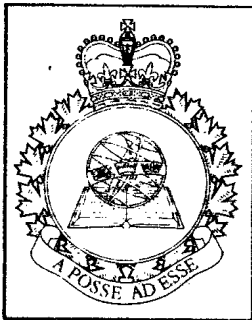


**THE ORIGINS and DEVELOPMENT
of
OPERATIONAL RESEARCH
in
CANADA**

by
J. W. MAYNE



ORAE REPORT NO. R83



**OPERATIONAL RESEARCH AND ANALYSIS ESTABLISHMENT
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OTTAWA, CANADA

DECEMBER 1980

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This report does not necessarily represent the views
of the Canadian Department of National Defence.

PREPARED WITH THE SUPPORT OF THE
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OTTAWA, Canada

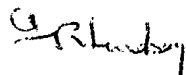
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F O R E W O R D

Initiated in the late 1930s by a small group of comparatively young men in Britain, and soon followed up in the wartime United States, it is still possible to meet most of the pioneers of operational research. The history of operational research in Canada is even more recent, commencing with military OR in the 1940s, for which good records are available. Application in industry and in government departments other than defence began in the 1950s, rather gradually, followed by recognition in university programs and by formation of a Canadian Operational Research Society.

John Mayne has been able to establish personal contact with most of the people responsible for the origins and development of operational research in Canada, and his own long association with the Department of National Defence has given him a close knowledge of the activities which represented the major application of OR in Canada in the earlier years.

This account is a timely one. Twenty years ago it would not have been possible to say much about OR in Canada outside of the application to national defence. Twenty years hence it will no longer be possible to communicate with many of the pioneers.



G. R. Lindsey
Ottawa
1981

A B S T R A C T

This history of operational research in Canada presents an account of its origins and development in the military and non-military areas. It includes some details about the origin and growth of operational research in World War II but is concerned mainly with its beginning and evolution in the several fields of application in Canada. An account is given of the introduction and growth of military operational research in Canada since World War II and of how and when OR was started in federal and provincial government departments, ministries, and agencies, in civic and municipal governments, and in business, commerce, and industry, and research centres. Included also is a description of the development of courses of instruction in operational research in Canadian universities and institutions of learning and some information about the Canadian Operational Research Society. An attempt is made to assess the impact of OR on decision making in Canada, in a qualitative sense. Some comments are offered on future developments and prospects and a few relevant topics are considered in a section on discussion and remarks. Much of the data concerning personnel and types of OR studies undertaken are summarized in tables and charts. A short summary is also included in a final chapter.

RESUME

Cette histoire de la recherche opérationnelle au Canada rend compte de ses origines, et de son développement dans les domaines militaires et civils. On y présente quelques détails concernant l'origine et la naissance de la recherche opérationnelle pendant la deuxième guerre mondiale, mais on y discute surtout du début et de l'évolution de plusieurs champs d'application au Canada. On y trouve l'histoire de l'apparition et du progrès de la recherche opérationnelle militaire canadienne depuis la deuxième guerre, et de ses débuts dans les bureaux gouvernementaux fédéraux, provinciaux et municipaux, dans les organisations commerciales, industrielles, et dans les centres de recherche. Ce document offre d'un part une description du développement des cours d'enseignement de la recherche opérationnelle dans les universités canadiennes, et d'autre part des informations concernant la Société pour la R.O. canadienne. On essaie d'évaluer d'une manière qualitative l'influence de la R.O. sur la prise des décisions au Canada. On fournit des commentaires sur les développements futurs, et on considère quelques autres sujets dans un chapitre d'observations générales. Un sommaire de la plupart des données sur les individus, et des genres d'études en R.O. est présenté sous forme de graphiques. Un dernier chapitre résume brièvement l'ensemble du travail.

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Many others, managers and operational research scientists, in the agencies mentioned, kindly replied to written questions, participated in seminars and discussions, or in personal interviews, thereby providing much relevant material that was used in preparing this report.

Most of those who have assisted in one way or another are named in the text in some relevant connection and are not specifically mentioned in this acknowledgement. However, I am grateful to all those who have contributed in any way by providing me with pertinent information.

To each and all of them I extend my sincerest thanks and appreciation. I also wish to express my gratitude to the Social Sciences and Humanities Research Council of Canada for the financial support received in preparing this report.

