand feet to expand the visible search horizon and dropping a 'stick' of depth charges along (not astride) the U-boat's path.²⁶ As Bulloch's biographer, Tony Spooner, remarks, Bulloch and his crew, using these tactics

during 1942 “had tracked down no less than 19 [U-boats]: far more than anyone else on the sea or in the air: more indeed than any of the other of the dozen or so coastal squadrons which made up Coastal Command’s anti-U-boat force.”²⁷ It is therefore, not surprising that when Small implemented both the change in colour scheme and the switch to Bulloch’s tactics, 113 (BR) was to assume a similar level of success as Bulloch.

The U-boat campaign in North American waters slowly reached its denouement during the fall of 1942 as Doenitz reverted to ‘wolf pack’ attacks on convoys sailing through the mid-ocean ‘gap’ where little to no Allied air cover was available.²⁸ When the Eastern Air Command Operational Research Section was formed in November 1942, the first major area of study requested by Command Headquarters was an assessment of Canadian airborne anti-submarine operations during the 1942 campaign. The resulting March 1943 study, prepared by Professor Barnes, entitled “Comments on Anti-Submarine Effort, 1941-42, E.A.C.,” marked not only the first Canadian OR study but also the first systematic attempt to draw lessons from the often frustrating and costly battle with Doenitz’s U-boats off the coast of Canada (and in the Gulf of St. Lawrence) during much of 1942.

Barnes explored the period 1 November 1941 to 31 December 1942, during which 8600 anti-submarine sorties and roughly 51,000 hours were flown by Eastern Air Command aircraft.²⁹ Despite this effort, only 40 attacks were made by B.R. Aircraft of the Command during the period, resulting in 16 claims of damage including three ‘probables,’ later confirmed postwar to be ‘kills’.³⁰ Barnes pointed out that this compared quite favourably with Coastal Command’s average of 1 kill for every 50 attacks and added that the absence of a confirmed kill at the time “is not so far indicative of any

demonstrable inferiority of performance in comparison with Coastal Command using the same tactics.”³¹ However, when one takes into account the average number of sorties per sighting, Barnes asserted, Eastern Air Command’s record became less impressive. He determined that for Coastal Command “an average of 1 sighting for each 30 to 40 operational sorties of all kinds has generally prevailed,” but in Eastern Air Command, when one adds the 23 sightings not resulting in attacks to the 40 attacks, “this leads to an average of 1 sighting per 134 sorties. only about one-quarter of the Coastal Command ratio.”³²

Barnes explained that “while the number of sightings made during the period... may have been susceptible of some increase with greater experience of aircrews and more effective use of A.S.V., any such increase would ultimately be limited by the low density of U-boats in the E.A.C. operational area.”³³ This low density of approximately 1 U-boat per 40,000 square miles combined with the lack of a definite ‘transit route’ for submarines such as that in the Bay of Biscay ensured that the number of sightings and kills by Eastern Air Command would be much lower than the equivalent totals achieved by Coastal Command that operated in more ‘U-boat rich’ regions.³⁴ Barnes concluded that “if this situation continues, some deviation of E.A.C. tactics from those employed in Coastal Command might prove to be advantageous”; more specifically, a shift to submarine hunts to exhaustion, which were studied in due course by Eastern Air Command ORS.³⁵ Barnes did not offer any other potential solutions other than a rather vague suggestion that “there is doubtless scope for improvement in bombing accuracy,” which in fact. would form the first official Eastern Air Command ORS operational study.³⁶

II

The question of bombing accuracy on attacks on U-boats was a preoccupation of Eastern Air Command throughout the war as there was a general feeling that several opportunities for kills were missed due to poor attack techniques. This problem was even more distressing for the leadership of the Command when statistical data was made available in 1943 pointing to the very low U-boat density in the EAC operational area, which simply reaffirmed the need to effectively prosecute all U-boat sightings. One individual at Command Headquarters who had become particularly concerned with this question as early as the fall of 1940 was the Command armament officer, Squadron-Leader C.L. Annis. In a 1979 interview, Annis complained that the weapons with which EAC conducted its anti-submarine operations during the first two and a half years of the war were wholly unsuitable, with 10 (BR)'s Digbys being equipped with "the American 600-lb bomb which wasn't very satisfactory" as it had a low maximum release height (which gave the target time to dive) and was plagued with an unreliable detonation mechanism.³⁷ Other squadrons were even less fortunate, being equipped with the British 250-lb anti-submarine bomb, which as noted in Chapter 1, had a nasty habit of bouncing off the surface of the water, leaving the target unscathed but proving deadly to the attacking aircraft.

Although airborne depth charges began to trickle into Eastern Air Command squadron service during the summer of 1941, they arrived too late to bring about decisive results in the first attack on a submarine in the Command's area in October 1941. Several U-boats were reported to be operating in the Straits of Belle Isle between Newfoundland and

Labrador against convoy traffic in the area, thus marking an unintended prelude to the 1942 Campaign and 10(BR) based at Gander was ordered to search the area.³⁸ Annis happened to be visiting the base on October 25 as part of a Court of Enquiry into a series of Digby crashes and as he notes since “No. 10 (BR) was also short of pilots and I was fully qualified on the aircraft I took a turn, although Armament Officer, and went up.”³⁹

Annis continues:

Aircraft on patrol were flying the legs of a parallel search and because of the weather had come down to 600 feet. I remember the salt spray was hitting the windscreen when I suddenly spotted a submarine. We cast out markers and prepared to attack. However, the bomb aimer had set the 600-lb bombs to safe- in accordance with regulations that fused bombs could not be carried below a certain height. Consequently, no damage was done to the submarine. It was just another instance of the need for training.⁴⁰

W.A.B. Douglas, in his discussion of the disappointing results of this attack, observes that the bomb-aimer made “the kind of mistake that crew training in operational training units [OTUs] was designed to avert, but Eastern Air Command had no resources for OTUs. Squadron commanders were merely urged to advance aircrew effectiveness by any means available.”⁴¹ The need for a high level of aircrew training, although never entirely achieved in Eastern Air Command due to the demands for experienced aircrew overseas, was noted by Coastal Command AOC-in-C Air Marshal John Slessor who remarked on the “profound influence of training” in the Atlantic battle.⁴² He added that “one of the main enemies [of anti-submarine aircrew] was boredom, the endless monotony of patrolling apparently empty wastes without ever sighting a U-boat or getting the chance of a kill.”⁴³ This monotony interrupted by the sudden sighting of a U-boat required extensive training to ensure that the attack was accurate and perhaps more importantly, that the crew would survive to tell of it.

A direct consequence of improved training in aircrew is invariably an improvement in the accuracy of weapons delivery. However, as noted in Chapter 2, E.J. Williams seminal Coastal Command ORS study of depth charge settings demonstrated that even crews which delivered accurate attacks were hamstrung by misguided policies that ignored the fact that aircraft could only be effective against visible targets, making shallow-set depth charges the only useful weapon.⁴⁴ During 1942, Coastal Command ORS began to explore the question of the proper spacing within a 'stick' of multiple depth charges dropped on a target. Coastal Command's tactical instructions advocated a 'tight' spacing of 36 feet between charges, which was subsequently adopted by Eastern Air Command.⁴⁵ However, as C.H. Waddington recounts, Coastal Command ORS discovered that this spacing ensured that the lethal and damaging ranges of the stick overlapped and instead recommended a spacing of "at least 38 ft plus the beam width [of the U-boat- about 16 ft]; and even this is only the minimum for kills, while for maximizing the probability of damage we should take twice the damaging radius plus the beam width."⁴⁶ Both Coastal Command and Eastern Air Command squadrons persisted in using the tight spacing through March 1943, when new tactical instructions were issued to Coastal Command squadrons while as late as October 1942, RCAF tactical instructions citing "the available reports on anti-submarine operations both British and American" emphasized that "the ground spacing between bombs is set at 36 ft. where depth charges are used."⁴⁷ Certainly it would be unfair to critique Eastern Air Command for persisting in a policy still upheld by Coastal Command, but it undoubtedly did not enhance the accuracy or lethality of both Commands' crews while the policy was in place.

In an attempt to improve the accuracy and lethality of Eastern Air Command attacks, the ORS undertook a study similar in nature to that of Coastal Command ORS regarding bombing accuracy and stick spacing. Entitled "Attacks on Submarines- Relation of Tactics To Bombing Accuracy," this report was released for circulation on 8 May 1943, two months after the release of Coastal Command's revised tactical instructions calling for larger spacing within depth charge sticks and six months after the creation of the Section. This study, conducted by Professor Barnes and Doctors Hopkins and Smith, revolved around the simply stated hypothesis that "at the present time bombing error is considered to be the major factor determining the probability of success in attacks on U-boats by aircraft."⁴⁸ The authors observed that bombing error involved not only "errors in line and range in the estimation of the position of the target (U-boats at the instant of attack being as a rule either submerged, or if surfaced, in motion)" but also "subsequent errors in placing the centre of the D.C. stick at the point of aim."⁴⁹ They added incredulously that "it is a striking fact that in spite of the great effort devoted to creating and operating A/S squadrons, no specific quantitative study of the bombing accuracy attained by such units seems yet to have been undertaken," save for the work of Coastal Command ORS which discovered an average error of 56 yards (168 feet) in a review of attack photographs.⁵⁰

The authors, on the basis of a detailed statistical analysis, concluded that "it is at once apparent that the short stick spacing of 36 ft. hitherto used by E.A.C. should be abandoned," adding that "a spacing of from 70-100 ft. would be in better agreement with our present estimates of bombing errors, and there would be no reason to adopt much shorter spacing until evidence has been accumulated to show that the errors themselves

have been substantially reduced.”⁵¹ Noting that this change could be harmful to accurate bomb-aimers by reducing the concentration of lethality on the target, the authors observed that ultimately, “adoption of the long stick when bombing is inaccurate may therefore be justified on the ground that it is better to inflict morale-impairing damage on an appreciable proportion of all U-boats attacked than to restrict results to the total destruction of a very much smaller number.”⁵² This reference to the morale effects of attacks is interesting as this view had already been shown to be a relic of the early days of airborne anti-submarine warfare when aircraft were capable (on the main) of little more than being annoyances to submarines.

The ultimate influence of this first Eastern Air Command ORS operational study is open to question. In a review of the summaries of the U-boat attacks resulting in kills, the spacing used in the attacks in the Command’s two kills after May 1943 were 50 and 60 feet whereas pre 1943, they ranged from a low of 20 feet to a high of 46 feet.⁵³ Clouding the issue further is the fact that training was left very much in the hands of individual squadrons. For example, given that Wing-Commander Annis commanded 10 (BR) during the period in question, his expertise with bombing accuracy likely was the determining factor in the adoption of the longer stick (although not as long as that recommended by Eastern Air Command ORS). Whatever the case may be, the Eastern Air Command study addressed a serious issue in the Command but ultimately it came almost a year after the major influx of U-boats into Canadian waters.

III

The question of bombing accuracy was predicated upon two very uncertain variables, namely whether aircraft could locate a submarine contact in the first case and whether

they could keep in touch with the target until it was destroyed. In the majority of Eastern Air Command sightings, the target submarine was able to escape by submerging before the aircraft was able to prosecute the attack. Of course, six U-boats were destroyed by the Command's aircraft and several others damaged before they could make good their escape. However, the low U-boat density in the Eastern Air Command operational area increased the need to fully prosecute all contacts either until they were destroyed or until contact was lost. not only to increase the Command's kill totals but more importantly, to remove the threat posed by a handful of marauding U-boats such as occurred during the summer of 1942 in the Gulf of St. Lawrence.⁵⁴

As early as September 1941, Coastal Command ORS produced a study, "Notes on U/B hunts," which dismissed the value of hunts to exhaustion. The report, prepared by an OR researcher by the name of Whitehead, drew a distinction between purposeful hunts and "all other A/S operations," which by definition would include escort duties, patrols and sweeps.⁵⁵ Adding "that a hunt is not a matter of routine but is a contest between the controller and the U/B commander," the author asserted that given the low probability of gaining a second sighting (3 to 1 against) "the odds are against the controller, who can therefore afford to experiment boldly with new methods."⁵⁶ Based on this information, the author commented that "the exhaustion hunt is rejected as being too expensive in a/c if carried out thoroughly, and a waste of effort otherwise."⁵⁷ He supported this assertion by noting that "the idea of the exhaustion hunt grew out of a belief that attacks on U/Bs by a/c were ineffective, whereas it is now reasonable to expect that up to 20% of future attacks will result in serious damage to the U/B."⁵⁸ As a result, the author concluded that hunts must be kept as short and deadly as possible in order to maximize the results with

the greatest economy of effort, which as he notes, “implies a sharp contrast with the exhaustion hunt, since it is now desirable that the U/B should spend an appreciable part of the time on the surface, instead of submerged.”⁵⁹ Indeed, the purpose of a hunt to exhaustion, to force a submerged submarine to deplete its batteries and surface, thus leaving it open to attack by the patrolling forces dispatched to take part in the hunt, was seen by the Coastal Command ORS as being extremely wasteful in effort since the potential existed with the weaponry, sensors and aircraft becoming available in late 1941 such as the Liberator to strike a telling blow upon the target upon sighting. Instead, Whitehead suggested that “a thorough search should not be maintained over an area under which the U/B is presumed to be,” with the focus being on “clear ‘white’ areas, in which the U/B will be encouraged to surface, and heavily patrolled ‘black’ areas through which, having surfaced, she may be expected to pass.”⁶⁰ This system was implemented in modified form in place of hunts to exhaustion for Coastal Command’s successful Biscay Offensive of 1943, the specifics of which have been discussed in great detail elsewhere.⁶¹

However, this system was also based on the idea that the target U-boat would be in transit through the area, therefore lacking options on its routing if it was to arrive at its ultimate destination. For example, U-boats transiting the Bay of Biscay from French bases were limited, by geography and the defensibility of the English Channel chokepoint, to the use of westerly routes out of the Bay. If a U-boat could be sighted early enough on its outward journey, then estimates based on its underwater range could be made as to its approximate location when it would surface to recharge its batteries, thus providing a series of ‘black’ zones which could be patrolled.

The situation in Eastern Air Command was quite different as there were no identifiable transit routes in the operational area. Although chokepoints such as the Straits of Belle Isle did exist, the lack of resources plaguing Eastern Air Command did not allow continuous patrols, nor would this be efficient. As Professor Barnes noted in his 1943 "Comments On Anti-Submarine Effort, 1941-42, E.A.C.," the lower U-boat density in the Western Atlantic than in the Western Approaches of the British Isles, the Bay of Biscay and astride the convoy routes south of Iceland ensured that "opportunities for attacks on U-boats may always be much fewer in number in E.A.C."⁶² Based on this observation, Barnes commented that "tactics logically adopted by Coastal Command therefore may not always be the most suitable ones for E.A.C. and vice versa."⁶³ He suggested that instead of the typical Eastern Air Command practice of abandoning the target after contact was lost, it should adopt "an aggressive and persistent hunting procedure following each attack whenever weather and distance permit."⁶⁴

Despite being inefficient regarding flying time, Barnes asserted that had the 40 attacks during 1942 been fully prosecuted, only 2% more flying time would have been required to extend the hunt to an average of 12 hours.⁶⁵ Given the British estimate that a second sighting would occur in only 25% of the hunts, Barnes concluded that even "this would have produced a further 10 sightings, of which E.A.C. statistics suggest that 5/8 (40[attacks]/64[total sightings]) or 6 would have resulted in attacks."⁶⁶ This would have increased the total number of attacks by 15%, ensuring that "such hunts as were undertaken would have been about 7 times as profitable, in terms of attacks on U-Boats, as E.A.C. anti-submarine flying in general."⁶⁷ Barnes qualified his assessment of the value of hunts to exhaustion with the proviso that 1/3 of the 1942 cases, if extended

would have been severely affected by weather while 45% would have had to have been conducted in darkness, requiring the use of night proficient crews and ASV.”⁶⁸ Barnes noted that the latter factor “currently present obstacles to efficient night operations” but adds that “these obstacles should however be capable of being surmounted by intensive training and technical development.”⁶⁹

Barnes’ comments obviously struck a chord as Professor J.O. Wilhelm, in May 1943, elaborated on the question of hunts to exhaustion in a memorandum to the Air Member for Air Staff, Air Vice-Marshal N.R. Anderson. Regarding the implementation of Barnes’ proposal, Wilhelm suggested that “a purely statistical study of this type of tactics [sic] involves an impractical number of aircraft and service vessels when the attack is considered to take place in open ocean at fair distances from bases and under conditions of poor visibility.”⁷⁰ Instead, Wilhelm opined that “if... in advance special plans for specific areas were prepared in which advantage was taken of every facility at our disposal, at the same time striking when the U-Boat was at a definite disadvantage and having the additional advantage of good weather forecast in our favour, then though 100% certainty would not result there would be a reasonable chance of putting the U-Boat out of the picture.”⁷¹ In particular, Wilhelm suggested that hunts to exhaustion would be ideal in Canadian coastal waters, particularly the Gulf of St. Lawrence, as only at short range could Eastern Air Command hold the upper hand due to the availability not only of all types of EAC aircraft but also of aircraft of BCATP training schools and OTUs in Prince Edward Island and Nova Scotia equipped with hundreds of short-range maritime aircraft like Avro Ansons.⁷²

Anderson, according to Wilhelm, “indicated sympathy with the idea, provided always that the protection of convoys and shipping remain with No. 1 priority.”⁷³ Wilhelm did note that the implementation of even a limited plan of hunts to exhaustion would have to overcome several daunting obstacles. First, Wilhelm included a page-long list of the various military and civilian elements which would need to be integrated in order to actively undertake such a hunt in coastal waters, ranging from RCAF units, American aircraft in Newfoundland to Army coastal lookouts, RCN ships and command centres, merchant shipping and even lighthouse keepers.⁷⁴ He added that a general plan, able to be implemented immediately upon receipt of a sighting report with “formula for utilizing the various search plans prepared should be set up for each area and these plans with the requisite detailed information should be available to the controllers at each area control centre.”⁷⁵ Wilhelm concluded that “probably the most important item would be the briefing procedure which would be necessary at various stages of the plan and this would depend for success on communications and a proper appreciation of all the factors involved by the officers responsible for the briefing.”⁷⁶ Given the reluctance of the RCAF and the RCN to coordinate their efforts in any meaningful way until mid-1943 due to their desire to maintain their autonomy, the unity required by the command and control structure envisioned by Wilhelm in this case appears, on paper at least, to be overambitious at best.

However, the deep shock both within the Canadian Home War Establishment and across the country generally caused by the operations of U-boats in the Gulf of St. Lawrence during 1942 certainly produced a desire to counter the inshore submarine threat if it reappeared in the future. Indeed, Wilhelm captured this air of resolution, noting that

“we have every reason to expect that the U-boats will operate in the same area again this summer and exhaustion hunts in part of the area should be considered.”⁷⁷ Despite Wilhelm’s call, naval historian Marc Milner notes that submarine hunts to exhaustion, code-named ‘Salmons,’ “never got much beyond the planning stage in 1943” as “no operational orders were issued and no joint training was undertaken.”⁷⁸ However, by July 1943, the pieces to make ‘Salmons’ a reality were coming together. The provision of Naval Service Headquarters ‘Otter’ submarine tracking intelligence finally provided Eastern Air Command with the up-to-date intelligence required to launch effective sweep patterns which had a higher probability of detecting a U-Boat, thus creating one of the necessary conditions for the launching of a ‘Salmon’.⁷⁹ As well, the equipment of the Command had been dramatically improved during early 1943 with the arrival of Lockheed Ventura medium range and Consolidated Liberator very long range aircraft as well as Leigh Lights, sonobuoys and acoustic torpedoes, which improved the lethality of the squadrons.⁸⁰

However, the defeat of the ‘wolf packs’ in the series of mid-ocean convoy battles during the summer and fall of 1943 had dramatically changed ‘the rules of the game.’ W.A.B. Douglas asserts that this defeat drew the U-boats back into North American coastal waters during the last year and half of the war but did so in a manner quite different than the operations of 1942. Not only did the U-boats trickle in singly, Douglas points out that “submariners were now cautious, sometimes to the extreme, intent upon a quick kill and getaway” and tended to remain submerged, lying in ambush for their victims. making them extraordinarily elusive foes.⁸¹

On 29 October 1943, Naval Service Headquarters Operational Intelligence Centre (OIC) requested that Eastern Air Command and Naval Headquarters, Halifax, implement the first search plan 'Salmon' to locate *U-537*.⁸² This particular U-boat had been engaged in landing a weather station on the Labrador coast when it was ordered by Doenitz to patrol off St. John's, a signal intercepted by ULTRA that enabled OIC to issue an 'Otter' report and the request for the implementation of a 'Salmon' hunt.⁸³ Milner and Douglas note, however that neither the Commander-in-Chief Canadian Northwest Atlantic, Admiral Lowell Murray or the AOC-in-C of Eastern Air Command, Air Vice-Marshal G.O. Johnson, were terribly eager to implement the Salmon, preferring to focus on convoy escort.⁸⁴ Murray reluctantly ordered Johnson (whose command was under his operational control) to search for *U-537* in the area 150 miles off St. John's noted in the 'Otter' signal. On 31 October, a Hudson of 11 Squadron found *U-537* on the surface and attacked it with rocket projectiles, the first and only time this weapon was used in Eastern Air Command history.⁸⁵ The 'Salmon' search procedure was immediately implemented and several aircraft were dispatched to search the area, but with no success. The attacking Hudson departed too soon, for the crew did not realize that their continued presence was essential to force the U-boat to submerge and thus limit its mobility.⁸⁶

Although *U-537* escaped this 'Salmon,' a second operation was launched against it on 10 November when a Canso of 5 (BR) Squadron attacked it off Cape Race while on convoy escort.⁸⁷ Despite the dispatch of several of the escorts of convoy HX 265 to the scene, *U-537* made a temporary escape, in large part due again to the premature departure of the attacking aircraft.⁸⁸ However, the submarine was relocated by another Canso on the morning of 11 November, this time slightly damaging it with depth charges.⁸⁹ Even more

promising was the fact that the pilot of this aircraft remained in the area until a relief aircraft arrived. Unfortunately, the crew of this aircraft did not conduct a complete search of the area, which meant that the arriving support group of RN and RCN escorts were forced to sweep an ever-increasing area for the next three days in a Newfoundland fog which robbed them of air support.⁹⁰ *U-537* escaped the Canadian net, and as Douglas observes, although two attacks had limited the submarine's offensive freedom, poor air-sea cooperation and the lack of detailed instructions particularly for aircrews (despite Wilhelm's assertion that this was essential) made the first 'Salmon' a disappointing affair.⁹¹

Nor would future 'Salmons' over the next year produce more satisfying results. Both Milner and Douglas provide excellent discussions of the searches for *U-543* (26 December 1943- 6 January 1944), *U-845* (9-12 February 1944), *U-541* and *U-802* (7-10 September 1944), all of which ended with much exhaustion of effort but no sinking.⁹² Much of the blame emanating from the enthusiastic supporters of 'Salmons' at RCAF and Naval Service Headquarters in Ottawa for these failings was levelled at the conservatism of Murray, Johnson and their subordinates who allegedly preferred convoy escort to 'Salmon' searches. In a memorandum dated 3 February 1944, acting Air Member Air Staff Air Commodore K.M. Guthrie criticized Johnson, noting that although protection of convoys was definitely the first priority, "it can hardly be argued from this, however, that if we protect the convoys we have done our job, and that there is therefore no need to take the offensive" adding that "this argument has the weakness of all arguments in favour of the defensive."⁹³ Guthrie recommended to Johnson that "it is felt that serious consideration should be given to whether aircraft escort is sometimes wasted

on convoys which are not threatened” but quickly protests that “it is not intended in this letter to dictate operational policy which must lie in the hands of yourself as the operational Commander; this is simply setting forth the argument, which is considered a sound one, in favour of an offensive policy.”⁹⁴ Clearly, Ottawa was unhappy at the lack of success in the implementation of ‘Salmons’ and although such discussions are beyond the scope of this thesis, it strikes this author that the desire for an offensive policy against U-boats was entirely politically-motivated, based on a desire to calm public concern of military operations in Canadian waters while also being a thinly veiled attempt to garner the acclaim that U-boat kills would create for the RCAF and RCN.

Ultimately, the initial recommendation by Eastern Air Command ORS to Command Headquarters to consider implementing hunts to exhaustion was based upon an objective consideration of the operational circumstances faced by the Command, which was the primary purpose of the ORS. The low submarine density combined with the proven dangers posed by U-boat operations in Canadian coastal waters pointed in the direction of the potential benefits of hunts to exhaustion, if properly implemented. Despite being dismissed by Coastal Command ORS as wasteful of effort, Eastern Air Command implemented ‘Salmons’ during 1943-44, albeit reluctantly given the Command’s focus upon convoy escort. The result could be best described as a debacle caused not by any fundamental flaw in the concept of hunts to exhaustion but due to improper execution. The lack of air-sea cooperation, the lack of resources (a perpetual problem in the history of the Command) and a distinct reluctance to devote assets to ‘Salmons’ on the part of the RCN and Eastern Air Command leadership ensured that this ORS experiment was doomed to fail. However, the potential success, if properly executed, of hunts to

exhaustion provided food for thought in future doctrinal considerations by the postwar Canadian anti-submarine establishment.

IV

The search for the elusive U-boat enemy was severely complicated by the hostile environment in which Eastern Air Command had to operate. In a 1943 report on the Command's anti-submarine effort, then-Wing Commander C.L. Annis remarked that "meteorologists are quick to say that no worse weather exists anywhere than is found over the North Atlantic" but also offered high praise to the aircrew of the Command, noting that "where experienced pilots are operating it is gratifying to see how large a percentage of days can be made good."⁹⁵ As W.A.B. Douglas comments, the results Canadian crews obtained in spite of "some of the worst flying weather in the world, plagued by fog and ice... knowing too well that the prevailing westerly winds would often make their return flights the most hazardous part of each mission" were nothing short of remarkable.⁹⁶ Naturally in wartime flying in these conditions, losses would inevitably occur. In the case of Eastern Air Command the vast majority of losses were due to mechanical failures or weather and all missing aircraft were searched for to the extent of the Command's capabilities if there was any hope of locating survivors.

The unique difficulties posed by searches for missing aircraft in the Eastern Air Command operational area made this an ideal topic for study by the ORS. During 1944 and 1945, the Section conducted two short theoretical studies of this problem based heavily upon not only the work of Coastal Command ORS but also of Western Air Command ORS.⁹⁷ Many of the points under discussion in the first report, a February 1945 revision of a draft produced in September 1944, were not novel findings but instead

were intended to ensure that “the organization of a search... [would] be guided by certain general principles.”⁹⁸ The report explored the proper height and search patterns for both sea and land searches while also drawing attention to the unique problems of currents and tidal forces on the drift of survivors’ dingys. The significance of this report and its successor produced during the summer of 1945 is twofold. First, its emphasis on proper procedures for searches for missing aircraft points to a desire on the part of the authors to provide a useful tool for use by the operational squadrons. More importantly, the Eastern Air Command ORS illustrated its growing confidence and maturity through a novel use of the ‘density method’ pioneered by E.J. Williams at Coastal Command ORS for use in plotting probability areas for more efficient allocation of aircraft patrols. The staff of Eastern Air Command ORS adapted Williams’ methods to a more peaceful task, advocating the use of both probability areas and what they term ‘density charts’ to make the search more efficient and, hopefully, more effective.

In the February 1945 report, “Searches for Missing Aircraft,” the concepts of probability areas and density charts were introduced, to be subsequently refined in the post war “A Review of Searches for Missing Aircraft, Eastern Air Command 1 January, 1944- 1 June, 1945.” Probability areas were defined as “areas to which it is deemed reasonable to give special emphasis in the search procedure.”⁹⁹ These were divided into three classes:

- (i) Probability Area I, defined as the area about a position whence a distress message has been received.
- (ii) Probability Area II, defined as the area on either side of the estimated track of an aircraft, for which no specific crash position is available.
- (iii) Probability Area III, defined as an extension of Probability Areas I and II and suggesting logical regions to be searched if the original probability areas have been searched without avail.¹⁰⁰

These probability areas may be understood as an ever-expanding search area, which is familiar to those who have followed contemporary civilian air disasters and the search procedure undertaken. Density charts, on the other hand, were related to the administration of the searches conducted according to the probability areas. According to the report, “ordinarily at the end of the day, [of searching] a map is drawn showing the extent of searching done that day” with a master map being compiled over the course of a multi-day search to keep a visual record of the area covered.¹⁰¹ The value of density charts was to be found in situations where a large number of sorties searching an area with variable coverage made an ordinary map difficult to decipher.¹⁰² The density chart illustrated “the relative amounts of coverage given to different areas” through variations in shading, in order to arrive at which, “each sortie is assessed for the amount of coverage given and the total coverage for a given area is obtained by adding the coverages provided by different sorties for that area.”¹⁰³ These assessments were based primarily on visibility as reduced visibility would reduce the area which can be visually scanned but it was also influenced by aircraft serviceability and availability as a smaller number of aircraft than a given ideal (based on the size of the area) would not provide as effective coverage.¹⁰⁴

The post war modifications recommended in ORS Report No. 20 were largely confined to minor points of detail regarding the construction of effective density charts. However, the importance of this report rests in the fact that these conclusions were drawn from a study of 29 searches for missing aircraft in the Eastern Air Command area during the period 1 January 1944 to 1 June 1945.¹⁰⁵ The results of these searches are beyond the

scope of this paper but the crucial point is that the methodology discussed in previous reports was used in the searches after September 1944, which illustrates not only the effectiveness of the Section's recommendations but also a growing willingness on the part of the Command's operational personnel to utilize the advice provided by the ORS civilian 'boffins'.¹⁰⁶

V

As previously noted, the war against the U-Boat was dramatically altered after the mid-ocean defeat of the wolf-packs during the summer and fall of 1943. The German shift to inshore tactics off the coast of North America during 1944-45 was in part motivated by a desire to find a hunting ground where the effectiveness of Allied aircraft and surface escorts could be hindered, to allow the U-boats a chance at inflicting damage on merchant shipping. This shift in tactics was, however, enhanced by the advent of a new piece of equipment which transformed the U-boat from a submersible dependent on frequent and dangerous surfacings to recharge its batteries and refresh the stale air inside the boat into a submarine, capable of extended operation below the waves with a previously unknown degree of safety. This invention, the schnorkel, was first fitted to submarines of the Royal Netherlands Navy during the 1930s, but was seen as a quaint, rather pointless device by both the British and the Germans when they inspected examples of the device following the collapse of the Netherlands in May 1940.¹⁰⁷ The extreme dangers posed by 1943 to surfaced U-boats at all times of the day by radar equipped escorts and Leigh Light and ASV long-range patrol aircraft encouraged the *Befehlshaber der U-boote* (BDU- U-Boat Headquarters) to re-evaluate their earlier dismissal of the schnorkel.¹⁰⁸ Douglas McLean describes the schnorkel as "a

comparatively simple device which provided enough air to allow U-boats to operate their diesel engines while submerged” and adds that the huge advantage of the schnorkel rested in the fact that instead of having the conning tower of the submarine fully surfaced while operating its diesels, a U-boat now only had to raise “little more than a tube about as long as the submarine’s periscope.”¹⁰⁹ Given that the raised periscope was essentially invisible to the naked eye in anything but ideal atmospheric conditions from an aircraft and was only detectable by the new Allied centrimetric radar (again, only in certain conditions), the problems posed to Allied anti-submarine forces by this innovation had the potential to be immense and dangerous.¹¹⁰

This was a priority problem to which the Allies devoted a great deal of effort to counter. A report dated 27 January 1945 from Wing Commander D.H. Wigle, a member of the Canadian Joint Staff in Washington, reported that “operational experience has not yet confirmed, but tests conducted by both U.S. Navy and the R.A.F. indicate that centimetre type radars can pick up Schnorkel, but the resulting blip, because of its size, is most difficult to track through sea return and is hard to distinguish from noise.”¹¹¹ Wigle added that increased training of radar operators and improved maintenance of radar equipment to maximize its detection ability were the two main short-term solutions devised by the US Navy. But he also noted that the successful tests versus schnorkel using the AN/APS15 radar made it essential, in the Joint Staff’s opinion, “that the procurement of this equipment for installation in Liberator aircraft being received in 1945 be thoroughly considered” by the Air Staff.¹¹² However, Wigle also pointed out that “the supply situation of the main equipment and associated items is extremely tight, a fact which made the availability of this device, a long term solution at best.”¹¹³

In the meantime, operational research sections in Great Britain, the United States and Canada worked to maximize the effectiveness of existing aircraft and equipment against U-boats equipped with this dangerous new device. Two days after the end of the war in Europe, Eastern Air Command ORS released a report, "An Analysis of the 'Scouting Effectiveness' of Some Current A/S Patrols (With special reference to Schnorkel and Type XXI Tactics)." Basing their analysis upon two studies produced by the US Navy's Anti-submarine Warfare Operations Research Group (ASWORG), the unnamed authors of the Eastern Air Command study examined a variety of common patrol patterns used by Canadian aircraft in the convoy escort role using two American analysis tools: the 'scouting coefficient' and the 'danger area'. The 'scouting coefficient' was "defined... as the percentage of U-boats which may be expected, on the average, to be detected by the patrol before they have entered the danger area surrounding the convoy."¹⁴ The 'danger area,' therefore, "is the region within which a U-Boat can not only detect the convoy, but can also either catch up with it or be overtaken by it."¹⁵ The authors noted that "one must be rather careful in the interpretation of the meaning of the 'Scouting Coefficient'" as it "is not a measure of the tightness of screening and it does not therefore take into account the fact that a given patrol which may show a relatively low S.C. may be a good patrol because it is a tight barrier."¹⁶

Eight patrol types were examined, six used by Canso aircraft (the most common in EAC ASW squadrons 1944-45), one used by any aircraft and one used by Liberators or Venturas. The 'Viper' patrol (close escort of a convoy within visible range) common to all aircraft types was not explored in detail as its scouting coefficient was described as "virtually nil" and viewed generally as a "very poor patrol indeed."¹⁷ Of the patrol types,

only the 'Modified Crocodile' patrol used by all aircraft types (with minor variations in range from convoy between that used by Cansos (15-17.5 miles) and Liberator/Ventura (15 miles) due to speed differences) was viewed in a positive light with scouting coefficients of 81.5% and 80.0% for the Canso variants and 86.5% for Liberators and Venturas.¹¹⁸ This conclusion must have been welcome to Command Headquarters for as the authors note, "the "modified Crocodile" was recently devised in an attempt to increase the protection afforded to convoys against schnorkelling U-Boats (including Type XXI)" adding that "it requires only one aircraft and is designed to act as an efficient barrier against the undetected passage of schnorkelling U-Boats approaching from ahead and from the forward quarters."¹¹⁹ The utility of this search pattern used by aircraft fitted with existing equipment provided at least a temporary stopgap until adequate supplies of AN/APS15 radar could become available, at which point this patrol would become even more effective.

In any case, the report was essentially out of date upon its release as the U-boat threat had ended with VE Day. However, this report is significant for two reasons. First, it provided a working basis from which to further research into the aerial detection of schnorkel-equipped U-boats, research which would become vital in the coming years as the Soviet Union began to field large numbers of diesel submarines based heavily on the late war German designs such as the Type XXI which caused such a stir in the final year of the war within the Allied anti-submarine warfare establishment. Of more direct importance to the theme of Canadian airborne anti-submarine warfare operational research, the fact that this analysis was based not upon research undertaken by Coastal Command ORS but instead upon that done by the American ASWORG is symbolic of

the larger shift not only in technological expertise to the Americans by war's end but also of the general shift in the Canadian military towards a closer relationship with the American military in lieu of the traditional attachment to Great Britain. This shift, although slow, would characterize the postwar development of Canadian airborne anti-submarine warfare doctrine, which would be based around a Canadian interpretation of Anglo-American principles and would reach its pinnacle with squadrons equipped with the Canadair Argus, a Canadian designed maritime patrol aircraft based on the British Bristol Britannia airliner powered by American engines and equipped with a mix of weapons and sensors from all three nations.

VI

As may be seen from the above reports, the nature of airborne anti-submarine warfare became increasingly sophisticated over the course of the Second World War. In one of the last reports conducted by Eastern Air Command ORS before it was dissolved in the fall of 1945, a study of the various trends in the 81 separate attacks on U-boats by aircraft of the Command was undertaken. The report, "Summary of Aircraft Attacks on U-Boats Eastern Air Command 1 October, 1941- 1 June, 1945," did not attempt to draw conclusions from the evidence discussed, likely in part due to the conclusion of hostilities prior to the report's release in June 1945. Instead, it serves not only as a record of the Command's attacks and thus has value historically but it also is an example of the independent analysis which an ORS can provide for a command in order to objectively explore and define the scope of its previous achievements.

The 81 separate engagements by Eastern Air Command of U-Boats yielded, according to the report, 88 individual attacks with the primary weapons of the Command's

squadrons, namely depth charges, bombs and rocket projectiles.¹²⁰ The distribution of these attacks by year were 1941- 1, 1942- 42, 1943- 31, 1944- 8, 1945- 6, with the majority (71) centred on the western mid-ocean convoy routes, with 8 in the Gulf of St. Lawrence. 5 in American coastal waters, 3 in the St. Lawrence River and 1 in the Strait of Belle Isle.¹²¹ Of particular note is the significant decrease in attacks after 1943, which is not surprising given the radical transformation in U-boat warfare after that year as discussed above. Of these attacks, 75 involved depth charges, 10 utilized 600lb depth charges, 2 involved anti-submarine bombs while 1 utilized rocket projectiles.¹²²

The authors of the report then conducted a statistical analysis of the above information to assess the lethality of EAC's attacks. They noted that "for the 88 attacks under consideration the assessments... are:

"A"- Known sunk-	1
"B"- Probably sunk-	2
"C"- Probably damaged A-	0
"D"- Probably damaged B-	6 ¹²³

They concluded that this breakdown produces the equivalent of 2.6 kills out of 88 attacks (1x1.0 kill and 2x0.8 kills= 2.6) which "gives a lethality of 3% kills and the number of "seriously damaged" (6.4 out of 88) [2 x.2 seriously damaged and 6x1.0 seriously damaged] gives a damage rate of 7.3%," which gives a total lethality of 10.3% (or 27% if 15 "slightly damaged" assessments are included).¹²⁴ This ratio, when compared to the comparative rates of Coastal Command and Eastern Air Command up to 31 August 1943 illustrates the lack of targets in the Command's area and a dramatically lower lethality than that of Coastal Command. Up to the end of August 1943, Coastal Command had made 936 attacks, with 74 estimated kills (7.9%) and 87 estimated as damaged (9.3%) for

a total lethality of 17.2%.¹²⁵ For the same period, Eastern Air Command made 56 attacks, with 1 estimated kill (1.8%) and 4 estimated as damaged (7.1%) for a total lethality of 8.9%.¹²⁶ The vast discrepancy in the number of attacks even by 1943 certainly played a major role in Eastern Air Command's lower lethality level as it reduced the number of opportunities for successful attacks. However, this does not explain the large percentage variations between Eastern Air Command and Coastal Command in 1943. The inexperience of the Canadian crews and the problems of operations in the Eastern Air Command area as discussed previously played major roles. As well, mechanical failures during attack runs, such as the 9 partial or total failures of depth charge releases (out of 75) were no higher than the similar rate for Coastal Command but were magnified out of all proportion by the smaller number of attacks.¹²⁷ As a result, such failures, combined with insufficient training which caused inaccurate bombing (the authors note the rate of which cannot be accurately estimated due to the lack of photographic evidence, which they also attribute to inadequate training) reduced the potential effectiveness of Eastern Air Command's attacks generally, thus creating in large part, the discrepancies when compared to the results obtained by Coastal Command during the first four years of the war.

Post-war research which cross-referenced all Allied claims of kills and damage to U-boats to captured German records revealed that Eastern Air Command's estimates were actually far too low. Home-based aircrews killed six U-boats during the Battle of the Atlantic while No. 162 (BR) Squadron, an EAC unit dispatched to Iceland in January 1944 killed six more U-boats while based in Iceland and Scotland to cover the Normandy landings.¹²⁸ Overall, as W.A.B. Douglas records, RCAF squadrons at home and in Europe

“accounted for, or participated in the destruction of twenty-one U-boats, over 10 per cent of the 197 credited to Commonwealth air forces and just under 9 per cent of the 245.5 destroyed by all Allied shore-based aircraft in almost six years of war.”¹²⁹ Given the difficulties encountered by home-based Canadian squadrons in regards to equipment, lack of targets generally and a hostile operating environment, their accomplishments were definitely credible. The relatively dismal findings of Eastern Air Command ORS in their analysis of the Command’s successes can be attributed primarily to the rigorous claim-testing procedure instituted by Coastal Command and the British Admiralty on the outbreak of war which was subsequently adopted by the RCAF and RCN. This procedure demanded record of definitive evidence of a kill (flotsam, large amounts of oil, etc if the U-boat had submerged, or the observed sinking of a surfaced U-boat) which was often difficult to obtain, particularly from aircraft which were dependent on the difficult art of aerial photography, which, as noted above was a problem in Eastern Air Command. However, Eastern Air Command ORS was simply objectively analysing the available evidence, and thus fulfilled its task of impartial analysis but in so doing, provided a starting point for further postwar research into U-boat claims.

The seven reports discussed in the above case studies demonstrate the range of issues examined by Eastern Air Command ORS during its two and a half years of existence. Much of the foundation of the analyses were previous research undertaken by Coastal Command ORS, and by the end of the war, American operations research groups but in all cases tailored by EAC ORS to the unique operational conditions and requirements of Canadian airborne anti-submarine operations. In fact, as the Section gained experience, it

began to conduct highly original studies, such as those conducted regarding searches for missing aircraft, where diverse theoretical methods were applied to a situation for which they were not intended, but proved to be quite useful. In the end, although EAC ORS conducted only a handful of studies in comparison to its larger cousin, Coastal Command ORS, its influence not only on Eastern Air Command's operations but on the establishment of a tradition of scientific analysis in the Canadian military was out of all proportion to its size.

Chapter 5- EAC ORS Efficiency Studies Based on Monthly Statistical Analyses

A common theme of the airborne anti-submarine operations conducted by Royal Air Force Coastal Command and Royal Canadian Air Force Eastern Air Command was the perpetual scarcity of resources. Both Commands suffered from a shortage of trained aircrew and effective aircraft, largely due to the demands made on the same pool of these resources by other, more 'glamorous' commands. In the case of RAF Coastal Command, its operational needs placed a poor second to the Strategic Bombing Offensive conducted by Air Marshal Sir Arthur Harris' Bomber Command, who was reluctant to release to Coastal Command any aircraft remotely capable of strategic bombing.¹

Eastern Air Command, on the other hand, was faced with threats to its manpower and equipment from two major sources. First, the squadrons of the Canadian-based Home War Establishment always suffered in the shadow of the British Commonwealth Air Training Plan (BCATP) which required vast numbers of aircraft and experienced aircrew for the purposes of training pilots, navigators and wireless air gunners. Compounding this was what AVM C.L. Annis referred to as "a continuous movement of personnel to Bomber Command" out of EAC squadrons to replenish the severe losses suffered by the Canadian No. 6 Group.² As Annis remembers, "the training of crews in navigation and bombing fitted them for the bomber role" and he asserts that "most people wanted to get overseas to see something new."³

Compounding the manpower problems of Eastern Air Command was the difficulty in obtaining adequate supplies of effective airborne anti-submarine aircraft. Coastal Command suffered from a shortage of such aircraft, particularly during the first two years of the war when the short and medium range aircraft in its inventory could not reach the

ocean hunting grounds of the U-boats, which left the task to a slowly increasing number of flying boats and the trickle of long range bombers grudgingly released from Bomber Command orders. However, Coastal Command also had direct access, through Lend-Lease, to American sources of supply and therefore obtained large numbers of Catalina flying boats and more importantly, Liberator very long range aircraft (VLRs).