P R E F A C E

The purpose of this report is to provide as complete an account of the origins and development of operational research in Canada as is at present conveniently practicable. Regrettably, this purpose has not been achieved to the extent originally hoped as relevant information from some possible sources was not forthcoming. On the other hand, not all details of the information obtained during the course of compiling this history has been used, mainly for reasons of brevity.

The original intention was to cover the period from the first use of operational research under that name, in Canada, in 1942 to about 1967, the first quarter century. However, in responding to questions and particularly questionnaires, much relevant material was received relating to the introduction and use of operational research up to 1979-1980. Accordingly, the period covered by this report is actually from 1942 to 1980, almost forty years.

Since the coverage of the use of operational research is not complete, particularly in the case of business and industry, the author would welcome any information that would extend the coverage given herein, and especially any relating to the early period, e.g. 1945-1970. Although almost all federal and provincial government departments, ministries, and agencies, and universities and institutions of higher learning have provided data for this record, there are still some that have not been asked to do so. Relevant information about any of these would also be appreciated as would notification of errors of any kind. Errors and omissions are, of course, the sole responsibility of the author.

Many outstanding examples of the impact of operational research on operations, procedures, and decision making in Canada exist and are known to many of those mentioned in the text. And many have been reported to the author during discussions and interviews. These have not been included herein as this treatise is historical in nature and only a qualitative assessment of such impact is offered. A quantitative treatment of this important aspect of the contribution of operational research to all sectors of the Canadian scene where it has been applied must await a more comprehensive study.

CHAPTER I

I N T R O D U C T I O N

GENERAL

Although operational research was introduced into Canada less than forty years ago, some details of its origins and early development in Canada are already difficult, if not, almost impossible, to ascertain. The purpose of this report is to record as complete an account of these origins and early developments in all relevant areas of activity in Canada as is presently conveniently practical.

METHODS USED IN OBTAINING INFORMATION

The sources of information used in preparing this record were questionnaires, available written material and reports, and interviews and discussions with users, practitioners, and teachers of operational research in Canada. Details of questionnaires and other data sources are described in appropriate sections in the sequel and copies of the questionnaires and covering letters are included as Appendix A.

In obtaining data on the origins and use of operational research (OR), the twin difficulties of definitions and the use of methodologies associated with OR by scientists and engineers who are not organized as OR units or call themselves OR workers confuse attempts to determine origins and applications. While the main concern in this report has been

with individuals, teams, or units specifically engaged and organized to do OR under that name, consideration has also been given to persons and units applying the techniques normally used by OR scientists but not organized as OR units or designated primarily OR workers.

THE ORIGIN OF OPERATIONAL RESEARCH

The term 'operational research' originated in the United Kingdom (UK) during the Second World War (WWII) and the actual study of military operations by scientists and their entrance into the area of military tactics did not really occur until just before the beginning of WWII. However, throughout history there has been some useful exchange of ideas between scientists and military men (Ref 1). For example, Archimedes designed and made catapults for the citizens of Syracuse to resist besieging Romans, and da Vinci produced designs of a wide variety of revolutionary weapons of war.

Since its origin many definitions of OR have been given. One offered in Ref 1 is "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". Another is "a scientific method of providing executive departments with a quantitative basis for decisions regarding the operations under their control" (Ref 2). Others are "quantitative common sense" and "a method of providing bad answers to operational problems to which otherwise worse answers would be given".

With such definitions it is also clear that many activities in various areas conducted prior to the advent of OR as such were properly OR or OR-type work. Examples are

job analysis studies performed by various investigators for many years and the development and application of Lanchester's Equations in the early 1900's. Some claim that Archimedes was the original operational research scientist and justify this claim by citing the work done by him for King Hieron at the siege of Syracuse early in the third century B.C. Many aspects of time and motion studies, traffic analysis, and systems engineering, which have been done for many years contain elements of what is now referred to as operational research.

There is some difference of opinion regarding the actual introduction of the term 'operational research'. The excellent history of the origins and development of OR in the Royal Air Force (RAF) published by Her Majesty's Stationery Office (Ref 1), states that it was at the time of the 1938 air exercises that the term 'operational research', which apparently originated with Mr A.P. Rowe, Superintendent of the Bawdsey Research Station*, was first used to describe the work being done at Bawdsey by a small team under E.C. Williams. They were concerned with the process of plotting, filtering, and telling aircraft track information provided by the recently introduced chain of radar stations.