Eastern Air Command, in contrast, was, as W.A.B. Douglas notes, “dependent upon reluctant British and American sources for most of their aircraft” as well as weapons and sensors, ensuring that “the Canadians were frequently many months behind in acquiring ‘state-of-the-art’ technical devices that might give them a tactical edge over the enemy.”⁴ The Command began the war with only a handful of maritime patrol aircraft, mostly biplane Supermarine Stranraer flying boats, and was forced to slowly equip its rapidly expanding force with whatever aircraft were available.

The major deficiency in the Eastern Air Command order of battle through 1943 was the lack of long and very long range aircraft. The Catalina/Canso squadrons and the Douglas Digbys of 10 (BR) Squadron struggled month after month to patrol far out into the Atlantic where the U-boats primarily operated but were limited by their lack of range and speed.⁵ Annis remembers that given their lack of engine power (to fly above the weather) and range, “for the Digbys and Cansos on patrol there was always the problems of the prevailing west wind; if you got too far out from base you could easily run out of fuel battling back against it.”⁶

The Canso/Catalina family, in particular, suffered from a series of inadequacies which limited its usefulness as a long-range maritime patrol aircraft. In a 1943 report, Annis pointed out six problem areas with the aircraft: low cruising speed, large silhouette

(easier for U-boats to spot), poor downward visibility (which hindered bombing accuracy), aircrew fatigue due to the long missions flown (as a result of low cruising speed), severe wing icing (caused by the inability to fly over inclement weather due to low powered engines) and a poor weapons load at maximum weight of only 1000lbs.⁷ To supplant both the Digby and the Canso/Catalina, Annis echoed the calls being made at Air Force Headquarters that supplies of the Liberator be allocated for use by Eastern Air Command, noting that “it has the required high cruising speed, good rate of climb, good forward vision and general reliability that is required.”⁸ The RCAF’s fight to obtain the Liberator during 1942-43 is beyond the scope of this thesis, but its eventual supply to 10 (BR) and later 11 (BR) Squadrons beginning in June 1943 not only gave EAC a potent new weapons system but also the range and reliability to hunt U-boats deep into the so-called Atlantic ‘air gap’ where they lurked.⁹

Clearly, these difficulties were of great concern to both RAF Coastal Command and EAC as their limited resources threatened their ability to perform their primary mission of locating and eliminating the U-boat threat to shipping within range of each Command’s bases. The Operational Research Sections of both Commands investigated the question of how to maximize the efficiency of the resources on hand in order to fulfil assigned tasks while not neglecting maintenance, crew rest needs or the various ancillary duties performed by the anti-submarine squadrons.

This chapter will explore an example of the Eastern Air Command ORS work in this area during six months of 1943 in order to illustrate not only the importance placed upon such inquiry by the ORS and Eastern Air Command Headquarters but also how the theoretical methods developed earlier by Coastal Command ORS were applied to

statistical analyses of use in the unique context in which EAC operated. A brief inquiry into both the elements of efficiency in airborne anti-submarine operations and the development of the methodology of efficiency studies by Coastal Command ORS will begin the discussion. This will be followed by an exploration of the findings of Eastern Air Command ORS in a series of monthly "Statistics of Anti-Submarine Operations" covering February-July 1943. This period was selected as it was a time of transition in the Command with 10 (BR) Squadron's Liberators and the huge potential increase in efficiency over the Digbys they replaced and the Cansos which they supplanted (but never replaced) in the long range anti-submarine role. As well, it was a period of uncertainty in the Battle of the Atlantic: the huge convoy battles of May-June 1943 which effectively sealed the fate of the U-boat wolf packs were ongoing, and although the Allied asw forces were beginning to take the upper hand and move to the offensive, the Atlantic convoy lifeline remained tenuous. Finally, the period was marked by a transition in the nature of the reports themselves as they became not only more detailed but also more systematic and standardized over the course of the six months, with July's forming the pattern that was largely followed for the remainder of the war.

The monthly reports themselves explored five areas of importance in determining the efficiency of EAC's bomber-reconnaissance squadrons. First, the influence of weather on the operations of each month were calculated by airbase and for the Command overall to determine the number of missions 'scrubbed' due to inclement conditions. Aircraft serviceability based on the total strength and average percentage available daily during the month in question for each of the Command's bomber-reconnaissance squadrons was an obvious and crucial measure of efficiency. The above two measures determined the

number of hours of operational flying flown by each squadron in the month, with more effective convoy coverage being provided, when more aircraft could fly more and longer missions. The final three factors explored were U-boat density, sightings and attacks and convoys covered and met in the Command's area during the month in question. The factors of U-boat density and sightings and attacks were, in combination, a means by which to calculate the Command's effectiveness against the U-boat. The former factor provided an estimate of the number of targets available while the latter reported actual encounters with enemy submarines. which when correlated, yielded an informed estimate of the anti-submarine effectiveness of Eastern Air Command's squadrons. The number of convoys covered and met was the clearest measure of Eastern Air Command's effectiveness as only consistently high levels of airborne coverage could provide security to the convoys and give the Command's crews chances to attack a U-boat. Indeed, a decrease in efficiency in meeting convoys was a sign of other areas of inefficiency such as serviceability.

The purpose of this case study is twofold. First, a consideration of Eastern Air Command's efficiency will be valuable on its own merits to trace whether its squadrons had become more efficient by the end of the period in question and whether this upward trend was present during each of the six months of 1943 being studied. An examination of the methodology used by the Command's ORS in the compilation of the monthly statistical summaries during the six months of 1943 in question will demonstrate a growing sophistication in the methods and range of information compiled and used by the Section over the course of the period, a trend similar to that found in the previous chapter and one which demonstrates a growing maturity in the pioneering Canadian ORS.

I

Before exploring the efforts of Coastal Command ORS in the study of efficiency after it became a priority during 1942, it is essential to define the main terms which will be used in the following discussion. Interestingly, the two major British sources which discuss this issue, Professor C.H. Waddington's OR in World War 2 and the Air Ministry's Official History of Operational Research in the R.A.F., do not define 'efficiency' or 'effectiveness' despite using these terms frequently and indeed, almost interchangeably. However, a close reading of both sources reveals that both terms have specific meanings which are quite similar to common usage, with a notable exception. 'Effectiveness' has two related meanings which will be used in the course of this discussion. First, it will be used to describe how close anti-submarine squadrons came to obtaining their desired results, namely the coverage of convoys and the sighting and destruction of U-boats. Additionally, 'effectiveness' will be used in its military context of those units actually available for service at a given moment and will be used interchangeably with 'operationally available' to describe aircraft capable of performing its assigned mission. Therefore, 'efficiency' is, quite simply, the degree of effectiveness with which something is done. This definition covers both aspects of that of 'effectiveness' as both Waddington and the authors of the Air Ministry Official History use the term to describe the variable level of effectiveness of anti-submarine squadrons versus the U-boat and to describe the maximization of aircraft available for operations at a given moment with the specific meaning being clear from the context.

As noted above, Coastal Command did not take an interest in the study of efficiency until 1942, when it was forced to explore difficult alternatives for future operations

against the U-boat.¹⁰ During a year characterized by the strain of a now-global conflict and damaging attacks on Atlantic convoys, an innovation produced by Coastal Command ORS, the ‘density method,’ emerged which had the potential to revolutionize airborne anti-submarine operations. As noted in previous chapters, the density method was based on a series of probability calculations pioneered by E.J. Williams in reports released in March and October 1942 which allowed the section, “to calculate the number of flying hours required to sink a U-boat, and thus to estimate the minimum flying effort required to give adequate cover over the patrol areas of the Command.”¹¹ These calculations produced the conclusion that the Command required more aircraft, which unfortunately were unlikely to be forthcoming in sizeable numbers.¹² As a result, the Command turned to the alternative of maximizing the use of their existing aircraft resources. There was, however, “no clearly stated theory as to how much flying could be obtained from a given number of aircraft, and in the standard service practice, little attention was paid to the relation between flying effort and the level of manning of the force concerned.”¹³ Once again, the services of Coastal Command ORS would be called to the fore.

Coastal Command ORS’ research into aircraft efficiency/organization of flying effort can be divided into two distinct phases. The first was the formulation of a general theory to determine the limits to efficiency before problems such as losses through wastage (crashes, etc.) begin to reduce the overall efficiency of individual squadrons or the Command in general. The second phase, the experimental, involved the application of this theory on a selected Coastal Command squadron (No. 502, equipped with Armstrong Whitworth Whitleys) with extensive records kept to record the results of the trial. C.H. Waddington comments that although the preliminary investigations in this area began as

the work of one researcher, Dr. C. Gordon, “the number of staff concerned with such matters rapidly increased, under the leadership of Dr. Gordon, and eventually formed the largest single group within the Section.”¹⁴

The first report on the subject was released on 15 November 1942 and it explored several fundamental issues related to “the interactions of manpower, aircraft and effort.”¹⁵ After tracing the average flying and maintenance hours of sampled squadrons “it was discovered that the number both of flying and non-flying days had a profound influence on the possible number of hours that a squadron of 20 aircraft could achieve in one month and that the maximum effort could not be achieved unless the squadron attained the right, not necessarily high, level of serviceability.”¹⁶ The report’s primary conclusion was instead of allocating ground servicing crew manning levels in relation to the squadron’s aircraft strength, the allocation should have been based on the flying hours performed by the squadron.¹⁷

The second aspect of the organization of effort study was the quantitative experimental phase using No. 502 Squadron as the test subject for the five month duration of the study, beginning in early 1943. In a quite remarkable arrangement. ORS personnel created the squadron’s flying plan, a state of affairs which illustrates the importance Coastal Command leadership attached to this study.¹⁸ In order to remove as many variables as possible, squadron aircraft were not allowed to remain on the ground in fit weather if they were serviceable but had no assigned mission for the day: instead, they were dispatched on asw patrols, ensuring that all serviceable aircraft were flying each fit day.¹⁹ Regarding maintenance, the ORS personnel increased the flying schedule by 1 sortie per day until a point was reached where there was always one aircraft waiting for

servicing.²⁰ The authors of the Air Ministry Official History note that this allowed easy record of each aircraft's status (flying and maintenance) to be kept every half-hour.²¹ They add that "as a check on the balance of establishment the histories of men were also taken to show whether any one trade was overworked and forming a bottleneck in aircraft servicing, for although the presence of one aircraft always awaiting manpower is a guarantee that the maintenance organization as a whole is fully employed, it does not ensure that there is an adequate balance of trades within the organization."²² Ultimately, the experiment was a tremendous success as "during three out of the five months in which the trial was conducted, the squadron exceeded its own previous maximum flying effort per aircraft by 61 per cent and exceeded the best average of any squadron over a single period by 79 per cent. This could largely be attributed to planning of the flying, since little change was made in the maintenance organization beyond keeping it fully employed by flying the squadron to capacity."²³

The model created by the ORS with this experiment was immediately applied to the dwindling number of Whitley squadrons in Coastal Command service. During the summer of 1943, a system was created by which all squadrons in the Command submitted a daily return code-named 'Conspectus' which demanded that the status of all aircraft on strength as of 1800 hours daily be described using a series of codes.²⁴ The results were collected not by the ORS but by the new Utilization Control Room at Coastal Command Headquarters which then summarized the information to assist the Command staff in operational planning based on the planned flying and maintenance needs of each squadron.²⁵

Coastal Command ORS also explored several other areas which had varying degrees of influence on the efficiency of airborne anti-submarine squadrons. Not only was the 'density method' refined and expanded in scope to justify and support Coastal Command's Biscay Offensive but the crucial influence of weather and navigation upon the rates of met convoys, both of which were also of great interest to Eastern Air Command, were examined in detail.

Although obviously little could be done to control the weather, Coastal Command ORS focused on two areas in particular. First, in planning operations, it was essential to be able to track the influence of weather on operations. Thus, the early weather studies conducted by the ORS during the spring of 1943 focused on encouraging the Command's Groups to "schedule all sorties which they would desire to fly, paying no attention to the meteorological conditions; records would then be kept of any cancellation or curtailment of these sorties or meteorological or other reasons."²⁶ Early experimental results under this program discovered that the Command "was unable to fly a quarter of sorties which it wished to" due to weather conditions either over bases or in the patrol areas.²⁷

The second area studied revolved around weather conditions and their influence on operations from specific bases. The reasoning behind this study was quite simple: if the weather could not be controlled, the location of operational bases, although limited by the need to effectively cover certain geographical areas, was more firmly within human power to modify. For example, a series of studies undertaken during the period following the Normandy landings in June 1944 when the transit routes of U-boats shifted, due to the Allied advance in France, to the north of Scotland, illustrated that the northern based squadrons were forced by weather to reduce their operations on 27 days of an average

month, a severe limitation on the efficiency of operations.²⁸ As will be seen below, the influence of weather on operations from Canadian EAC bases, where few alternative options existed, posed a severe additional difficulty in Eastern Air Command's search for efficiency in airborne anti-submarine warfare.

The second area of study undertaken by Coastal Command ORS during this period was the problem of the navigation of aircraft to ocean rendezvous points with the convoy they were assigned to escort or cover. The preliminary investigations of this fundamental problem began with two studies produced in July and December 1941.²⁹ At this time, navigation was based on dead reckoning and searches from a specific point where a convoy was believed to be (as the wireless silence of convoys during passage prevented accurate data being provided to the squadrons). The studies concluded that overall 75% of aircraft found their assigned convoys, but while "the 'not met rate' was found to be about 8 1/2% per 100 miles from shore, and at distances over 600 miles, where the threat was greatest, only 40% of escorts successfully made contact."³⁰ Waddington adds that "the situation was even worse than these lugubrious figures indicate, since escort to threatened convoys was less likely to make contact than that to unthreatened, probably owing to the greater evasive action taken by the convoy, and the resulting greater uncertainty in its position."³¹

As Anti-Surface Vessel (A.S.V.) radar began to be fitted in ever-increasing numbers in Coastal Command aircraft by 1942, the ORS undertook a study which revealed that the ASV Mk II then in service did not significantly improve the 'not met rate' for distant convoys or convoys operating in poor weather.³² Instead, the ORS emphasized the value of wireless homing of escort aircraft to their target convoy. This system, based on short

brecches of radio silence later known as Procedure 'B', was estimated by the ORS that 90% of aircraft would find their convoy if they could pick up the homing signal within 100 miles of it.³³ The value of this system was proven as by August 1943, it was used in over two-thirds of Atlantic sorties by Coastal Command's 15 Group (assigned primarily to Atlantic duties).³⁴ When taken in conjunction with the above factors and the ORS' responses to them, the steady march towards increased efficiency once it was initiated by the ORS' initial research becomes apparent.

II

The research into maintenance and flying efficiency conducted by Coastal Command ORS during 1942 and 1943 was closely followed at Eastern Air Command Headquarters in Halifax. However, the primary focus of the Command's ORS in this area would rest in the operational planning end of efficiency, which as noted above, was an area seen by Coastal Command ORS as an administrative not a research task. The reasoning behind the Canadian decision is unclear, although one can speculate that the lack of resources, both in the form of researchers and squadrons available to be used as test subjects, played a significant role in the move to statistical analysis instead of experimental research. A significant advantage of this decision was that the data was already being collected for the monthly "Statistics of Anti-Submarine Operations" prepared by the section. The following discussion will explore the components of efficiency as examined in the monthly "Statistics"; namely weather, aircraft serviceability and numbers, operational flying, U-boat sightings, attacks and density and, convoys met and protected. The monthly returns during the period in question will be examined in detail to delineate the trends noted by Eastern Air Command Operational Research Section.

(a) Weather

It has been noted repeatedly throughout this thesis that in many ways, the weather not the U-boat, was Eastern Air Command's primary enemy during the Second World War. The primary bases in Newfoundland, Gander, Torbay, Botwood and Goose Bay all suffered from the inclement weather endemic to Newfoundland for long periods of the year. In a January 1943 report, Wing Commander C.L. Annis analysed the typical weather conditions to be found at each of the above bases. He noted that Gander was the base least likely to be adversely affected by weather as it "is located far enough back from the coast to escape coastal fogs, common to the area in spring" a factor which had informed the original decision to locate the major portion of No. 1 Group's strength there.³⁵ Annis listed Goose Bay as a useful alternate if Gander was closed due to weather, but given the poor facilities, did not recommend extended operations from the base.³⁶ Torbay, on the Avalon Peninsula north of St. John's, suffered not only from severe "cross winds to 30"⁰ but also "is very subject to coastal fogs which renders it inoperative about 40% of the time during the months of May to mid-July."³⁷ Torbay's good facilities and proximity to the trans-Atlantic convoy routes made it particularly useful, especially for Cansos and Venturas/Hudsons to extend their range further into the Atlantic.³⁸ Finally, Botwood was only a summer seaplane anchorage, which meant that it was operational only in the short period of good flying weather.³⁹ Annis notes that the bases in the Maritimes were less affected by weather than those in Newfoundland, but suffered from their distance from the main U-boat operational areas and were therefore only valuable for coastal patrol operations and as alternative landing grounds for long range aircraft.⁴⁰

Regarding the general weather patterns affecting bases in the Eastern Air Command area, Annis observed that “it may be said of Gander that it has very poor flying weather during the months from January to April inclusive and of Goose Bay, that it has excellent weather during these months. Conversely Goose Bay weather is less reliable during the summer months while Gander weather is of a relatively high order during the same period.”⁴¹ He noted that “weather fronts move into Newfoundland from the west and forehand knowledge is obtainable of what is coming, even including the hour by hour progress of a front across the island.”⁴²

Gander was of particular interest to Annis given that it was the main EAC base in No. 1 Group and he had personal knowledge of the conditions there, having served there in 1940 and again during 1942-43.⁴³ He remarked that the movement of weather fronts, particularly the odd one which approached from the east, made the influence of weather at Gander quite variable which created the unique problem of the weather being “fit for take off but not for a landing on a return flight.”⁴⁴ He added that such unpredictability has a definite impact on operations as “medium range aircraft have to be grounded because they can’t go out and convoy in clear areas in the ocean and return far enough inland to reach an open base” and consequently, “this fact has been responsible for a considerable number of successful attacks by U-Boats on convoys.”⁴⁵

The analysis conducted by Eastern Air Command ORS of the influence of weather upon operations during the period February-July 1943 offered a far more statistical form of discussion than Annis’ personal observations. The basic trend of the findings for the period, however, confirms Annis observations regarding the influence of weather on EAC bases, particularly those in Newfoundland. The analysis covered several bases:

Gander, Torbay and Botwood (July 1943 only) in Newfoundland; Sydney, Dartmouth, Yarmouth and Shelburne (to May 1943) in Nova Scotia; and beginning in May, Mont Joli, Gaspé and Chatham (May, July only) in the Gulf of St. Lawrence sector. In order to trace consistently the ORS' findings regarding weather and provide a general sketch of the influence of weather on operations, only the results for the major year-round bases, Gander, Torbay, Sydney, Dartmouth and Yarmouth, will be discussed.

During the winter and early spring months of February, March and April, both Gander and Torbay suffered a significant loss of 'flying days' to weather conditions. Throughout this three month period, both airports averaged approximately 17 fit flying days, whereas the Nova Scotia bases averaged roughly 22.⁴⁶ In the "Statistics" for March and April, the authors referred to the way in which weather "interfered seriously with operations." confirming the January 1943 observations of Annis that the Newfoundland bases in particular were difficult operational stations during the winter months.⁴⁷ The months of May, June and July witnessed a definite general improvement in flying conditions. The weather at Gander and Torbay improved significantly, averaging over 25 fit flying days in each of the three months, although both bases suffered partial operation cancellations due largely to the coastal fogs and variable conditions which plagued the area.⁴⁸ Even at the height of the summer, the authors observed in the July "Statistics" that "except at Dartmouth and Yarmouth, there were few days on which no operations at all were possible; nevertheless patrols from Newfoundland and Nova Scotia were again more or less seriously curtailed on the majority of days during this month."⁴⁹ They added that "Torbay, Sydney, Dartmouth and Yarmouth were particularly handicapped by the frequency of fog in patrol areas," a key limitation for medium range aircraft like the

Hudson which did not have the range to extend their searches to fog-free areas.⁵⁰

Certainly weather was a major hindrance to Eastern Air Command planners who witnessed their operational flying plans reduced to mere shadows by inclement conditions beyond their control. Indeed, the only purpose behind this particular analysis, given the absence of alternative ‘fair weather’ bases from which to operate in the EAC area, was to inform planners of the sizeable influence of weather on operations so they could take it into account when preparing flying plans.

The methodology utilized by Eastern Air Command ORS in this analysis was modified significantly for the April 1943 report. During February and March, the “Statistics” only listed the number of ‘flying days’ over the course of the month, which covered not only good weather days in which the flight plan could be completed but also days when only some patrols were flown as planned (See Appendix 4). This simple presentation did not accurately reflect the significant influence of weather on flight operations as a large number of days witnessed a curtailment of operational flying due to conditions either in the area of the base or in the patrol area. However, beginning in April, a more detailed presentation of the impact of weather on the Command’s operations was introduced with the month’s flying being divided into the number of days when all patrols were completed, the number when patrols were curtailed due to weather and those when the day’s flying was cancelled due to weather conditions (See Appendix 4). This more nuanced categorization provided a truer representation of the influence of weather on the Command’s operations, and therefore provided a more valuable resource for Headquarters.

(b) Aircraft Serviceability and Numbers

The question of aircraft serviceability was of particular importance in the Command's bomber-reconnaissance (BR) operations due to the chronic lack of aircraft throughout the entire war and the need to maximize the efficiency of those on strength. For example, in February 1943, Eastern Air Command's average daily strength (including aircraft being serviced) of BR aircraft was only 84 while five months later, in July the same figure had increased to only 145.9 despite an influx of new types such as the Liberator and Ventura and the completion of the 'working up' period of two new squadrons, 117 and 162.⁵¹

As in the case of the presentation of weather data, Eastern Air Command ORS significantly modified the manner in which the information regarding serviceability was discussed. In this case, however, the change, although presenting a more realistic view of the average strength of the BR squadrons from month to month as well as providing detailed information on variations in serviceability between aircraft types, made it more difficult to analyse long term trends due to the use of incompatible categories. The complexity of the evolution of the methodology in this case makes it essential that we explore it before summarizing the findings for the period.