A team of scientists under Mr Williams moved to Stanmore, Headquarters Fighter Command, for the summer air exercises of 1939. The team performed such useful services

* An Air Ministry Experimental Research Station at Bawdsey Manor near Felixstowe, Suffolk doing research work and acting as headquarters for a chain of radar stations. It has been called the birthplace of OR (Ref 1).

that the Air Officer Commanding-in-Chief (Air Chief Marshal Sir Hugh Dowding) requested that a section be stationed at Stanmore permanently. A second team of scientists under Mr G.A. Roberts was released from Bawdsey and became known as the Operational System Research Section. They were concerned with observing and recording the activities of air controllers dealing with the information provided by the radar chain and analysing the data so obtained (Ref 1).

The arrangement for the scientists of the two teams to be based at Stanmore became effective on the first day of WWII, (Ref 1), September 3, 1939. Mr Harold Larnder, who had participated in the early development of radar, and was working at Bawdsey was appointed to lead the combined team, other members of which were G.A. Roberts, E.C. Williams, and I.H. Cole. He soon named the unit the Stanmore Research Section and it became agreed and accepted that what they were doing should be called operational research. It should be noted that this Section was set up specifically to undertake the study and investigation of the operational aspects of the Fighter Command systems rather than the technical aspects.

It was not long before OR teams were organized at other RAF Commands, (Bomber Command, Coastal Command, Tactical Air Force Command, Transport, and Flying Training Command), and at Anti-Aircraft Command Headquarters (HQ) in the UK. The latter was concerned with problems arising from the operational performance of the anti-aircraft (AA) guns and with the operation and coordination of radar equipment at the gun sites. A little later the British Army set up the Army Operational Research Group (AORG) and, at about the same time, the UK Admiralty began employing scientists in the study of problems

in anti-submarine warfare (ASW). Other OR work on civil defence and bomb damage studies was done in the same time period by the UK Ministry of Home Defence.

In January 1944 a Deputy Directorate of Science (DD Science) was formed in the UK Air Ministry, replacing an Operational Research Centre formed in October 1941 under Wing Commander (W/C) A.C. Menzies. The work of the former Centre continued and Menzies, by now Group Captain (G/C), was appointed the first Deputy Director DD Science. As noted later a Canadian OR scientist subsequently was attached to DD Science.

The AORG developed from the Operational Research Group of the Air Defence Research and Development Establishment which had been set up in May 1941 and was controlled jointly by the Ministry of Supply and the War Office (Ref 1). This group in turn, had emerged from an earlier team of scientists known as the Anti-Aircraft Command Research Group, and familiarly referred to as 'Blackett's Circus' in honour of its founder Professor P.M.S. Blackett who had earlier been appointed by General Sir Frederick Pile, General Officer Commanding-in-Chief, Anti-Aircraft Command, as his scientific adviser. This team of scientists had been assembled to study the problems involved in controlling and directing the fire of AA guns at unseen aircraft. They spent much time on AA gun sites during the night raids on London (Ref 1). It is interesting to note that OR in the British Army was started because AA gunnery was an Army assignment, although Anti-Aircraft Command was under the operational control of HQ Fighter Command.

The Operational Research Group of the Air Defence Research and Development Establishment was originally (May 1941) headed by Dr Ratcliffe and directly responsible to the Ministry of Supply. Shortly afterward Dr B.F.J. (afterwards Sir Basil) Schonland, a South African physicist, became superintendent of the Group. By May 1942 the Operational Research Group which had originated out of applying scientific methodology to the study of anti-aircraft defences began to study military operations, and became concerned mainly with the improvement of new weapons and equipment (Ref 1).

In February 1943 this Operational Research Group severed its connections with the Air Defence Research and Development Establishment and became known as the AORG. It soon expanded into eight sections dealing with AA defence, new radar equipment, signals equipment and performance, field and anti-tank (ATk) gunnery, army air operations, infantry operations, weapon lethality, and land mines, obstacles and special weapons. During 1942 and 1943 OR sections were set up by the War Office in 21 Army Group, the Middle East, Italy, and India for "the collation and critical analysis of facts and quantitative data on military problems" (Ref 1). Relationships between these OR units and Canadian OR personnel are described later.