In February and March, the categories focused upon the 'availability' of aircraft, noting by squadron, group and the Command as a whole the average number of aircraft on strength and the average number and percentage available daily during each month (See Appendix 5). This system provided only the roughest sketch of a squadron or groups daily status as it did not provide information as to why the average available daily may be higher or lower than other squadrons or groups. As well, it was a very general category, ignoring maintenance problems with aircraft which may not have affected their ability to

fly but may have adversely influenced their ability to perform certain tasks (i.e. unserviceable ASV radar would have made it impossible to fly effective night patrols). Finally, it ignored the influence of crewing factors as available aircraft may not be available for active operations due to a lack of crew members.⁵²

As may be seen in Appendix 5, in April, the Eastern Air Command ORS discarded the category of 'available' in favour of 'serviceable'. The data, based on the daily and weekly operation summaries submitted to Command Headquarters by the squadrons, provided a more useful tool for the Command staff as it immediately highlighted squadrons suffering from maintenance difficulties, often caused by conversion to new aircraft types. This information could then be taken into account when formulating operations orders (which did occur when squadrons were in the midst of converting) or could be used to intervene if the figures were found to represent a more serious problem. In May, the methodology was once again dramatically altered. The innovation of April was retained, but instead of being applied to individual squadrons, it was now applied by aircraft type and by region (Newfoundland, Nova Scotia and Gulf Area) in which the squadrons were based in order to reflect the highly variable situation in the Command with new squadrons being formed, old ones re-equipping and detachments being created.⁵³ (See Appendix 5) This modification brought the Eastern Air Command ORS methodology in line with that being undertaken at Coastal Command ORS with 502 Squadron, whose results were intended not to be applied by squadron but only to those operating similar aircraft. This system ensured that unproductive comparisons between aircraft types were not affecting the results of the analysis and fostering misleading interpretations.

In the June “Statistics,” a clarification and yet another modification were introduced. The authors clarified the meaning of ‘serviceable,’ noting that serviceable aircraft were not necessarily ‘operationally available,’ (i.e. ready to undertake all aspects of BR operations) they were only ‘available’.⁵⁴ This marked one of the few times in the “Statistics” of February-July that the changes of methodology were discussed by the researchers, which in this case may indicate that a measure of confusion at Command Headquarters over the April shift of focus to serviceability prompted the ORS to provide some additional clarification. As well, the classification by aircraft type, as the authors noted, “has been modified... to conform to that employed by the Air Ministry.”⁵⁵ The changes, as may be seen in Appendix 5, affected the categories of short (eliminated in June), medium and long range aircraft, with the Ventura and Digby being reclassified as long range aircraft instead of medium while the Hudsons were reclassified as medium range.⁵⁶ This move not only further standardized the methodology used by Eastern Air Command ORS with that of Coastal Command ORS but also ensured that aircraft of similar performance would be compared.

In July, the final modifications of the period were implemented with a significant new category being added. As the authors had mentioned in June, serviceable aircraft were not always operationally serviceable. Therefore, in the July “Statistics,” the daily average number and percentage of operationally serviceable aircraft types in each of the three regions was included in the serviceability table (See Appendix 5). This produced the most accurate reflection of the actual circumstances, for as the authors note, “in most, although not all, cases the percentage of aircraft reported as operationally serviceable was appreciably lower” than the total percentage serviceable.⁵⁷ This new category was

facilitated by EAC ORS' use of form "Yellow" which showed the daily operational serviceability for each station by squadron while the total percentage serviceable continued to be "compiled from the E.A.C. Hq. Daily Aircraft Disposition Report."⁵⁸

Although these significant modifications to the manner in which Eastern Air Command ORS reported aircraft serviceability ultimately provided a more meaningful and useful discussion of the true nature of serviceability, it certainly reduced the Command's ability to compare results with past performance as specific focus of the analysis had shifted from 'availability' to "serviceability' and operational serviceability'. However, certain trends may still be determined. First, the period February through May showed a distinct availability and serviceability problem in certain squadrons. Hudson squadrons in Nova Scotia such as 119 (BR) and 113 (BR) suffered from particularly poor daily average aircraft availability and serviceability with the former beginning the period at a low of 46% available in February while the latter recorded 38% serviceability during April.⁵⁹ These figures, significantly lower than those reported by most EAC squadrons over the same period may be explained in the case of 113 (BR) as being caused "by the grounding of newly acquired aircraft [Venturas] awaiting acceptance checks or necessary adjustments."⁶⁰ The low figure for 119 (BR) in February appears to be an anomaly based not on maintenance problems but in a diversion of aircraft to non-operational duties such as transport and training which would have a significant influence on the daily number available for operations. A similar situation affected 10 (BR) squadron's average availability during February and March (including only 29% in February) "because of diversion of some aircraft to duties other than A/S operations."⁶¹

The second major factor, alluded to in the above discussion of 113 (BR) squadron's difficulties, was caused by the conversion by several squadrons to new aircraft types during the period. This variable affected not only 113 (BR) but also 10 (BR) (Digbys to Liberators), 117 (BR) (Cansos to Catalinas) and 162 (BR) (new squadron formed May 1942 but still working up with Cansos).⁶² The latter's difficulties were further complicated as during March and April "some newly delivered aircraft of 162 B.R. Squadron were still undergoing acceptance checks and others were grounded by reason of primer flakes in fuel tanks."⁶³

The disruption that these conversions caused should not be disregarded. For example, as air historian Carl Vincent observes, during the spring of 1943, 10 (BR) Squadron not only had to integrate the large number of aircrew and ground crew members to operate the new Liberators but also suffered from a severe shortage of spare parts, which by June "affected the situation to the point that there were more operationally trained crews than aircraft for them to fly."⁶⁴ Ultimately, despite these difficulties, EAC bomber-reconnaissance squadrons posted during the period April-July 1943 average daily serviceability rates in the high 60% range, a figure much higher than that of approximately 50% achieved through the efforts of a rather pleased Coastal Command ORS in their 1943 experiments with 502 Squadron.⁶⁵ These figures, although less than the 70-75% serviceability previously considered ideal by the RAF, more accurately reflected not only the long-term sustainable operational tempo required in anti-submarine warfare but also the maintenance difficulties presented by the need to ensure very high levels of reliability for long missions over water by heavily loaded bomber aircraft which

were operated at much lower altitudes and in more severe weather conditions than their designers had envisioned.⁶⁶

(c) Operational Flying

This category in the monthly “Statistics” was intimately related to the previous two categories of weather and serviceability as the number of completed sorties carrying out the number of tasks assigned to BR squadrons could be dramatically affected by changes in weather conditions (either at the bases or in the patrol areas) and aircraft serviceability. In regard to methodology used, unlike the previous subjects, very few modifications appear during the period in question. The changes which did appear were enhancements of the clarity and detail provided in the analysis. The charts followed the general pattern of illustrating the number of sorties flown on various mission types (categorized by either group or region) while a summary for the total flying of the Command was also provided.⁶⁷ (See Appendix 6)

The data regarding operational flying presented by Eastern Air Command ORS yields two interesting general patterns. First, the total sorties and hours flown of the Command as a whole increased during the entire period from a low of 443 sorties and 2270 hours in February to a peak sortie rate of 1203 in June (8074 hours) and a peak total of hours in July of 8738 (1189 sorties).⁶⁸ The increased number of sorties may be attributed to several factors such as the general improvement in weather and aircraft serviceability noted above and the full introduction of several new or re-equipped squadrons into the Command’s order of battle during the last three months of the period which significantly bolstered its total average strength (see above). The increased hours flown was not only directly related to the number of sorties flown but was also influenced by the longer

sorties flown by the very long range Liberators of 10 (BR) Squadron at Gander which in July flew 98 sorties totalling 1165 hours (11.8 hours average) while RCAF Cansos and Catalinas also based in Newfoundland flew slightly under double the number of sorties (173) but flew 1790 hours (10.3 hours).⁶⁹

The second pattern is related to the above discussion regarding flying hours. Throughout the entire period, the Newfoundland-based No. 1 Group squadrons averaged longer sorties than the squadrons in Nova Scotia-based No. 3 Group. For example, the authors of the February "Statistics" report that "No. 1 Group carried out slightly less than one-third of the total sorties but had rather more than a third of the total flying time."⁷⁰ This trend continued through April when it was noted that "the average duration of all April operational sorties was 6.9 hours for No. 1 and 5.6 hours for No. 3 Group, both slightly in excess of the 6.7 hours recorded for March."⁷¹ The pattern continued into July, largely due to the specific missions of the respective groups, No. 1 Group being devoted to long-range convoy escort and anti-submarine patrols and being equipped primarily with long range Catalinas/Cansos and very long range Liberators to fulfil these missions.⁷² On the other hand, No. 3 Group, being so far from the U-boat hunting grounds in the mid-ocean, was devoted primarily to coastal escort and sweeps to protect shipping in the Halifax approaches.⁷³ Overall, the findings of this component of the "Statistics" were not particularly radical in nature, being primarily statistical confirmation of the high level of activity of Eastern Air Command squadrons and the growing role the Command was playing in the Battle of the Atlantic as it approached its climax during the spring and summer of 1943.

(d) Submarine Density

This area was included in the monthly summaries to provide an assessment of the U-boat presence in the EAC operational area. It provided valuable context for not only the subsequent discussion of convoy coverage but also as a sobering reminder of the difficulties of airborne anti-submarine warfare when the large number of operational sorties and flying hours is contrasted with the negligible sightings and lack of confirmed kills during the period. The methodology in this section was very straightforward, with the findings being presented in narrative form only. The only change occurred in March when sightings and attacks were reported as in February but with the addition of summaries of the daily Royal Canadian Navy submarine forecasts which were used by Eastern Air Command ORS to summarize the average monthly U-boat density in the various sectors of the Command's operational area.⁷⁴ This reporting of estimated density simply republished the intelligence available at Command Headquarters but was used in this case to provide the background for the other topics explored in the "Statistics."

The period February-July 1943, according to the results presented in the monthly summaries, resulted in few sightings and attacks on U-boats by the bomber-reconnaissance aircraft of Eastern Air Command, despite the increase over the period in the operational flying of the Command. In February and March, EAC aircraft (all of 5 (BR) Squadron at Gander) only sighted 5 submarines (4 in February), attacking all of them with no result, with 1 other attack being made in March by a Royal Air Force Hudson of 36 Operational Training Unit which attacked a U-boat off Yarmouth.⁷⁵ This lack of success in detecting U-boats by all EAC squadrons save No. 5 (BR) can be explained by the distances at which the four sightings by No. 5 (BR) during February

occurred. The first two sightings occurred as the authors note “at distances of roughly 350 and 175 miles from base, [Gander] while the last two are about 600 miles from base.”⁷⁶ Given that 10 (BR) Squadron’s Liberators did not arrive at Gander until May, 5 (BR)’s Canso amphibians represented the only EAC anti-submarine aircraft able to reach the fringes of the U-boat prime operating area northeast of 50N 50W.⁷⁷

In the April “Statistics,” the authors report that intelligence provided by the RCN “indicated a significant increase in the number of U-boats present in the E.A.C. operational area (north of 40N and west of 40W) during the latter half of April” adding that “this increase was greatest in the zone northeast of 30N 50W... but was noticeable to some extent throughout the region.”⁷⁸ The estimated U-boat density during the last weeks of April increased from 11 during the first two weeks to 24 in the last two weeks.⁷⁹ This increased activity translated into more sightings (9) in the EAC area, with five attacks (2 by EAC, 3 by American aircraft operating out of Newfoundland).⁸⁰ This pattern of large amounts of U-boat activity concentrated largely at the outer edge of the EAC operational area persisted into May, yielding six attacks by EAC and three by American aircraft.⁸¹ The departure of U-boat Groups AMSEL, DANUBE, ISAR, MEISE, MOSEL and SPECHT in May 1943, which included, according to postwar information obtained by Robert Baglow and J.D.F. Kealy, “more than 50 [U-boats] in groups AMSEL and SPECHT” alone, reduced contact with U-boats in the EAC area during June and July to only 2 unsuccessful attacks.⁸² This summary of U-boat density provided by Eastern Air Command ORS in the monthly “Statistics,” although obviously disappointing for Command Headquarters given its lack of success versus the U-boat would, over the course of the next year, trace the retreat of the wolfpacks from their mid-ocean hunting

grounds and their transformation into the hunted and Eastern Air Command's significant role, particularly during September and October 1943, in accomplishing this feat.

(e) Convoy Coverage

The final section of the monthly anti-submarine "Statistics" explored the area which represented the primary purpose of Eastern Air Command, namely to assist the Allied naval forces in ensuring that transatlantic convoys passed safely through the Command's operational area. As with all of the previous areas discussed previously, the methods by which the ORS examined the success of the Command's convoy coverage were also modified during the period February-July 1943. The one constant in the analysis by Eastern Air Command ORS was the use of the construction 'convoy-days' which represents quite simply, the number of days a convoy spent in the EAC area, at sea and organized as a convoy.⁸³ The coverage of each convoy provided by anti-submarine aircraft of Eastern Air Command, the United States Navy, the United States Army Air Forces (the latter two operating out of Newfoundland) and Royal Air Force aircraft operating out of Iceland was expressed as a portion of the total 'convoy-days' for each convoy. In February and March, the analysis was provided in short narrative form with an attached graph which illustrated the average protection afforded to the convoys during the month by EAC aircraft expressed in the bulky "minutes of flying within 50 miles of the convoy track per mile of convoy track."⁸⁴ (See Appendix 7)

From April onwards, the analysis became more detailed, with the graph being omitted and four tables being introduced in its place. The first table displayed the convoy-days with air cover for each convoy which passed through the Eastern Air Command area during the month, while the second illustrated the same data by map sector (See

Appendix 7). The third table displayed the duration of convoy coverage by sector (expressed in hours), which simply demonstrated that convoys close to the eastern edge of the Eastern Air Command area received less air cover than those closer to Canadian bases. The final table illustrated the number of aircraft per convoy-day assigned to cover individual convoys and displayed the trend that the more aircraft assigned to cover a convoy, the more likely more than one will successfully located the convoy, thus providing it with more convoy-days of coverage. The added statistical detail beginning in April definitely enhanced the amount of information provided in the “Statistics” regarding the coverage of convoys. This provided Command Headquarters with the opportunity to track the quantity of coverage being provided to convoys in transit by Canadian bomber-reconnaissance aircraft and the relationship between air coverage and decreased shipping losses to U-boats. As with the other areas of the “Statistics,” the revised methods of Eastern Air Command ORS in tabulating data made it more accessible and specific, thus enhancing its utility to Command planners.

The major finding of the ORS regarding convoy coverage was the influence of factors such as aircraft serviceability and above all, weather, on the total quantity of air cover which could be provided to convoys in transit through the Eastern Air Command area. During the period February-April, the authors noted that “the vicissitudes of weather and location resulted in the coverage of individual convoys exhibiting marked deviations from the... average.”⁸⁵ The 45 convoys which passed through the EAC area during the period (13 in February, 15 in March, 17 in April) spent averages of 8.9, 8.7 and 8.4 convoy-days in the area respectively.⁸⁶ In February, out of 116 convoy-days, Eastern Air Command and Newfoundland-based American aircraft were able to provide air cover on

63 or 53%.⁸⁷ This reasonable percentage for an Atlantic winter, however, decreased dramatically during the next two months to 49% of convoy-days with air cover in March and only 47% in April.⁸⁸ These results correspond to the severe reduction in flying operations due to inclement weather described in the February-April "Statistics" (see above).

However, as the weather began to improve during May, there was a vast improvement in convoy coverage. From the April low of 47% coverage, the May figure increased by 15 percentage points to 62% of convoy-days being provided with air cover.⁸⁹ This increase is even more impressive when one considers that 20 convoys passed through the EAC area over 164 convoy days, so obviously the improvement in weather facilitated a much increased operational tempo.⁹⁰ Of note is that "R.C.A.F. aircraft provided or participated in 53 of the total of 101 convoy-days with air protection" while "U.S.A.A.F. and U.S.N. (Newfoundland) accounted for most of the remainder, but on 7 occasions R.A.F. (Iceland) aircraft successfully met convoys in the north-eastern portion of the area."⁹¹ The increased participation of the Royal Air Force, in particular, in convoy protection in the EAC area represented the vast increase in range of the growing number of Very Long Range Liberators in service with all three nations which effectively closed the 'Atlantic Gap,' enabling a measure of air cover to be provided to convoys throughout their entire journey. The improved weather and withdrawal of the large number of U-boats which had been operating since late April on the boundaries of the Eastern Air Command area (see above) combined to allow the Command to afford complete protection to all May convoys, allowing no sinkings by U-boats.⁹² The authors of the May "Statistics" speculate that "as long as the current U-boat strategy is maintained, the success of E.A.C.

protection of outward bound convoys will be manifested not so much in the prevention of... attacks in the area, as in the frustration of efforts of the assumed patrolling... U-boats to secure and maintain firm contact as a prelude to the development of further concentrations” concluding that “in this event the efficacy of E.A.C. operations will have to be gauged mainly from the history of SC [eastbound slow] and HX [eastbound fast] convoys during the first day or two after they have left the E.A.C. area.”⁹³

This trend of ever-increasing protection afforded to convoys in the EAC area continued through June and July. In June, 64% of the 104 convoy-days were provided with air cover while in July 77% of the 120 convoy-days received air support which was a direct result of improved weather and the availability of additional aircraft in Eastern Air Command following the completion of various squadrons’ re-equipment and return to full operations during April and May (see above).⁹⁴ Of particular note was the extension of effective EAC air cover to the perimeter of the operating area with very long range aircraft meeting their distant convoys at rates of 74% in June and 81% in July, which represents only a slight drop from the average of 85% in the sectors closer to Canadian bases.⁹⁵ The growing effectiveness of airborne convoy escort provided by Eastern Air Command over the course of the period, despite the challenges posed by the weather of the Northwest Atlantic, and its implications for the German U-boat offensive was made very clear by the ORS in its “Statistics” and illustrated that the moves Command Headquarters had made in the areas of improved training and re-equipment with more and better aircraft were reaping rewards.

The search by RAF Coastal Command and RCAF Eastern Air Command for efficiency in airborne anti-submarine operations was directed not only at maximizing their forces' lethality against the U-boat but also in maximizing the efficient use of scarce resources. Despite the critical importance of protecting Britain's Atlantic lifeline, both Commands had to wage sharp battles against other segments of their respective air forces to obtain even the minimum number of long range aircraft and adequate numbers of aircrew to conduct their vital operations. In the Canadian context, the prospect of receiving any more than minimal numbers of new aircraft from British and American sources reinforced the need to emulate the work of Coastal Command ORS in rationalizing and organizing the operational activities of the bomber-reconnaissance squadrons to maximize their efficiency. However, due to a lack of resources both at Eastern Air Command ORS and within the Command as a whole, extended studies such as that conducted by Coastal Command ORS with 502 Squadron were not considered to be practical. Instead, Eastern Air Command ORS functioned in a operational planning capacity, a role rejected by Coastal Command ORS as being simply unproductive bureaucratic activity, and assisted Command Headquarters in locating areas of concern in the operations of Canadian BR squadrons and providing the Command staff with the statistical data upon which to formulate solutions. As a result, the ORS was serving primarily in a consultative capacity, a role ideally suited to such a small section. The desire to ensure that their statistical analyses of the impact of factors such as weather and aircraft serviceability on key areas such as convoy coverage drove the many changes in methodology employed during the period February-July 1943. Although these changes often rendered the tracing of long-term trends difficult due to the focus on different

aspects of problems and the use of different criteria, they marked a growing recognition on the part of Eastern Air Command ORS of the essential information required by Command Headquarters. By focusing on the needs of its Headquarters, Eastern Air Command ORS ensured that it would become entrenched as a key component of the chain of command.

Conclusions

Following the climactic convoy battles of the summer and fall of 1943 and the resulting defeat of the German Kriegsmarine's massed 'wolfpacks' of U-boats by Allied sea and air escorts, the Atlantic lifeline to Great Britain was in theory secured. No longer did scores of U-boats make massed, persistent and deadly attacks on convoys as they transited the open expanse of the North Atlantic Ocean. Instead, equipped with schnorkel, U-boat commanders began to conduct during 1944 a form of nautical guerrilla warfare, stealthily attacking targets of opportunity in shallow water, making life difficult for the Allied air and sea escorts which would invariably scour the area in an often frustrating attempt to detect their elusive enemy.¹ These events represent a continuation of the pattern of the competing technological development of aircraft and submarine; as one became dominant, the other, through the efforts of servicemen and scientists working in cooperation, would begin its ascent to primacy. Certainly, during the last two years of the war, the U-boat force was in decline, both in potency and in numbers, but still posed a threat which occasionally achieved tactical successes against Allied convoys and their escorts.

Although the U-boat force was still in being, 1944 witnessed the start of demobilization within Eastern Air Command. In January 1944, the Command's strength peaked at 21,234 officers and airmen, with drastic reductions being undertaken to support operations in Europe.² Six Eastern Air Command fighter squadrons were transferred to Great Britain in preparation for the planned invasion of Europe while the Command's anti-submarine strength was reduced by four squadrons as the demand for experienced bomber-reconnaissance aircrew for service in Bomber Command remained high.³ These

reductions did not severely limit the operational efforts of Eastern Air Command as continuing qualitative improvements actually allowed the Command to fulfil its assigned missions with fewer resources. For example, the replacement of No. 11 (BR) Squadron's ageing twin-engined Lockheed Hudsons with very long range Liberators provided the Command with a second VLR squadron, thus complementing and extending the potential convoy coverage provided by No. 10 (BR) Squadron.⁴ As well, the widespread introduction of new weaponry and sensors such as the 'Mk 24 mine' (homing torpedo) and the disposable sonobuoy during the fall of 1943 provided Eastern Air Command aircraft with the potential to launch deadly attacks not only on surfaced submarines but also on those which had slipped below the surface.⁵

A similar personnel situation was unfolding during 1944 and 1945 at Eastern Air Command's Operational Research Section. During the fall of 1944, both the head of the Section, Professor Colin Barnes and his senior civilian researcher Dr. E.C. Smith, departed to return to academe.⁶ Similarly, Barnes' temporary replacement, Dr. J.W.T. Spinks, formerly of Western Air Command Operational Research Section and Professor J.O. Wilhelm, the head of the Air Force Headquarters Operational Research Centre had both returned to their pre-war university positions by November 1944.⁷ These researchers had pioneered air-related operational research in Canada and had been at the core of the dual efforts of increasing the Home War Establishment (particularly Eastern Air Command's) efficiency while at the same time learning and developing operational research techniques pioneered in Great Britain and applying them to the unique circumstances encountered by Canadian-based forces. Despite their departure, the handful of civilian and military personnel at Eastern Air Command ORS headed by Dr.

J.H. Soper produced an innovative study of searches for missing aircraft using the density method as well as a final assessment of Eastern Air Command's airborne anti-submarine effort during the Second World War. The continuation of the Section's research following the departure of its key founding figures points to the presence of an institutional memory and experienced personnel which enabled the section to continue its duties.

Upon the surrender of Germany on 8 May 1945, the U-boat menace disappeared. Almost immediately all but three of Eastern Air Command's bomber-reconnaissance squadrons were disbanded, with two No. 10 and No. 162 lasting only until August.⁸ With the completion of the final assessment of Eastern Air Command anti-U-boat operations (ORS Report No. 19) in June 1945, the ORS began to slowly wind down operations in preparation to suffer the fate of the operational squadrons and be demobilized and disbanded.⁹

With the benefit of hindsight, several commentators point to the short-sightedness of what amounted to the virtual elimination of operational research in the postwar Royal Canadian Air Force. In 1947, Squadron Leader Peter Millman commented that "it is felt that there is a definite place, in peace time, for scientific and statistical advice on operational matters whether it is called by the name "Operational Research" or not."¹⁰ Millman asserts that operational research could be of assistance in allowing "future trends in weapon development... [to] be anticipated and analysed to minimize costly overstocking of antiquated types" while it would also permit the adaptation of methods learned painfully during the war to new technology.¹¹ However, as the Government of Canada drew down all three armed services, airborne anti-submarine warfare was

deliberately omitted from the Royal Canadian Air Force's order of battle in favour of the role being carried out by the Royal Canadian Navy.¹² Although this decision would be reversed by 1949, the loss of institutional continuity should not be underestimated. This holds true for airborne-related operational research as although a measure of general retention of OR methods was maintained by Dr. O.M. Solandt's Operational Research Group within the Canadian Defence Research Board, a good deal of the specific expertise accumulated by Eastern Air Command ORS departed with the demobilized personnel, leaving only the files and a handful of military personnel as the inheritors of airborne anti-submarine operational research experience.¹³

This thesis began with the purpose of analysing the contributions of operational research to the work of RCAF Eastern Air Command. The ultimate goal of this thesis was to demonstrate that Canadian operational research made a small but important contribution to the war against the U-boat which has been largely overlooked by historians. At first glance, as with the record of Eastern Air Command's operational squadrons during the final 18 months of the war, the performance of the Command's ORS does not appear to be overly impressive. No more than eight operational researchers (civilian and military) staffed the section during the entire period of its existence with no more than four being present at any given moment.¹⁴ Certainly, a lack of personnel ensured that the Section's accomplishments would pale in comparison to the large amount of often pioneering work undertaken by its British 'mentor,' Coastal Command Operational Research Section. Indeed, we have seen that the Royal Air Force, with its support of the efforts of men such as Sir Henry Tizard, Professor P.M.S. Blackett, Harold Larnder and E.J. Williams, provided the atmosphere which was necessary for the

foundations of operational research to be articulated and accepted as a valuable adjunct source of information for senior officers. Blackett, in particular, with his 1941 paper "Scientists at the Operational Level," may be rightly termed as the intellectual father of military operational research. His work, first as General Frederick Pile's special advisor at Anti-Aircraft Command and then his pioneering OR efforts at both Coastal Command and the Admiralty, delineated the boundaries of operational research. His rapport with the commanders he advised provided an excellent example of the interaction required between officers and their scientific advisors to make the most effective use of the findings of operational research.

In early 1942, certain RCAF officers led by Air Vice-Marshal N.R. Anderson and E.W. Stedman began to take note of the work of Coastal Command ORS through contacts with their British colleagues and its effect of improving the efficiency and effectiveness of the Command's operational squadrons. They began to push the Canadian Air Staff to sanction the creation of operational research sections for the home-based Eastern and Western Air Commands based on the model of Coastal Command ORS. A series of British delegations to Eastern Air Command by British delegations during the first half of 1942 noted the need for improved efficiency in the Command's operations and advocated the creation of an ORS to assist in this task. In particular, one delegation, led by the Coastal Command operational researcher J.P.T. Pearman, implemented during February and March of 1942 a statistics-gathering system in Eastern Air Command to facilitate the early work of an ORS when it appeared. Following a rather difficult search for suitable Canadian scientists who could be released from other duties with the National Research Council and a delay while the selected candidates received training in Britain

by Coastal Command and other ORS', the Eastern Air Command ORS emerged under Professor Colin Barnes in November 1942.

The nascent Eastern Air Command ORS, faced with limited resources and the urgent need to provide assistance to the Command's battle against the U-boat wolfpacks, undertook a series of studies which utilized methods pioneered by Coastal Command ORS but applied them to the unique Canadian context of harsh weather, a low U-boat density inshore and a lack of long-ranged aircraft to reach the U-boat hunting zones in the mid-ocean area. The scale of this 'Canadianization' of British OR methods varied. The first studies undertaken by the ORS, such as the urgent first report which focused on the problem of bombing accuracy, tended to emulate earlier studies conducted in Britain, in this case even advocating a similar solution that a longer spacing between depth charges dropped from aircraft would correct the problem of inaccurate bombing. However, over time, as the Canadian operational researchers spent more time in their roles, they became more innovative and experimental in their operational studies. The best example of this experimental trend is the series of studies examining the issue of Searches for Missing Aircraft (Reports 15, 20). Not only was this issue of great importance in the often desolate and harsh Eastern Air Command operational area which included largely uninhabited parts of the Gaspé and Newfoundland on land and the vast expanses of the Northwest Atlantic at sea but the ORS studies of this question utilized the application of methods not originally intended to be used for air-sea/land rescue. The use of E.J. Williams' density method, a series of probability calculations applied primarily to determining U-boat density in order to maximize patrol efficiency, to record and determine the proper allocation of search coverage in rescue operations was a highly

innovative adaptation to a uniquely Canadian problem. This trend which emerged during 1944 of focusing on problems primarily of concern only to Eastern Air Command and the application of a diverse variety of OR methods was continued in the study of Scouting Effectiveness and Schnorkel (Report 18). This report not only focused entirely on the effectiveness of Canadian patrol formats against the difficult target presented by a schnorkeling U-boat but also represented a break with the dependency upon British OR methods as this study was based (to a much more limited degree than previously) on American OR findings.

Similarly, Eastern Air Command ORS broke from the British model over the question of efficiency studies. The search to maximize the lethality and operational availability of limited numbers of anti-submarine aircraft was a primary concern for both EAC and Coastal Command throughout the entire war as the demands of British Bomber Command continually drew experienced crews and desperately needed aircraft out of the hands of the Anglo-Canadian maritime commands. In the case of Coastal Command, sizeable resources (both in terms of researchers, time and test squadrons) were devoted to the question of operational efficiency, with the 1942-43 study involving No. 502 Squadron serving as the pattern for the implementation of planned flying and maintenance not only throughout Coastal Command but indeed, throughout the Royal Air Force. Eastern Air Command, limited to a veritable handful (never more than 150) of bomber-reconnaissance aircraft, could ill-afford to disrupt a squadron's operational tempo to allow operational researchers to experiment in the search for efficiency. In fact, Eastern Air Command ORS lacked the staff to conduct such a detailed study while also undertaking other vital studies and statistical analyses for Command Headquarters. As a

result, the pragmatic course of the Section assisting its Headquarters in operational planning through the provision of annotated monthly statistical summaries exploring such variables as aircraft serviceability, weather and U-boat density was followed, if only because it was the only viable option. This decision, however, marked a break from the pattern set by Coastal Command ORS as such operational planning work was seen as being largely administrative and thus not within the desired scope of an operational research section. Despite not being very innovative by the standards of Coastal Command ORS, the provision by Eastern Air Command ORS of efficiency information through the monthly "Statistics" provided Command Headquarters with valuable information which was not being provided from any other source and which could have an immediate influence on planning and operations.

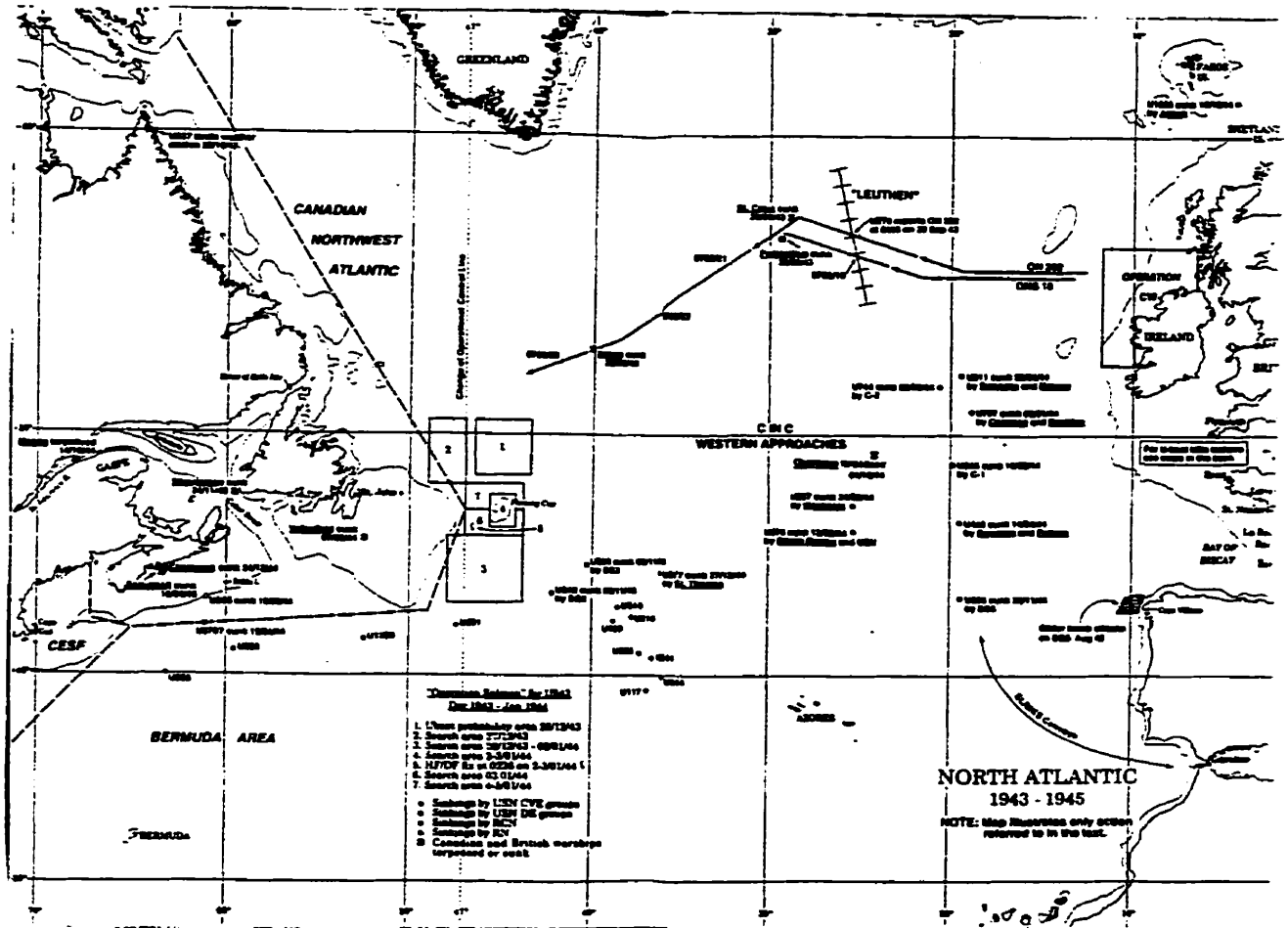
Although the full expression of this trend toward the OR-based study of problems of specific concern in Canadian airborne anti-submarine squadrons was cut short by the defeat of Germany and subsequent demobilization of Eastern Air Command's bomber-reconnaissance force and the ORS itself, the example created by EAC ORS and the Army and Navy ORS' as well would serve as the pattern for the reestablishment and continuation of Canadian military OR in the postwar era. The purpose of this thesis was not to magnify the historical significance of Eastern Air Command's Operational Research Section out of proportion to its real accomplishments; the section was one of many components which assisted Eastern Air Command in its battle against the U-boat. Despite its small size and limited activities, Eastern Air Command ORS was formed in 1942 in desperate circumstances when senior RCAF officers searched for any potential assistance to transform the Command into a more lethal enemy to the marauding German

U-boats which were taking such a toll on Atlantic convoys and Canadian coastal shipping during the dark days of 1941-43. Many of the handicaps of Eastern Air Command such as lack of aircraft and operational conditions which often mitigated the chances of detecting U-boats (if they were even present in the area) could not be solved by an operational research section. What EAC ORS could, and indeed, did, do was offer possible options in response to certain key problems relating to Canadian bomber-reconnaissance operations while also passing a continuous stream of interpreted statistical analysis of past operations upon which Command planners could develop their future dispositions to better counter the U-boat. As the contest between aircraft and submarine began to reach ever-higher technological heights during the Battle of the Atlantic in which countermeasures almost instantly reduced the effectiveness of new devices almost as soon as they entered service. the Operational Research Sections of Canada. Britain and the United States provided a key factor which was largely absent in German operational planning, namely objective statistical assessment of operations. It was this early foray into information warfare which countered the German U-boats by maximizing the potential of existing Allied weaponry, thereby allowing an overwhelming anti-submarine force to come to fruition without being rendered obsolete by German technological advances. In the case of Eastern Air Command, this was essential given its limited resources. which the ORS' provision of information served to 'artificially' augment and maximize. The resulting achievements of Eastern Air Command were the result of a collective effort, from the operational squadrons who flew long and dangerous missions over the wastes of the Atlantic Ocean desperately searching for a glimpse of a U-boat to the diverse group of support arms, of which EAC ORS was only but a small part. It is all

of the personnel of Eastern Air Command who deserve recognition for their achievements during the Battle of the Atlantic. Although the Command largely disappeared after the conclusion of hostilities, its legacy, in a small way, lives on with the continuation and acceptance of operational research and indeed scientific warfare of all shapes in the Canadian Forces to this day.

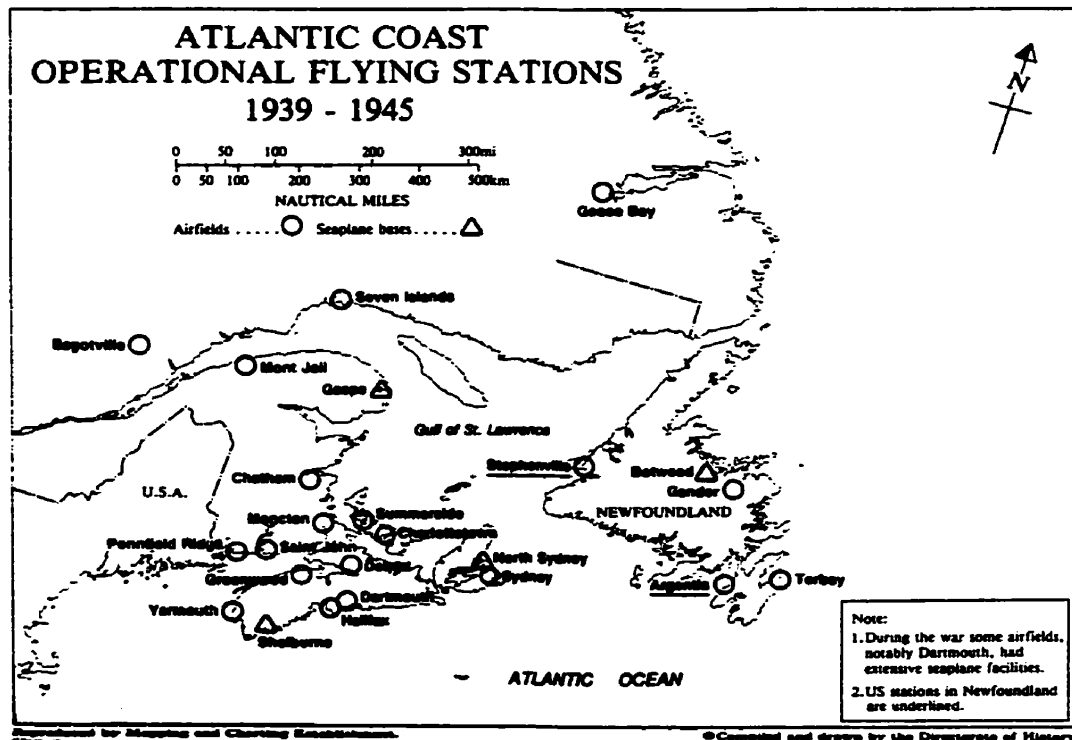
Appendix 1: North Atlantic Theatre of Operations

From: Marc Milner, The U-Boat Hunters: The Royal Canadian Navy and the Offensive against Germany's Submarines (Toronto: University of Toronto Press, 1994): back end plate.



Appendix 3: Atlantic Coast Operational Flying Stations of Eastern Air Command

From: Norman Hillmer ed., The Official History of the Royal Canadian Air Force, vol. 2, The Creation of a National Air Force, by W.A.B. Douglas (Toronto: University of Toronto Press, 1986): 396.



Appendix 4: EAC ORS Monthly "Statistics" Charts: Weather

From: Eastern Air Command Operational Research Section, Royal Canadian Air Force,
"Statistics of Anti-Submarine Operations February, 1943," DHH 181.003 (D233): 2;
Eastern Air Command Operational Research Section, Royal Canadian Air Force,
"Statistics of Anti-Submarine Operations April, 1943," DHH 181.002 (D379): 4; Eastern
Air Command Operational Research Section, Royal Canadian Air Force, "Statistics of
Anti-Submarine Operations May, 1943," DHH 181.002 (D379): 5; Eastern Air Command
Operational Research Section, Royal Canadian Air Force, "Statistics of Anti-Submarine
Operations June, 1943," DHH 181.003 (D41): 4.

Table I

Flying Days at PAC Stations

February, 1943

STATION	Flying Days	
	Number	Per cent
Gander	17	61
Torbay	18	64
Sydney	22	78
Dartmouth	21	75
Shelburne	21	75
Yarmouth	21	75

TABLE 1
ON OPERATIONAL FLYING AT E.A.C. STATIONS
APRIL, 1943

STATION	NUMBER OF DAYS		
	Patrols Completed	Patrols Curtailed	All Patrols Cancelled
GANDER	12	5	13
TORBAY	10	8	12
SYDNEY	15	8	7
DARTMOUTH	13	11	6
SHELBURNE	17	3	10
YARMOUTH	17	4	9

TABLE 1
Effect of Weather on Operational Flying
E.A.C. Stations, May, 1943

Region	Station	Number of Days		
		All Patrols Completed	Patrols Curtailed	All Patrols Cancelled
Newfoundland	Gander	6	15	6
	Torbay	6	15	6
Gulf Area	Chatham)	13	13	5
	Caspe)			
	Mont Joli)			
Nova Scotia	Sydney	13	7	11
	Dartmouth	13	12	6
	Shelburne	12	14	5
	Yarmouth	13	14	4

TABLE 1
Effect of Weather on Operational Flying
at E.A.C. Stations, June, 1943

Region	Station	Number of Days		
		All Patrols Completed	Patrols Curtailed	All Patrols Cancelled
Newfoundland	Gander	10	16	4
	Torbay	7	17	6
Gulf of St. Lawrence	Mont Joli	19	9	2
	Gaspe	17	10	3
Nova Scotia	Sydney	11	15	4
	Dartmouth	11	13	6
	Yarmouth	12	12	6

Appendix 5: EAC ORS Monthly "Statistics" Charts: Aircraft Serviceability

From: Eastern Air Command Operational Research Section, Royal Canadian Air Force, "Statistics of Anti-Submarine Operations February, 1943," DHH 181.003 (D233): 3; Eastern Air Command Operational Research Section, Royal Canadian Air Force, "Statistics of Anti-Submarine Operations April, 1943," DHH 181.002 (D379): 4; Eastern Air Command Operational Research Section, Royal Canadian Air Force, "Statistics of Anti-Submarine Operations May, 1943," DHH 181.002 (D379): 5; Eastern Air Command Operational Research Section, Royal Canadian Air Force, "Statistics of Anti-Submarine Operations June, 1943," DHH 181.003 (D41): 4; Eastern Air Command Operational Research Section, Royal Canadian Air Force, "Statistics of Anti-Submarine Operations July, 1943," DHH 181.003 (D251): 5.