In the summer of 1942 Dr O.M. Solandt, a graduate of the University of Toronto in both science and medicine, who had been Director of the British Medical Research Council Laboratories Experimental Station at Lulworth, was appointed Deputy Director of the AORG, and in May 1944 he became Director. He was particularly interested in guns and tanks but ably represented his organization and directed it

effectively in the study of a wide range of Army problems and types of armaments. In early 1945 he was selected to join Lord Louis Mountbatten's South East Asia Command staff as his special scientific adviser (Ref 3).

In the meantime Professor Blackett, who had become head of the Operational Research Section (ORS) in RAF Coastal Command following his appointment as personal scientific advisor to the Air Officer Commanding (AOC) Coastal Command in March 1941, was, in January 1942, appointed Director of Naval Operational Research at the Admiralty. However, the actual naval OR unit did not form until a short time afterwards (Ref 1).

As was the case with the other Services the Royal Navy (RN) had previously employed some scientists to carry out research into new weapons and techniques such as wireless telephony and ASW. But with the formation of the new group of scientists under Professor Blackett, advice and analysis were provided on strategical and tactical problems. The OR unit was concerned mainly with the U-Boat threat and ASW, but it was also involved in problems of gunnery, mining, radar, and radio, etc.

The RN operational research organization was concentrated in the Admiralty in London, and in contrast to OR services in the RAF and Army, naval research sections were not permanently attached to operational commands. However, as occasion required, OR observers were sent to naval commands, duty aboard ships, or units overseas on temporary duty.

The preceding paragraphs provide a brief description of the origin of OR as a recognized and organized applied scientific activity in the UK in the early days of WWII. As a result of these military applications, OR was soon introduced into the Canadian Armed Forces so that its Canadian origin was also with the Armed Services. Before discussing the development of military OR in Canada a short description of the growth of military OR during WWII may be appropriate.

DEVELOPMENT OF MILITARY OPERATIONAL RESEARCH

By 1943 the UK OR organization had spread overseas to the various theatres of war in Europe, North Africa, and the Far East. Also, in the UK itself OR extended into the fields of administration and planning and was employed, amongst others, by Prime Minister Churchill's personal scientific advisor, Lord Cherwell, and by Professor Solly Zuckerman, scientific advisor to Lord Louis Mountbatten on Combined Operations and to the Allied Expeditionary Air Force and Supreme Headquarters, Allied Expeditionary Force in WWII.

Benefiting from the example and success of the British OR services, OR sections were soon formed in the Armed Forces of the Dominions, including Canada. Similarly, OR units were organized by the American Services. The US Navy (USN) and US Army Air Forces (USAAF), in particular, early developed OR services stimulated by the UK OR organization. In 1942 the USN set up an OR group to study U-Boat problems. This first United States OR group was formed under Dr Ellis Johnson in the Naval Ordnance Laboratory (Ref 4). It was organized before any of the USAAF Analysis Sections or the Anti-Submarine Warfare Operations Research Group under Dr Phillip M. Morse came into being.

In October of the same year, OR, under the guidance of the ORS at Bomber Command, began in the US Eighth Bomber Command based in Great Britain (Ref 5). This command was subsequently designated the Eighth Air Force; it was the American strategic bomber force. In the USA the activity became known as 'operations research', a nomenclature which has persisted in that country. The US Army followed suit with the introduction of an OR organization in its ground forces at home and abroad (Ref 5).

Thus by the end of 1943, military OR had been introduced into the Armed Forces of the UK, United States of America (USA), and Canada and into those of India, Australia, and New Zealand as well. Close working relations were maintained between OR Sections in the several Allied Forces. In particular, the arrangements whereby Canadian civilian and military scientists were attached to UK and other Commonwealth OR units, while being mutually advantageous, certainly were of outstanding value in the training of Canadian scientists in OR methodology and in expediting the early and successful introduction of OR into the Canadian Armed Forces. Some details of the co-operation and liaison between OR units in the Allied Forces in WWII appear in the sequel.

With the general background sketched above, it is now possible to outline the introduction, growth and development of OR in the Canadian Armed Forces in WWII. As well, the more important activities and projects of the several OR units and their personnel involved will be discussed. Relevant organizations, terms of reference, and personal contributions will be described, as appropriate,

subject to the availability of relevant information. The order of presentation will be to deal with OR in the Royal Canadian Air Force (RCAF) first, as it was the first Canadian Armed Force to organize OR services, then treat OR in the Royal Canadian Navy, (RCN) and finally OR in the Canadian Army (CA).