- 3 -

Table 2

Average Availability of BR Aircraft of EAC

February, 1943

BR Squadron	Average Number on Strength	Average Available	
		Number	Per cent
5 Gander (Canso A)	6.5	4.7	72
162 Gander (Canso A)	1.0	0.75	75
145 Torbay (Tudson)	9.7	5.6	60
119 Sydney (Tudson)	13.5	6.2	46
10 Dartmouth (Digby)	10.0	2.0	20
11 Dartmouth (Tudson)	12.0	7.6	63
116 Dartmouth (Catalina)	4.0	2.1	52
117 Dartmouth (Com., Cat.)	10.4	2.2	21
116 Shelburne (Catalina)	4.0	2.4	59
113 Yarmouth (Tudson)	11.9	6.8	57
162 Yarmouth (Canso)	1.0	0	0
No. 1 Group	17.2	11.2	65
No. 3 Group	66.8	30.1	45
EAC	84.0	41.3	49

TABLE 2
DISPOSITION AND AVERAGE SERVICEABILITY OF B.R. AIRCRAFT OF E.A.C.
APRIL, 1943

B.R. SQUADRON	STATION	Average No. of A/C On Strength	Average Serviceable	
			Number	Percent
5 (Canso A)	Gander, Torbay *	10.3	5.6	55
145 (Hudson)	Torbay	11.4	7.8	68
119 (Hudson Anson)	Sydney, Chatham, Mont Joli **	11.7	7.4	63
10 (Digby)	Dartmouth	10.0	7.8	78
11 (Hudson)	Dartmouth	11.0	7.7	70
117 (Canso Cat)	Dartmouth	9.2	6.9	75
116 (Catalina)	Shelburne	9.0	6.4	71
113 (Hudson, Ventura)	Yarmouth	16.8	6.4	38
162 (Canso A)	Yarmouth	12.9	6.3	49
B.R. Total, No. 1 Group		21.7	13.4	62
B.R. Total, No. 3 Group		80.6	48.9	61
B.R. Total, E.A.C.		102.3	62.3	61

* Detachment of 4 A/C at Torbay, April 24 - 30
 ** Detachments of 2 A/C each at Chatham and Mont Joli, April 25 - 30

TABLE 2
Disposition and Serviceability of RCAF BR Aircraft of MAC
Daily Averages - May, 1943

Aircraft Type	Daily Average	Newfoundland	Gulf Area	Novu Scotia	Total
Short and medium range (Hudson, Ventura, Digby)	No. on strength	19.6	11.4	44.0	75.2
	No. serviceable	11.0	8.7	23.2	42.9
	Percent serviceable	56	76	53	57
Long range (Canso, Catalina)	No. on strength	13.9	1.7 *	39.7	55.3
	No. serviceable	8.4	1.6	23.7	33.7
	Percent serviceable	60	94	60	61
Very long range (Liberator)	No. on strength	11.4	-	-	11.4
	No. serviceable	7.1	-	-	7.1
	Percent serviceable	62	-	-	62
Totals	No. on strength	45.1	13.1	83.7	142
	No. serviceable	26.5	10.3	46.9	84
	Percent serviceable	59	79	56	59

* Note: No long range aircraft at Gaspe until May 21. For the period May 21-31 daily average no. on strength 5.0, daily average number serviceable 4.7 94% serviceability.

TABLE 2

Disposition and Serviceability of RCAF BR Aircraft of EAC

Daily Averages - June, 1943

Aircraft Type	Daily Average	Newfoundland	Gulf Area	Nova Scotia	Total
Medium Range (Hudson)	No. on Strength	11.5	14.1	18.0	43.6
	No. Serviceable	6.4	10.1	11.6	28.1
	Total serviceable, %	56	72	65	65
Long range (Canso, Digby, Catalina, Ventura PV 1)	No. on strength	40.1	5.5	49.6	95.2
	No. serviceable	27.2	4.4	34.5	66.1
	Total serviceable, %	68	80	70	70
Very long range (Liberator)	No. on strength	15.0	-	-	15.0
	No. serviceable	10.8	-	-	10.8
	Total serviceable, %	72	-	-	72
All types	No. on strength	66.6	19.6	67.6	153.8
	No. serviceable	44.4	14.5	46.1	105.0
	Total serviceable, %	67	74	63	68

Aircraft types follow Air Ministry Classification.

TABLE 2

DISPOSITION AND SERVICEABILITY OF RCAF BR AIRCRAFT
OF EAC - DAILY AVERAGES - JULY, 1943

Aircraft Type	Daily Average	Newfound- land	Gulf of St. Lawrence	Nova Scotia	Total
Medium ranges: Hudson	No. on strength	4.2	15.0	15.2	34.4
	Total serviceable	24%	82%	64%	66%
	Oper. serviceable	21%	52%	53%	46%
Long ranges: Canso, CansoA Catalina	No. on strength	28.4	5.8	24.8	59.0
	Total serviceable	67%	91%	74%	72%
	Oper. serviceable	59%	90%	57%	61%
Digby	No. on strength	-	-	8.0	8.0
	Total serviceable	-	-	70%	70%
	Oper. serviceable	-	-	55%	55%
Ventura PV-1	No. on strength	15.0	-	14.5	29.5
	Total serviceable	64%	-	67%	65%
	Oper. serviceable	60%	-	65%	62%
Very long ranges Liberator	No. on strength	15.0	-	-	15.0
	Total serviceable	67%	-	-	67%
	Oper. serviceable	46%	-	-	46%
All types	No. on strength	62.6	20.8	62.5	145.9
	Total serviceable	63%	85%	69%	59%
	Oper. serviceable	54%	63%	57%	56%

Appendix 6: EAC ORS Monthly "Statistics" Charts: Operational Flying

From: Eastern Air Command Operational Research Section, Royal Canadian Air Force,

"Statistics of Anti-Submarine Operations February, 1943," DHH 181.003 (D233): 3;

Eastern Air Command Operational Research Section, Royal Canadian Air Force,

"Statistics of Anti-Submarine Operations July, 1943," DHH 181.003 (D251): 6-7.

Table 3

Operational Flying by BR Squadrons of No. 1 Group

February, 1943

BR Squadron	Number of Sorties			Total	Hours Flown			Total
	Routine Patrols	Sweeps, No-ports, etc	Other		Routine Patrols	Sweeps No-ports	Other	
5 Gander	-	57	-	57	-	433	-	433
162 Gander	-	-	-	-	-	-	-	-
145 Torbay	2	46	-	49	6	175	-	181
Total	2	103	-	106	6	612	-	618

Table 4

Operational Flying by BR Squadrons of No. 3 Group

February, 1943

BR Squadron	Number of Sorties			Total	Hours Flown			Total
	Routine Patrols	Sweeps, No-ports, etc	Other		Routine Patrols	Sweeps No-ports	Other	
119 Sydney	5	70	21	96	25	293	58	376
10 Dartmouth	11	17	-	28	137	148	-	285
11 Dartmouth	42	57	-	99	212	259	-	471
116 Dartmouth	1	1	-	2	11	8	-	19
117 Dartmouth	5	2	-	7	42	10	-	52
116 Shelburne	-	1	-	1	-	8	-	8
113 Yarmouth	35	65	1	101	123	317	1	441
162 Yarmouth	-	-	-	-	-	-	-	-
Total	102	213	22	337	550	1043	59	1652

TABLE 3

Summary of Operational Flying by BR Aircraft of Eastern Air Command, July, 1943
(Including USAAF and USN Squadrons under EAC Operational Control)

Region	Flying Effort	Type of Mission				Total
		Routine & Harbour Patrols	Shipping Protection	A/S Swoops & Searches	Other	
Newfoundland	No. of sorties	1	366	145	1	513
	Hours flown (base to base)	9	3405	1377	7	4798
Gulf of St. Lawrence	No. of sorties	-	94	161	2	257
	Hours flown (base to base)	-	725	776	3	1504
Nova Scotia	No. of sorties	96	210	111	2	419
	Hours flown (base to base)	473	1409	545	11	2436
Total EAC	No. of sorties	97	670	417	5	1189
	Hours flown (base to base)	480	5539	2698	21	8738

TABLE 4

Operational Sorties by BR Aircraft of EAC, July, 1943
(Including USAAF and USN Squadrons under EAC Operational Control)
Classified according to type of aircraft and mission

Region	Type of Aircraft	Number of Sorties								Total
		Routine & Harbour Patrols	Shipping Protection				Anti-Submarine		Other	
			Escorts	Swoops		Swoops	Searches			
Met	Not Met	Met	Not Met	Met	Not Met	Swoops	Searches			
Newfoundland	USAAF Liberator	-	38	9	1	2	11	-	-	61
	USN Liberator	1	24	29	1	3	5	-	-	63
	RCAF Liberator	-	57	13	6	3	16	3	-	96
	RCAF Canso, Catalina	-	61	19	1	-	92	-	-	173
	RCAF Ventura PV-1	-	87	12	-	-	18	-	1	118
	TOTAL	1	267	82	9	8	142	3	1	513
Gulf of St. Lawrence	Canso, Catalina	-	33	3	-	-	19	1	-	56
	Hudson	-	54	4	-	-	139	2	2	201
	TOTAL	-	87	7	-	-	158	3	2	257
Nova Scotia	Canso, Catalina	24	75	23	9	-	18	4	-	153
	Digby	20	13	1	3	-	1	1	-	39
	Ventura PV-1	3	21	3	20	15	80	3	2	147
	Hudson	49	6	-	20	1	2	2	-	80
	TOTAL	96	115	27	52	16	101	10	2	419
Total E.A.C.	Liberator	1	119	51	8	8	32	3	-	222
	Canso, Catalina	24	169	45	10	-	129	5	-	282
	Digby	20	13	1	3	-	1	1	-	39
	Ventura PV-1	3	108	15	28	15	98	3	3	265
	Hudson	49	60	4	20	1	141	4	2	281
	TOTAL	97	469	116	61	24	410	16	5	1189

Appendix 7: EAC ORS Monthly "Statistics" Charts: Convoy Coverage

From: Eastern Air Command Operational Research Section, Royal Canadian Air Force,

"Statistics of Anti-Submarine Operations February, 1943," DHH 181.003 (D233): 5;

Eastern Air Command Operational Research Section, Royal Canadian Air Force,

"Statistics of Anti-Submarine Operations July, 1943," DHH 181.003 (D251): 9-10.

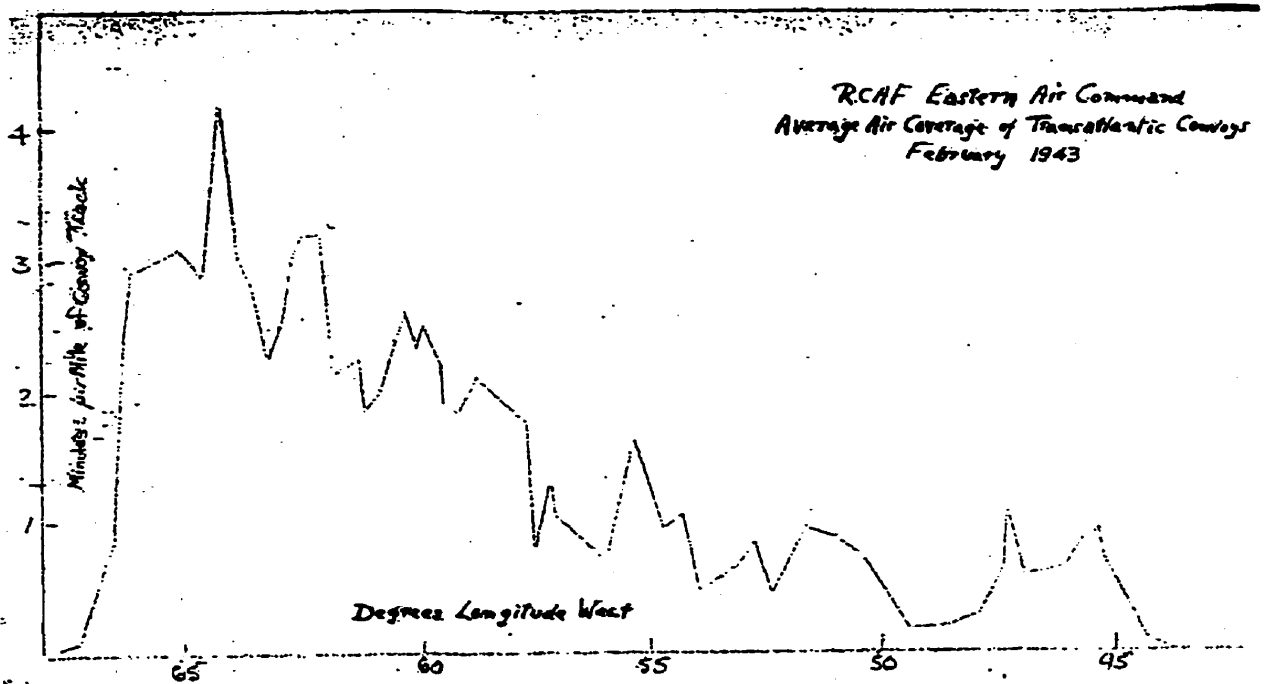


TABLE 6

DAILY AIR COVERAGE OF TRANSATLANTIC MERCANTILE CONVOYS
IN AREA NORTH OF 40°N AND WEST OF 32°W, JULY, 1943

Convoys	Convoy-days in area	Convoy-days with Air Coverage					
		Total	RCAF	USAAF or USN	RCAF & US	RCAF & RAF	US & RAF
SC.135-137	26	20	16	2	2	-	-
HX.245-248	32	28	24	4	-	-	-
ON. 190-193	33	23	19	2	-	1	1
OHS. 11-13	29	21	17	3	1	-	-
Total	120	92	76	11	3	1	1

TABLE 7

DAILY AIR COVERAGE OF TRANSATLANTIC MERCANTILE CONVOYS IN SECTORS
OF AREA NORTH OF 40°N AND WEST OF 32°W, JULY, 1943.

Sector Number (Ref. Map, Fig)	Total T.A.M. Convoy-days	Convoy-days with Air Coverage	
		Number	Per cent
2	22	13	59
4	32	28	83
5	17	15	94
6	23	18	76
7	26	17	65
Total	120	92	77

TABLE 8

DURATION OF DAILY AIR COVERAGE OF TRANSATLANTIC MERCANTILE CONVOYS
IN NEAR AND FAR SECTORS OF AREA NORTH OF 40°N AND WEST OF 32°W, JULY, 1943

Duration of Coverage, hours	Percentage of All Convoy-days with Air Coverage		
	Sectors 2&4	Sectors 5&6	Sector 7
Less than 1	10%	6%	0%
1 to 3	19%	15%	24%
3 to 6	32%	32%	11%
6 to 12	22%	26%	11%
Over 12	17%	21%	24%

TABLE 9

NUMBER OF AIRCRAFT PER CONVOY-DAY
ASSIGNED TO COVER INDIVIDUAL TRANSATLANTIC MERCANTILE CONVOYS
IN NEAR AND FAR SECTORS OF AREA NORTH OF 40°N AND WEST OF 32°W, JULY, 1943

Number of Aircraft per Convoy-day	Percentage of All Convoy-days with Air Coverage		
	Sectors 2&4	Sectors 5&6	Sector 7
1	39%	33%	6%
2	32%	23%	21%
3	16%	31%	38%
4	9	13%	6%
5	-	-	5%
6	-	-	11%
7	-	-	6%
8	-	-	6%

Endnotes

Introduction

1. Basil Collier, The Defence of the United Kingdom (London: Her Majesty's Stationery Office, 1957): 56.
2. P.M.S. Blackett, "Scientists at the Operational Level," in The Origins and Development of Operational Research in the Royal Air Force, Air Ministry (London: Her Majesty's Stationery Office, 1963): 193.
3. Professor C.H. Waddington, O.R. In World War 2: Operational Research against the U-boat (unpublished manuscript, 1946; London: Elek Science, 1973): xiii.
4. *Ibid.*, vii.
5. Air Ministry, iii.
6. See Sir Bernard Lovell, P.M.S. Blackett: A biographical memoir (London: The Royal Society, 1976).
7. *Ibid.*, 4.
8. Dr. N.W. Morton, "Brief History of the Development of Canadian Military Operational Research," Canada, Department of National Defence, Directorate of History and Heritage, Vol. 85/565: 2.
9. *Ibid.*, 4.
10. Squadron Leader Peter M. Millman, compiler, "Operational Research in the RCAF During World War II," [1947] Canada, Department of National Defence, Directorate of History and Heritage, Vol. 77/510.
11. *Ibid.*, 10-11, 17-19.

12. Wilfrid Eggleston, Scientists at War (London and Toronto: Oxford University Press, 1950).
13. George R. Lindsey, "Introduction," in No Day Long Enough: Canadian Science in World War II, ed. George R. Lindsey (Toronto: Canadian Institute of Strategic Studies, 1997): 9.
14. George R. Lindsey, "Canadian Wartime Operational Research," in No Day Long Enough: Canadian Science in World War II, ed. George R. Lindsey (Toronto: Canadian Institute of Strategic Studies, 1997): 209. The other two chapters are George R. Lindsey, "Reminiscences of Operational Research on the Air Defence of Great Britain," and G.L. Nelms, "Locating the Launching Sites of the V1 Missiles."
15. Joseph F. McCloskey, "The Beginnings of Operations Research: 1934-1941," Operations Research vol. 35, 1 (January-February 1987); Joseph F. McCloskey, "British Operational Research in World War II," Operations Research vol. 35, 3 (May-June 1987).
16. McCloskey, "British Operational Research," 457.
17. Terry Copp, "Introduction," in Montgomery's Scientists: Operational Research in Northwest Europe- The Work of No. 2 Operational Research Section with 21 Army Group June 1944 to July 1945 (Waterloo, Ontario: Laurier Centre for Military, Strategic and Disarmament Studies, 2000): 6.
18. Norman Hillmer, ed., The Official History of the Royal Canadian Air Force, vol. 2, The Creation of a National Air Force, by W.A.B. Douglas (Ottawa: Minister of Supply and Services Canada and Toronto: University of Toronto Press, 1986).
19. Ibid. Operational research is discussed by Douglas in short paragraphs on only 8 of 797 pages.

20. Ibid., 569.

Chapter 1- The Nature of Airborne Anti-submarine Warfare

1. Alfred Price, Aircraft versus Submarine: The evolution of the anti-submarine aircraft, 1912 to 1980, 2nd ed. (London: Jane's Publishing Company Limited, 1980): 6.

2. Ibid.

3. Ibid., 7.

4. Ibid., 7-8.

5. Ibid., 8. Williamson's vision ignored the risks of sailing a large warship unescorted in submarine patrolled waters. The loss of three Monmouth class cruisers to a single German U-boat on 22 September 1914 highlighted the vulnerability of surface ships tied to fixed patrol lines or course patterns (such as those required for operations involving aircraft).

6. Ibid., 9.

7. Ibid.

8. Ibid., 10. In August 1914 the submarine inventories of the major European powers was: Britain 75; Germany 30; France 67; Russia 36; Austria-Hungary 11; Italy 14.

9. Ibid., 11.

10. Ibid.

11. Ibid.

12. Ibid.

13. Ibid., 3-4.

14. Ibid., 4.

15. Ibid.
16. Ibid., 19.
17. Ibid.
18. S.F. Wise, The Official History of the Royal Canadian Air Force, vol. 1, Canadian Airmen and the First World War (Ottawa: Minister of Supply and Services Canada and Toronto: University of Toronto Press, 1980): 123.
19. Ibid., 182, 185.
20. Ibid., 172, 177.
21. Ibid.; Price, 23; Leslie Roberts, There Shall be Wings: A History of the Royal Canadian Air Force (Toronto: Clarke, Irwin & Company Limited, 1959): 23.
22. Wise, 172, 177; Price, 23; Roberts, 23.
23. Price, 28-29.
24. Ibid., 27; Chaz Bowyer, The Concise Encyclopedia of British Military Aircraft (London: Bison Books Limited, 1982): 35.
25. John Terraine, The Right of the Line: The Royal Air Force in the European War 1939-1945 (London: Hodder and Stoughton, 1985): 6.
26. Price, 32.
27. Ibid., 32.
28. Ibid., 32-33.
29. Ibid., 33.
30. Ibid.
31. Tony Spooner, Coastal Ace: The biography of Squadron Leader Terence Malcolm Bulloch, DSO and Bar, DFC and Bar (London: William Kimber, 1986): 79.

32. Price, 35.
33. Spooner, 74.
34. Terraine, 228-229.
35. Price, 45.
36. Ibid., 43.
37. Ibid., 46.
38. Terraine, 229.
39. Ibid.
40. Ibid.
41. Ibid., 232.
42. Ibid.
43. Price, 44.
44. Ibid.; Terraine, 233.
45. Price, 46.
46. Ibid., 41.
47. Douglas, 469.
48. Ibid.
49. Ibid., 470. In April 1941, the Admiralty officially assumed operational control of Coastal Command but the previous establishment of joint headquarters at the command/group level had already made this a reality.
50. Price. 46-47; Terraine, 233-234.
51. Terraine, 239.
52. Ibid.; Price, 55.

53. Price, 58.
54. Ibid., 59.
55. Ibid., 52.
56. Ibid., 53.
57. Ibid.
58. Ibid.
59. Ibid., 59-60.
60. Ibid., 60.
61. Ibid., 65.
62. John Buckley, "Atlantic Airpower Co-Operation, 1941-1943," The Journal of Strategic Studies 18, 1 (March 1995): 175-176.
63. Douglas, 476.
64. F.H. Hitchens, "The Story of No. 10 (BR) Squadron: "The North Atlantic Squadron",," no date [1955?], Directorate of History and Heritage (DHH), National Defence Headquarters, Ottawa, R S7 10.
65. C.R. Vincent with J.D. Oughton and E. Vincent, Consolidated Liberator & Boeing Fortress, Canada's Wings vol. 2 (Stittsville, Ontario: Canada's Wings, 1975): 18.
66. Roberts, 117.
67. Ibid.
68. Douglas, 375.
69. Vincent with Oughton and Vincent, 18; Douglas, 375.
70. Vincent with Oughton and Vincent, 18.

71. Christopher Shores, History of the Royal Canadian Air Force (Greenwich, Connecticut: Bison Books Corp., 1984): 25; Bowyer, 89.
72. Air Marshal C.L. Annis, "Eastern Air Command, Recalled" in I'll Never Forget... Canadian Aviation in the Second World War, ed. Les Wilkinson (Ottawa[?]: Canadian Aviation Historical Society, 1979): 61.
73. Shores, 30; Annis in Wilkinson ed., 61; Douglas, 379.
74. Carl Vincent, "North Atlantic Squadron: Story of 10 (Bomber Reconnaissance) Squadron, RCAF," photocopy of Air Extra #8, DHH R S7 10.
75. Annis in Wilkinson ed., 63.
76. Douglas, 379-380.
77. *Ibid.*, 384, 387.
78. Vincent with Oughton and Vincent, 19.
79. Wing Commander C.L. Annis, "Submarine Warfare, World War II," 29 January 1943, DHH 181.003 (D309): 9-11.
80. Vincent. 14.
81. Annis in Wilkinson ed., 65.
82. Douglas, 378.
83. *Ibid.*. 378-379.
84. Air Marshal C.L. Annis, interview by J.D.F. Kealy, 10 September 1979, DHH Bio A (Annis Biog File): 3-4.
85. Annis in Wilkinson ed., 63.
86. Douglas, 491.
87. Annis interview by Kealy, 7.

88. Ibid., 4.
89. Douglas, 390.
90. Annis interview by Kealy, 4; Vincent, 12.
91. Vincent, 12.
92. Robert L. Baglow, "An Examination of A/S Operations Off the East Coast of Canada Feb-Oct, 1942," 1979, DHH 79/649: 2.
93. Hitchens, 15.
94. Annis, "Submarine Warfare, World War II," 1.
95. See Eliot A. Cohen and John Gooch, Military Misfortunes: The Anatomy of Failure in War (New York: Vintage Books, 1991): chapter 4 for an excellent discussion of what they term as the American 'failure to learn' from British experiences against the U-boat. They believe that this was a key factor in the slaughter of merchant shipping off the American East Coast during 1942.

Chapter 2- Blackett and the Origins of Operational Research

1. McCloskey, "The Beginnings of Operations Research: 1934-1941," 143; Copp, 6; Air Ministry, 81-82.
2. McCloskey, "The Beginnings of Operations Research," 143.
3. Ibid.
4. Ibid., 144.
5. Ibid.
6. Ibid.; Air Ministry, 3.
7. Ibid.

8. McCloskey, "The Beginnings of Operations Research," 145.
9. Ibid.; Air Ministry, 6.
10. Air Ministry, 6. The authors of this volume assert that the term 'operational research' originated with Rowe.
11. Ibid., 7.
12. McCloskey, "The Beginnings of Operations Research," 146. Fighter Command's Stanmore Research Station under Harold Larnder focused during the spring of 1940 on the question of the dispatch of additional fighters to France. Their negative view of this informed Prime Minister Churchill's rejections of French pleas for additional British fighters during late May and June 1940.
13. Ibid., 148.
14. Ibid. McCloskey, "British Operational Research," 462.
15. Lovell, 56-57.
16. Ibid., 58. Lovell asserts that Joubert de la Ferte was the driving force but he did not become Commander in Chief Coastal Command until June 1941.
17. Ibid.
18. Ibid.
19. Copp, 9. It is unclear whether this paper was disseminated in the RCAF as no copies exist in the EAC, WAC or RCAF HQ OR files at DHH and NAC. However, given the presence and training of Canadian operational researchers at Coastal Command ORS and other British establishments it is quite probable that the paper was known to these individuals. Indeed, since the Canadian ORS's were officially constructed on the British model put forth by Blackett in this paper, its influence is clear.

20. Blackett, "Scientists at the Operational Level," 189.
21. Ibid.
22. Ibid.
23. Ibid., 191.
24. Ibid., 191-192.
25. Ibid., 192.
26. Ibid.
27. Ibid., 189.
28. Ibid., 189-190.
29. Ibid., 190.
30. Ibid., 191.
31. Ibid.
32. Ibid.
33. Ibid.
34. Waddington, ix.
35. Ibid.
36. Air Ministry, 75.
37. Waddington, xiii.
38. Ibid.
39. Terraine, 407.
40. McCloskey, "British Operational Research," 455.
41. Ibid.
42. Air Ministry, 75.

43. McCloskey, "British Operational Research," 457. Williams himself departed for the Admiralty in the fall of 1942 with Harold Larnder replacing him at Coastal Command.
44. Ibid., 456; Lovell, 58; Air Ministry, 77.
45. Ibid.
46. McCloskey, "British Operational Research," 456.
47. Ibid.
48. Air Ministry, 102.
49. McCloskey, "British Operational Research," 457.

Chapter 3- The Creation of Eastern Air Command ORS

1. Douglas, 485.
2. Air Vice-Marshal N.R. Anderson quoted in Ibid., 485-486.
3. Douglas, 486.
4. Ibid.
5. Ibid.
6. Annis interview by Kealy, 6.
7. Ibid.; Douglas, 520-21.
8. Annis interview by Kealy, 6.
9. Douglas, 490.
10. Ibid. See Douglas pages 545-550 for an excellent discussion of the 1943 agreement between Canada and the United States over the division of defence responsibilities in the Northwest Atlantic.
11. Ibid., 491.

12. **Ibid.**
13. **Ibid.**
14. **Ibid.**
15. **Ibid.**
16. **Ibid.** The first Torpex depth charges began to trickle into Eastern Air Command in late 1942, six months after their widespread introduction in RAF Coastal Command.
17. **Ibid.**
18. **Ibid.**, 525-526.
19. **Professor J.O. Wilhelm, "Operational Research Progress Report Activities Up To Aug. 31st, 1943," 20 August 1943, DHH, NDHQ, 181.003 (D4033): 5.**
20. **Ibid.**, 1
21. **Ibid.**
22. **J.P.T. Pearman, Royal Air Force Coastal Command Headquarters Operational Research Section, "Summary of Anti-Submarine Air Effort of Eastern Air Command, Halifax, N.S., February 1942," 29 March 1942, National Archives of Canada (NAC), RG24, vol. 5270, file 28-3-2: 1.**
23. **Ibid.**, 2.
24. **Douglas, 523.**
25. **Wing Commander Gibbs, Royal Air Force, "Report on Visit to E.A.C., Halifax and R.C.A.F. Station, Dartmouth [27-30 September 1942]," NAC, RG24, vol. 5233, file 19-17-4, vol. I: 1.**
26. **Ibid.**
27. **Ibid.**.. 2.

28. Ibid.
29. Ibid., 3.
30. Wilhelm, "Operational Research Progress Report," DHH 181.003 (D4033): 1.
31. Ibid.: Professor J.O. Wilhelm, "Operational Research in the RCAF Preliminary Outline" in "Operational Research in the RCAF During World War II," [1947] compiled by Squadron Leader Peter M. Millman, DHH, 77/510: 5.
32. Wilhelm in Millman, "Operational Research in the RCAF," 5.
33. Wilhelm, "Operational Research Progress Report," DHH 181.003 (D4033): 1.
34. Ibid., 2.
35. Ibid., 2.
36. Ibid.
37. Ibid.: Wilhelm in Millman, "Operational Research in the RCAF." 5.
38. Wilhelm. "Operational Research Progress Report," 2.
39. Waddington, xi.
40. Lindsey, "Canadian Wartime Operational Research," in No Day Long Enough, ed. G.R. Lindsey, 208.
41. Wilhelm in Millman, "Operational Research in the RCAF," 6; Wilhelm, "Operational Research Progress Report," 2-3.
42. Wilhelm, "Operational Research Progress Report," 2.
43. Professor C. Barnes, memorandum to Air Officer Commanding-in-Chief. Eastern Air Command (AOC-in-C, EAC) G.O. Johnson, "Status of Operational Research Personnel," 31 August 1943, DHH, NDHQ, 181.002 (D484): 1.
44. Ibid.

45. **Ibid.**
46. **Ibid.**
47. **Ibid.**
48. **Flight Lieutenant J.L. Morton, EAC ORS to Professor J.O. Wilhelm, AMAS/ORC, 6 November 1944, NAC RG24, vol 5233, file 19-17-4 vol. 2.**
49. **AVM N.R. Anderson, Air Member for Air Staff (AMAS) memorandum to Air Marshal L.R. Breadner, Chief of Air Staff, "Operational Research Organization-R.C.A.F.," 12 June 1942, DHH 181.002 (D484): 1.**
50. **Ibid., 2.**
51. **AVM N.R. Anderson, AMAS memorandum to AOC-inC's WAC, EAC, "Operational Research Organization," 8 September 1942, DHH 181.002 (D484): 2.**
52. **EAC ORS memorandum, "Operational Research Section- E.A.C.," 13 March 1943, DHH 181.002 (D484): 1.**
53. **Ibid.**
54. **EAC ORS memorandum to AVM G.O. Johnson, AOC-in-C EAC, "Problems under Investigation by the ORS/EAC," 2 July 1943, DHH 181.002 (D484): 1.**
55. **RCAFHQ Operational Research Centre (ORC), "Operational Research Centre: A Report for the period January 1st- June 30th, 1943," NAC RG24, vol. 5234, file 19-17-6 vol I: 1.**
56. **Terraine, 243-244. The so-called Coastal Command 'Charter' of March 1941 was the result of a meeting of the British Cabinet Defence Committee which reaffirmed "the predominance of the naval element in the existing operational partnership for the**

protection of sea-borne trade” but also granted Coastal Command the right of direct command of its component Groups.

57. Douglas, 466.

58. Ibid., 466, 547-548.

59. Air Vice-Marshal R. Leckie (for Chief of the Air Staff) to Admiral Percy Nelles, Chief of Naval Staff, 27 April 1943, NAC RG24, vol. 5233, file 19-17-4 vol I.

60. Ibid.

61. DHH, “Defence Research Board Collection: Anti-Submarine Warfare Operational Research,” finding aid 96/51, 25 November 1996, 3; Professor J.W.T. Spinks, “Searches for Missing Aircraft” in “Operational Research in the RCAF During World War II,” [1947] compiled by Squadron Leader Peter M. Millman, DHH 77/510: 19.

62. Group Captain A.D. Ross (for AOC-inC EAC) to The Secretary, Department of National Defence for Air, cover letter to J.P.T. Pearman, “Analysis of Anti-Submarine Air Effort of Eastern Air Command, R.C.A.F., February 1942,” 2 April 1942, DHH 181.009 (D1147).

63. Wilhelm in Millman, “Operational Research in the RCAF,” 7.

64. J.O. Wilhelm, “Appendix B- Typical Operational Research Problems,” in “Operational Research in the RCAF During World War II,” [1947] compiled by Squadron Leader Peter M. Millman, DHH 77/510: 4.

65. Wilhelm, “Operational Research Progress Report,” 3.

66. EAC ORS memorandum, “Operational Research Section- E.A.C.,” 13 March 1943, DHH 181.002 (D484): 1; Wilhelm, “Operational Research Progress Report,” 3.

67. Wilhelm. “Operational Research Progress Report,” 3.

68. Douglas, 523.

Chapter 4- Eastern Air Command ORS Operational Studies

1. Professor J.O. Wilhelm, AMAS/ORC, "Submarine Hunts to Exhaustion," 11 May 1943, NAC RG24, vol. 5233, file 18-17-4, vol. I: 3; Wilhelm in Millman, "operational Research in the RCAF," 7.
2. Wilhelm, "Submarine Hunts to Exhaustion," 3.
3. Douglas, 486.
4. Ibid.
5. Ibid.
6. Baglow, 2. The other two squadrons, 11(BR) equipped with Lockheed Hudson and 119(BR) with Bolingbroke (Canadian-built Bristol Blenheims) were medium range bomber-reconnaissance squadrons.
7. Douglas, 491.
8. Pearman, "Summary of Anti-Submarine Air Effort of Eastern Air Command," 1.
9. Ibid.
10. Ibid.
11. Ibid. The attack by the Lysander occurred on 23 February 1942 off Sambro, Nova Scotia with depth charges but yielded no results.
12. Ibid., 2.
13. Ibid.
14. Ibid.
15. Ibid.

16. Samuel Kostenuk and John Griffin, RCAF Squadron Histories and Aircraft, 1924-1968 (Toronto: Samuel Stevens Hakkert & Company, 1977): 46; Baglow, "An Examination of A/S Operations," 2.
17. Kostenuk and Griffin, 46; Baglow, 19.
18. Douglas, 504.
19. Ibid., 520.
20. Waddington, 164.
21. Ibid., 165; Air Ministry, The Origins and Development of Operational Research, 80.
22. Flying Officer E.C. Common, Intelligence Officer, RCAF Station Gander, "Some Further Observations on the Statistical Summary of Attacks on U-Boats by EAC Aircraft Obtained in EAC Monthly Submarine Report for September 1942, pages 4 and 5," 16 January 1943, NAC RG24, vol. 5270, file 28-3-2: 1.
23. Ibid., 2.
24. Ibid.
25. Waddington, 164.
26. Annis interview by Kealy, 6; Spooner, 29.
27. Spooner, 29.
28. Douglas, 515.
29. EAC ORS, "Comments on Anti-Submarine Effort, 1941-42, E.A.C.," 15 March 1943, NAC RG24, vol. 5270, file 28-3-2: 1.
30. Ibid.; See Kostenuk and Griffin, pp. 26, 31, 46, 64, for details of EAC's six U-boat kills by Canadian-based aircraft.
31. EAC ORS, "Comments on Anti-Submarine Effort," 1.

32. Ibid.
33. Ibid.
34. Ibid.
35. Ibid., 3.
36. Ibid.
37. Annis interview by Kealy, 4.
38. Douglas, 481.
39. Annis interview by Kealy, 5.
40. Ibid.
41. Douglas, 482, 484.
42. Air Chief Marshal Sir John Slessor in Price, xi.
43. Ibid.
44. Waddington, 172-177.
45. Ibid., 190.
46. Ibid., 176, 190.
47. Squadron Leader J.D. Heaman, Deputy Director, Armament Directorate RCAFHQ, "Methods of Submarine Attack- Operation Order D/56/42," 16 October 1942, DHH 77/541: 1. This paper includes a comprehensive analysis of AVM N.R. Anderson's rather bizarre idea of "lassoing" U-boats with a rope laden with explosive charges.
48. EAC ORS Report No. 1, "Attacks on Submarines Relation of Tactics to Bombing Accuracy," 8 May 1943, DHH 181.002 (D379): 1.
49. Ibid.
50. Ibid.

51. Ibid., 6.
52. Ibid.
53. See Michael J. Neufeld, "Search the Sea: An Illustrated Short History of the Long Range Patrol Aircraft in the Canadian Armed Forces" (Canada: Department of Supply and Service, August 1974, DHH 73/1456): 54-55; "RCAF a/c attacks on U-Boats re: Attack by Hudson 784 of 145 Sqn 20 Oct 42. U658 sunk," DHH 181.003 (D1328); "RCAF a/c attacks on U-Boats re: Attack by Digby 747 of 10 Sqn 30 Oct 42 U520 sunk," DHH 181.003 (D1329); "RCAF a/c attacks on U-Boats re: Attack by Canso A 9747 of 5 Sqn 4 May 43, U630 sunk," DHH 181.003 (D1341); "RCAF a/c attacks on U-Boats re: Attack by Liberator "A" of 10 Sqn 19 Sep 43 U341 sunk," DHH 181.003 (D1349); "RCAF a/c attacks on U-Boats re: Attacks by Liberator "A" of 10 Sqn 26 Oct 43 U420 sunk," DHH 181.003 (D1354) for details of EAC U-boat kills.
54. See Douglas, chapter 13 for an excellent discussion of the 1942 'Battle of the St. Lawrence.'
55. Coastal Command ORS [prepared by Whitehead(?)], "Notes on U/B hunts," September 1941, DHH AIR 23/4799 (photocopy of original Air Ministry file): 1.
56. Ibid.
57. Ibid.
58. Ibid.
59. Ibid.
60. Ibid.
61. See Price, chapter 8 for details of Coastal Command's 1943 Biscay Campaign.
62. EAC ORS, "Comments on Anti-Submarine Effort," 1.

63. **Ibid.**
64. **Ibid.**
65. **Ibid., 2.**
66. **Ibid.**
67. **Ibid.**
68. **Ibid.**
69. **Ibid.**
70. **Wilhelm, "Submarine Hunts to Exhaustion," 1.**
71. **Ibid.; Douglas, 494-495.**
72. **Wilhelm, "Submarine Hunts to Exhaustion," 1; Douglas, 494-495.**
73. **Wilhelm, "Submarine Hunts to Exhaustion," 2.**
74. **Ibid., 2-3.**
75. **Ibid., 2.**
76. **Ibid.**
77. **Ibid., 3.**
78. **Marc Milner, The U-Boat Hunters: The Royal Canadian Navy and the Offensive against Germany's Submarines (Toronto: University of Toronto Press, 1994): 35.**
79. **Douglas, 569.**
80. **Ibid., 568.**
81. **Ibid.**
82. **Ibid., 571.**
83. **Ibid.**
84. **Ibid.; Milner, 78-79.**

85. Douglas, 572; Milner, 79.
86. Douglas, 572.
87. Douglas, 572; Milner 79.
88. Douglas, 572.
89. Ibid.
90. Ibid.
91. Ibid., 573.
92. See Milner, 101-2, 109, 199-200 and Douglas, 568-573, 574-577 for complete details of Canadian 'Salmon' hunts.
93. Air Commodore K.M. Guthrie, acting Air Member for Air Staff to AOC-in-C EAC AVM G.O. Johnson, 3 February 1944, NAC RG24, vol. 5270, file 28-3-1: 1.
94. Ibid., 2.
95. Annis, "Submarine Warfare, World War II," 6.
96. Douglas, 465.
97. EAC ORS Report No. 15, "Searches for Missing Aircraft (Revision of ORS/EAC Report No. 13, Air-Sea Rescue Procedure," September 1944, DHH 181.009 (D4995): 2, 8.
98. Ibid., 1.
99. Ibid.
100. Ibid.
101. Ibid., 6.
102. Ibid.
103. Ibid.

104. Ibid.
105. EAC ORS Report No. 20, "A Review of Searches for Missing Aircraft, Eastern Air Command 1 January, 1944- 1 June 1945," DHH 181.009 (D4995): 4.
106. See Ibid., 4-10 for details of searches for missing aircraft during period in question.
107. Price, 183.
108. Douglas M. McLean, "Confronting Technological and Tactical Change: Allied Anti-Submarine Warfare in the Last Year of the Battle of the Atlantic," Canadian Military History, 7, 3 (Summer 1998): 23.
109. Ibid., 23-24.
110. Ibid., 24.
111. Wing Commander D.H. Wigle, Canadian Joint Staff Washington to The Secretary, Department of National Defence for Air, "Search Radar Versus Schnorkel," 27 January 1945, DHH 77/541: 1.
112. Ibid., 2.
113. Ibid.
114. EAC ORS Report No. 18, "An Analysis of the 'Scouting Effectiveness' of Some Current A/S Patrols (with special reference to Schnorkel and Type XXI Tactics)," DHH 181.002 (D379): 1.
115. Ibid.
116. Ibid., 2.
117. Ibid., 4.
118. Ibid., 2, 4.
119. Ibid., 2.

120. EAC ORS Report No. 19, "Summary of Aircraft Attacks on U-Boats Eastern Air Command 1 October, 1941- 1 June,1945," DHH 181.002 (D379): 1-2.
121. Ibid., 1-2.
122. Ibid.
123. Ibid., 3-4.
124. Ibid.
- 125 . Ibid., 4.
126. Ibid., 7.
127. Ibid.
128. Neufeld, 54-55; Kostenuk and Griffin, 68; Douglas, 610.
129. Douglas, 610.

Chapter 5- EAC ORS Efficiency Studies

1. Price, 113-114; Terraine, 426. Terraine quotes Air Marshal Harris quipping that Coastal Command was "merely an obstacle to victory."
2. Annis interview by Kealy, 10.
3. Ibid.
4. Douglas, 465.
5. Annis, "Submarine Warfare, World War II," 9.
6. Annis interview by Kealy, 7.
7. Annis, "Submarine Warfare, World War II," 9-11.
8. Ibid., 11.

9. See Douglas, 549-551 for details of Allied discussions during the spring of 1943 regarding the allocation of Liberators to Eastern Air Command.
10. Waddington, 40.
11. Ibid.; See Air Ministry, 82-83 for specific details regarding the density method.
12. Waddington, 40.
13. Ibid.
14. Ibid., 41. Dr. Gordon was a biologist by training.
15. Air Ministry, 102.
16. Ibid.
17. Ibid.; Waddington, 42, 52-53.
18. Air Ministry, 103.
19. Ibid.
20. Ibid.
21. Ibid.
22. Ibid.
23. Ibid.
24. Waddington, 56.
25. Ibid., 56-57.
26. Ibid., 112; Air Ministry, 99.
27. Waddington, 111.
28. Ibid., 115; Air Ministry, 100.
29. Waddington, 90.
30. Ibid.; Air Ministry, 97.

31. **Waddington, 90-91.**
32. **Ibid., 92; Air Ministry, 98.**
33. **Waddington, 92; Air Ministry, 98.**
34. **Waddington, 92-93; Air Ministry, 98.**
35. **Annis, "Submarine Warfare, World War II," 2.**
36. **Ibid.**
37. **Ibid., 3.**
38. **Ibid.**
39. **Ibid.**
40. **Ibid., 4.**
41. **Ibid., 5.**
42. **Ibid.**
43. **Annis Bio File (Bio A), DHH. Annis' service in Newfoundland included his tenure as commander of 10 (BR) Squadron at Gander from February 1942 to July 1942 and again from April 1943 until he was appointed in August 1943 as Station Commander at Gander.**
44. **Annis, "Submarine Warfare, World War II," 5.**
45. **Ibid.**
46. **EAC ORS, "Statistics of Anti-Submarine Operations February, 1943," DHH 181.002 (D379): 2; EAC ORS, "Statistics of Anti-Submarine Operations March, 1943," DHH 181.002 (D379): 3; EAC ORS, "Statistics of Anti-Submarine Operations April, 1943," DHH 181.002 (D379): 4.**

47. EAC ORS, "Statistics of Anti-Submarine Operations March, 1943," 1; EAC ORS, "Statistics of Anti-Submarine Operations April, 1943," 1.
48. EAC ORS, "Statistics of Anti-Submarine Operations May, 1943," DHH 181.002 (D379): 1, 5; EAC ORS, "Statistics of Anti-Submarine Operations June, 1943," DHH 181.003 (D41): 1, 4; EAC ORS, "Statistics of Anti-Submarine Operations July, 1943," DHH 181.003 (D251): 1, 4.
49. EAC ORS, "Statistics of Anti-Submarine Operations July, 1943," 1.
50. Ibid.
51. EAC ORS, "Statistics of Anti-Submarine Operations February, 1943," 3; EAC ORS, "Statistics of Anti-Submarine Operations July, 1943," 5.
52. Annis interview by Kealy, 10 September 1979, 5. 10 (BR) Squadron's shortage of pilots facilitated Annis' role in the first EAC attack on a U-boat on 25 October 1941.
53. EAC ORS, "Statistics of Anti-Submarine Operations May, 1943," 1.
54. EAC ORS, "Statistics of Anti-Submarine Operations June, 1943," 1.
55. Ibid.
56. EAC ORS, "Statistics of Anti-Submarine Operations May, 1943," 5; EAC ORS, "Statistics of Anti-Submarine Operations June, 1943," 4.
57. EAC ORS, "Statistics of Anti-Submarine Operations July, 1943," 1.
58. Ibid.
59. EAC ORS, "Statistics of Anti-Submarine Operations February, 1943," 3; EAC ORS, "Statistics of Anti-Submarine Operations March, 1943," 3; EAC ORS, "Statistics of Anti-Submarine Operations April, 1943," 4.
60. EAC ORS, "Statistics of Anti-Submarine Operations April, 1943," 1.

61. EAC ORS, "Statistics of Anti-Submarine Operations March, 1943," 1.
62. Kostenuk and Griffin, 31, 46, 50, 68.
63. EAC ORS, "Statistics of Anti-Submarine Operations March, 1943," 1.
64. Vincent with Oughton and Vincent, 29, 31.
65. Waddington, 55.
66. Ibid.
67. See EAC ORS, "Statistics of Anti-Submarine Operations" for February-July 1943 for examples of the changes to the display of operational flying information.
68. EAC ORS, "Statistics of Anti-Submarine Operations February, 1943," 1; EAC ORS, "Statistics of Anti-Submarine Operations June, 1943," 1; EAC ORS, "Statistics of Anti-Submarine Operations July, 1943," 1.
69. EAC ORS, "Statistics of Anti-Submarine Operations July, 1943," 7-8. The averages noted are of course rough. VLR Liberators not only generally flew the longest missions in terms of time but also in terms of distance flown.
70. EAC ORS, "Statistics of Anti-Submarine Operations February, 1943," 1.
71. EAC ORS, "Statistics of Anti-Submarine Operations April, 1943," 1.
72. EAC ORS, "Statistics of Anti-Submarine Operations July, 1943." 1.
73. EAC ORS, "Statistics of Anti-Submarine Operations February, 1943," 1.
74. EAC ORS, "Statistics of Anti-Submarine Operations March, 1943," 2. These are listed as 'D.D.S.D. (Y)' signals which were forerunners of the RCN's 'Otter', the British Admiralty's 'Stupple' and Coastal Command's 'Tubular' daily U-boat density signals (See Douglas, 556 for additional information).

75. EAC ORS, "Statistics of Anti-Submarine Operations February, 1943," 1; EAC ORS, "Statistics of Anti-Submarine Operations March, 1943," 2.
76. EAC ORS, "Statistics of Anti-Submarine Operations February, 1943," 1.
77. Kostenuk and Griffin, 26, 31; EAC ORS, "Statistics of Anti-Submarine Operations March, 1943," 2.
78. EAC ORS, "Statistics of Anti-Submarine Operations April, 1943," 1-2.
79. Ibid., 2.
80. Ibid.
81. EAC ORS, "Statistics of Anti-Submarine Operations May, 1943," 2.
82. Robert L. Baglow and J.D.F. Kealy, "A Statistical Analysis of the Performance of RCAF Maritime Aircraft Dec42- Nov43" (Canada: National Defence Headquarters Directorate of History, 1980, DHH 80/151): 5, 7; EAC ORS, "Statistics of Anti-Submarine Operations June, 1943," 1-2; EAC ORS, "Statistics of Anti-Submarine Operations July, 1943," 2.
83. EAC ORS, "Statistics of Anti-Submarine Operations February, 1943," 2.
84. Ibid.
85. EAC ORS, "Statistics of Anti-Submarine Operations April, 1943," 2.
86. EAC ORS, "Statistics of Anti-Submarine Operations February, 1943," 2; EAC ORS, "Statistics of Anti-Submarine Operations March, 1943," 2; EAC ORS, "Statistics of Anti-Submarine Operations April, 1943," 2.
87. EAC ORS, "Statistics of Anti-Submarine Operations February, 1943," 2.
88. EAC ORS, "Statistics of Anti-Submarine Operations March, 1943," 2; EAC ORS, "Statistics of Anti-Submarine Operations April, 1943," 2.

89. EAC ORS, "Statistics of Anti-Submarine Operations May, 1943," 3.
90. Ibid.
91. Ibid.
92. Ibid., 4.
93. Ibid.
94. EAC ORS, "Statistics of Anti-Submarine Operations June, 1943," 2; EAC ORS, "Statistics of Anti-Submarine Operations July, 1943," 3.
95. EAC ORS, "Statistics of Anti-Submarine Operations June, 1943," 3; EAC ORS, "Statistics of Anti-Submarine Operations July, 1943," 3.

Conclusions

1. McLean, 24-25.
2. Douglas, 394.
3. Ibid., 395.
4. Ibid.
5. Ibid., 560-561.
6. Squadron Leader Peter M. Millman, "Appendix A- List of Personnel Engaged in Operational Research in the RCAF During World War II." In "Operational Research in the RCAF During World War II," [1947] compiled by Squadron Leader Peter M. Millman, DHH 77/510: 1-2.
7. Ibid.; Royal Canadian Air Force Headquarters Operational Research Centre, "Operational Research Personnel- RCAF," 18 April 1945, DHH 181.003 (D4033): 1. A search of the 1949-1951 edition of The Canadian Who's Who (the first complete postwar

edition) yielded only two entries for civilian researchers connected with Eastern Air Command ORS. Professor J.O. Wilhelm, after departing the RCAF Headquarters Operational Research Centre, served first as Assistant Director, General Research and Development Branch of the Dominion Department of Reconstruction during 1944-1945. By 1951, he had been named Director of the Research Council of Ontario while retaining his position as Special Lecturer in the Department of Physics, University of Toronto (The Canadian Who's Who, vol. V, 1949-1951 (Toronto: Trans-Canada Press, 1951): 1055). Dr. J.W.T. Spinks, returned on a part time basis to the University of Saskatchewan in November 1944 while also serving on the Canadian Atomic Bomb Project. By 1951, he had become Dean of the Graduate School at the University of Saskatchewan (The Canadian Who's Who, vol. V, 945).

8. Douglas, 398-399.

9. Morton, 3-4; Squadron Leader Peter M. Millman, "Introduction," in "Operational Research in the RCAF During World War II," [1947] compiled by Squadron Leader Peter M. Millman, DHH 77/510: 3.

10. Millman, "Introduction," 3.

11. Ibid.

12. Kostenuk and Griffin, 144-145.

13. Lindsey, "Canadian Wartime Operational Research," 210.

14. See Millman, "Appendix A," for details regarding the allocation of operational researchers to both the various RCAF home and British overseas operational research sections.

Bibliography

I. Primary Sources

A) Directorate of History and Heritage (DHH), National Defence Headquarters, Ottawa

1. Letters and Memoranda

Anderson, Air Vice Marshal N.R., Air Member for Air Staff, to Air Officers Command, Western Air Command, Eastern Air Command, 8 September 1942. DHH 181.002 (D484).

Anderson, Air Vice Marshal N.R., Air Member for Air Staff, to Air Marshal L.S.

Breadner, Chief of Air Staff, "Operational Research Organization- R.C.A.F.," 12 June 1942. DHH 181.002 (D484).

Barnes, Professor Colin, Head, Eastern Air Command Operational Research Section to Air Vice Marshal G.O. Johnson, Air Officer Commanding-in-Chief Eastern Air Command, "Problems under Investigation by the ORS/EAC," 2 July 1943. DHH 181.022 (D484).

Barnes, Professor Colin, Head, Eastern Air Command Operational Research Section to Air Vice Marshal G.O. Johnson, Air Officer Commanding-in-Chief Eastern Air Command, "Status of Operational Research Personnel," 31 August 1943. DHH 181.002 (D484).

Ross, Group Captain A.D. (for Air Vice-Marshal A.A.L. Cuffe, Air Officer Commanding Eastern Air Command) to The Secretary, Department of National Defence for Air, "Analysis of Anti-Submarine Air Effort of Eastern Air Command, R.C.A.F., February, 1942," 2 April 1942. DHH 181.009 (D1147).

**Wigle, Wing Commander D.H., Canadian Joint Staff Washington to The Secretary,
Department of National Defence for Air, "Search Radar Versus Schnorkel," 27
June 1945. DHH 77/541.**

2. Interviews and Biographical Material

Annis, Air Marshal C.L. Biographical File. DHH (Bio A).

_____. **"Interview with Air Marshal C.L. Annis covering his experiences in EAC and
as Director of A/S operations during WW II." Interview by J.D.F. Kealy, 10
September 1979, DHH Annis Biographical File (Bio A).**

3. Reports and Studies

**Annis, Wing Commander C.L. "Submarine Warfare, World War II." 29 January 1943.
DHH 181.003 (D309).**

**Coastal Command Operational Research Section, Royal Air Force. "Notes on U/B hunts"
[prepared by Whitehead (?)]. September 1941. Photocopy of original Air Ministry
file. DHH AIR 23/4799.**

**Eastern Air Command, Royal Canadian Air Force. "RCAF a/c attacks on U-Boats re:
Attack by Canso A 9747 of 5 Sqn 4 May 43, U630 sunk." DHH 181.003 (D1341).**
_____. **"RCAF a/c attacks on U-Boats re: Attack by Digby 747 of 10 Sqn 30 Oct 42,
U520 sunk." DHH 181.003 (D1329).**
_____. **"RCAF a/c attacks on U-Boats re: Attack by Hudson 784 of 145 Sqn 30 Oct
42, U658 sunk." DHH 181.003 (D1328).**

- _____. "RCAF a/c attacks on U-Boats re: Attack by Liberator "A" of 10 Sqn 19 Sep 43, U341 sunk." DHH 181.003 (D1349).
- _____. "RCAF a/c attacks on U-Boats re: Attacks by Liberator "A" of 10 Sqn 26 Oct 43, U420 sunk." DHH 181.003 (D1354).
- Eastern Air Command Operational Research Section, Royal Canadian Air Force. "An Analysis of the 'Scouting Effectiveness' of Some Current A/S Patrols (with special reference to Schnorkel and Type XXI Tactics)." ORS Report No. 18, 7 May 1945. DHH 181.002 (D379).
- _____. "Attacks on Submarines Relation of Tactics to Bombing Accuracy." ORS Report No. 1, 8 May 1943. DHH 181.002 (D379).
- _____. "A Review of Searches for Missing Aircraft, Eastern Air Command 1 January, 1944-1 June, 1945." ORS Report No. 20, August 1945[?]. DHH 181.009 (D4995).
- _____. "Searches For Missing Aircraft (Revision of ORS/EAC Report No. 13, Air-Sea Rescue Procedure)." ORS Report No. 15, September 1944. DHH 181.009 (D4995).
- _____. "Statistics of Anti-Submarine Operations April, 1943." DHH 181.002 (D379).
- _____. "Statistics of Anti-Submarine Operations February, 1943." DHH 181.003 (D233).
- _____. "Statistics of Anti-Submarine Operations March, 1943." DHH 181.002 (D379).
- _____. "Statistics of Anti-Submarine Operations May, 1943." DHH 181.002 (D379).
- _____. "Statistics of Anti-Submarine Operations July, 1943." DHH 181.003 (D251).

- _____. "Statistics of Anti-Submarine Operations June, 1943." DHH 181.003 (D41).
- _____. "Summary of Aircraft Attacks on U-Boats Eastern Air Command 1 October, 1941- 1 June, 1945." ORS Report No. 19, 10 June 1945. DHH 181.002 (D379).
- Heaman, Squadron Leader J.D., Deputy Director, Armament Directorate Royal Canadian Air Force Headquarters. "Methods of Submarine Attack- Operation Order D/56/42." 16 October 1942. DHH 77/541.
- Millman, Squadron Leader Peter M. "Introduction." In "Operational Research in the RCAF During World War II," compiled by Squadron Leader Peter M. Millman, 1947, 2-3. DHH 77/510.
- _____. "Appendix A- List of Personnel Engaged in Operational Research in the RCAF During World War II." In "Operational Research in the RCAF During World War II," compiled by Squadron Leader Peter M. Millman, 1947, Appendix pages 1-2. DHH 77/510.
- Morton, Dr. N.W. "Brief History of the Development of Canadian Military Operational Research." 1955[?]. DHH 85/565.
- Royal Canadian Air Force Headquarters Operational Research Centre. "Operational Research Personnel-RCAF." 18 April 1945. DHH 181.003 (D4033).
- Spinks, Dr. J.W.T. "Searches for Missing Aircraft." In "Operational Research in the RCAF During World War II," compiled by Squadron Leader Peter M. Millman, 1947, 17-19. DHH 77/510
- Wilhelm, Dr. J.O., Head, Royal Canadian Air Force Headquarters Operational Research Centre. "Appendix B-- Typical Operational Research Problems." In "Operational

Research in the RCAF During World War II,” compiled by Squadron Leader Peter M. Millman, 1947, Appendix pages 1-6. DHH 77/510.

_____. **“Operational Research in the RCAF Preliminary Outline.” In “Operational Research in the RCAF During World War II,” compiled by Squadron Leader Peter M. Millman, 1947, 4-10. DHH 77/510.**

_____. **“Operational Research Progress Report Activities Up To Aug. 31st, 1943.” 20 August 1943. DHH 181.003 (D4033).**

B) National Archives of Canada (NAC), Ottawa

1. Letters and Memoranda

Guthrie. Air Commodore K.M. (for Air Marshal R. Leckie, Chief of the Air Staff) Royal Canadian Air Force Headquarters to Air Vice-Marshal G.O. Johnson, Air Officer Commanding-in-Chief Eastern Air Command, 3 February 1944. NAC RG24, vol. 5270, file 28-3-1.

Leckie, Air Vice-Marshal R. (for Air Marshal L.S. Breadner, Chief of the Air Staff) Royal Canadian Air Force Headquarters to Admiral Percy Nelles, Chief of the Naval Staff Naval Service Headquarters, 27 April 1943. NAC RG24, vol. 5233, file 19-17-4, vol. 1.

Morton, Flight Lieutenant J.M., Eastern Air Command Operational Research Section to Professor J.O. Wilhelm, Royal Canadian Air Force Headquarters Operational Research Centre, 6 November 1944. NAC RG24, vol. 5233, file 19-17-4, vol. 2.

2. Reports and Studies

Common, Flying Officer E.C., Intelligence Officer, RCAF Station Gander. "Some Further Observations On The Statistical Summary Of Attacks On U-Boats By EAC Aircraft Obtained In EAC Monthly Anti-Submarine Report For September 1942, Pages 4 and 5." 16 January 1943. NAC RG24, vol. 5270, file 28-3-2.

Eastern Air Command Operational Research Section, Royal Canadian Air Force.

"Comments on Anti-Submarine Effort, 1941-42, E.A.C." 15 March 1943. NAC RG24, vol. 5270, file 28-3-2.

Gibbs, Wing Commander, Royal Air Force. "Report on Visit to E.A.C., Halifax and R.C.A.F. Station, Dartmouth, 27-30 September 1942." No date [October 1942?]. NAC RG24, vol. 5233, file 19-17-4 vol. 1.

Pearman, J.P.T., Royal Air Force Coastal Command Headquarters Operational Research Section. "Summary of Anti-Submarine Air Effort of Eastern Air Command, Halifax, N.S., February 1942." 29 March 1942. NAC RG24, vol. 5270, file 28-3-2.

Royal Canadian Air Force Operational Research Centre. "Operational Research Centre: A Report for the period January 1st- June 30th, 1943." 13 July 1943. NAC RG24, vol. 5234, file 19-17-6, vol. 1.

Wilhelm, Professor J.O., Head, Royal Canadian Air Force Headquarters Operational Research Centre. "Submarine Hunts to Exhaustion." 11 May 1943. NAC RG24, vol. 5233, file 19-17-4, vol. 1.

C) Printed Primary Sources

Air Ministry. The Origins and Development of Operational Research in the Royal Air Force. London: Her Majesty's Stationery Office, 1963.

Blackett, Professor P.M.S. "Scientists at the Operational Level." In The Origins and Development of Operational Research in the Royal Air Force, ed. Air Ministry, 189-193. London: Her Majesty's Stationery Office, 1963.

The Canadian Who's Who. Vol. V, 1949-1951. Toronto: Trans-Canada Press, 1951.

Waddington, Professor C.H. O.R. In World War 2: Operational Research Against the U-boat. Unpublished manuscript, 1946; London: Elek Science, 1973.

II. Secondary Sources

A) Articles

Annis, Air Marshal C.L. "Eastern Air Command, Recalled." In I'll Never Forget... Canadian Aviation in the Second World War, ed. Les Wilkinson, 60-66. Ottawa[?]: Canadian Aviation Historical Society, 1979.

Buckley, John. "Atlantic Airpower Co-operation, 1941-1943." The Journal of Strategic Studies 18, 1 (March 1995): 175-197.

McCloskey, Joseph F. "The Beginnings of Operations Research: 1934-1941." Operations Research 35, 1 (January-February 1987): 143-152.

_____. "British Operational Research in World War II." Operations Research 35, 3 (May-June 1987): 453-470.

McLean, Douglas M. "Confronting Technological and Tactical Change: Allied

Anti-Submarine Warfare in the Last Year of the Battle of the Atlantic." Canadian Military History 7, 3 (Summer 1998): 23-34.

Vincent, Carl. "North Atlantic Squadron: Story of 10 (Bomber Reconnaissance)

Squadron, RCAF." Photocopy of Air Extra, 8: 10-17. Directorate of History and Heritage, National Defence Headquarters, Ottawa, DHH RS7 10.

B) Unpublished Manuscripts

Baglow, Robert L. "An Examination of A/S Operations off the East Coast of Canada

Feb-Oct. 1942," 1979. Directorate of History and Heritage, National Defence Headquarters, Ottawa, DHH 79/649.

_____ and J.D.F. Kealy. "A Statistical Analysis of the Performance of RCAF

Maritime Aircraft Dec42-Nov43," 1980. Directorate of History and Heritage, National Defence Headquarters, Ottawa, DHH 80/151.

Directorate of History and Heritage, National Defence Headquarters. "Defence Research

Board Collection: Anti-Submarine Warfare Operational Research," finding aid 96/51, 25 November 1996.

Hitchens, F.H. "The Story of No. 10 (BR) Squadron: 'The North Atlantic Squadron'," no

date. Directorate of History and Heritage, National Defence Headquarters, Ottawa, DHH RS7 10.

Neufeld, Michael J. "Search the Sea: An Illustrated Short History of the Long Range

Patrol Aircraft in the Canadian Armed Forces," August 1974. Department of Supply and Service, Ottawa. Directorate of History and Heritage, National Defence Headquarters, Ottawa, DHH 73/1456.

C) Books

Bowyer, Chaz. The Concise Encyclopedia of British Military Aircraft. London: Bison Books, 1982.

Cohen, Eliot A. and John Gooch. Military Misfortunes: The Anatomy of Failure in War. New York: Vintage Books, 1991.

Collier, Basil. The Defence of the United Kingdom. London: Her Majesty's Stationery Office, 1957.

Copp, Terry. "Editor's Introduction." In Montgomery's Scientists: Operational Research in Northwest Europe- The Work of No. 2 Operational Research Section with 21 Army Group June 1944 to July 1945, ed. Terry Copp, 6-30. Waterloo, Ontario: Laurier Centre for Military Strategic and Disarmament Studies: 2000.

Eggleston, Wilfrid. Scientists at War. London and Toronto: Oxford University Press, 1950.

Hillmer, Norman ed. The Official History of the Royal Canadian Air Force, vol. 2, The Creation of a National Air Force, by W.A.B. Douglas. Toronto: University of Toronto Press: 1986.

Kostenuk, Samuel and John Griffin. RCAF Squadron Histories and Aircraft, 1924-1968. Toronto: Samuel Stevens Hakkert & Company, 1977.

Lindsey, George R. "Canadian Wartime Operational Research." In No Day Long Enough: Canadian Science in World War II, ed. George R. Lindsey, 207-210. Toronto: Canadian Institute of Strategic Studies, 1997.

- _____ and G.L. Nelms. "Introduction." In No Day Long Enough: Canadian Science in World War II, ed. George R. Lindsey, 1-9. Toronto: Canadian Institute of Strategic Studies, 1997.
- Lovell, Sir Bernard. P.M.S. Blackett: A biographical memoir. London: The Royal Society, 1976.
- Milner, Marc. The U-Boat Hunters: The Royal Canadian Navy and the Offensive against Germany's Submarines. Toronto: University of Toronto Press, 1994.
- Price, Alfred. Aircraft versus Submarine: The evolution of the anti-submarine aircraft, 1912-1980, revised edition. London: Jane's Publishing Company Limited, 1980.
- Roberts, Leslie. There Shall Be Wings: A History of the Royal Canadian Air Force. Toronto: Clarke, Irwin & Company Limited, 1959.
- Shores, Christopher. History of the Royal Canadian Air Force. Greenwich, Connecticut: Bison Books Corp., 1984.
- Spooner, Tony. Coastal Ace: The biography of Squadron Leader Terence Malcolm Bulloch, DSO and Bar, DFC and Bar. London: William Kimber, 1986.
- Terraine, John. The Right of the Line: The Royal Air Force in the European War 1939-1945. London: Hodder and Stoughton, 1985.
- Vincent, C.R. with J.D. Oughton and E. Vincent. Consolidated Liberator & Boeing Fortress, Canada's Wings vol. 2. Stittsville, Ontario: Canada's Wings, 1975.
- Wise, S.F. The Official History of the Royal Canadian Air Force, vol. 1, Canadian Airmen and the First World War. Toronto: University of Toronto Press, 1980.