DEVELOPMENT OF MILITARY OPERATIONAL RESEARCH IN CANADA

Details on the introduction and development of operational research in the Canadian Armed Forces during WWII are given in Refs 6, 7, 8, 9, 10, and 11. Much of the material in preceding and some of the following sections have been taken from Refs 10 and 11. For the most part OR was introduced into the three Canadian services more or less independently. The stimulation for the innovations came mainly from the sister Services in the UK and to a much lesser extent in the USA.

It was, perhaps, inevitable that information concerning the valuable contributions of this new form of applied science and the high regard in which it was held in the British Armed Forces, particularly the RAF, would soon motivate senior Canadian military officers to enquire into its possible application to Canadian military problems. In making these enquiries and then acting on the information obtained such senior officers as General A.G.L. McNaughton and Colonel W.W. Goforth for the Army, Air Vice Marshals (AVMs) E.W. Stedman and N.R. Anderson of the RCAF, and Captain (later Vice Admiral) H.E. Reid and Commodore (later Vice Admiral) H.G. DeWolf of the RCN demonstrated foresight and an

appreciation of the part that could be played by science in the development of military equipment and weapons, and in devising methods of improving the use of military manpower, resources, and facilities.

In preparing plans for introducing and then implementing OR in the Armed Forces military staff were greatly assisted by the scientific community, universities, and the National Research Council (NRC). Some of the ways in which such collaborative efforts were successfully applied are described briefly in subsequent paragraphs.

In particular the valuable contributions of the NRC and the National Research Laboratories should be noted. The Laboratories had been doing much technical research and development on matters of military concern and application as well as those of academic and industrial interest, pertinence, and utilization. Of special value to the Armed Forces was the work underway in such fields as communications, radio and radar, ballistics, ammunition, and fire control.

When the question of organizing operational research units in support of the military arose, senior scientists of NRC were consulted and they provided substantial assistance in a variety of forms. These included scientific advice, promoting the introduction of OR, undertaking to recruit scientists suitable for OR work or to nominate scientists for recruiting, contributing to committees and discussion groups, and providing NRC scientists to the Services for OR duty as civilian scientists or military officers. For example Dr D.C. Rose became Scientific Advisor to the Chief of the

General Staff and responsible for OR in the Army, Dr G.H. Henderson joined the Naval OR staff at Atlantic Command HQ, and Drs J.W. Hopkins and A.G. Nickle became OR analysts in the RCAF. Further details of NRC contributions appear in the sequel.

When the Defence Research Board (DRB) was set up in 1947 NRC was relieved of its responsibilities for military research. But the NRC continued to be prepared to operate its laboratories on research problems assigned by the military authorities (Ref 9). In particular the staff of the National Research Laboratories continued to collaborate with military OR scientists in several fields, notably in radar, communications, and fire control research and development.

THE ORIGINS OF NON-MILITARY OPERATIONAL RESEARCH IN CANADA

It can be argued that the foregoing account of the origins of OR in the Armed Services constitutes a description of the origins of OR in Canada. While such an argument is certainly valid, the development of OR in other areas and activities did not necessarily derive from the example and stimulation of OR in military applications. Other influences such as readings and conferences frequently provided the stimuli for getting business, industries, and other government departments interested in using OR. Further discussion of this topic appears later in the text.

On the other hand the contributions of military OR to the initiation and diffusion of OR techniques and tools in Canadian business, industry, government, and universities has been impressive and widespread. Many scientists who

practiced OR first in the military sphere left the Department of National Defence to take OR posts in other Federal Departments, business, industry, or on University staffs. The Canadian Operational Research Society was started mainly through the efforts of OR scientists of the Defence Research Board.

Records show that outside the Departments of National Defence the first Canadian activity in OR occurred in industries in Ontario in the early 1950's, then in the universities in the mid-fifties, and in other Federal government departments and Provincial governments in the early to mid-sixties. The descriptions of these beginnings and the development of OR in other areas are given in latter chapters of this report.

Since OR in Canada originated in the Canadian Armed Forces in WWII, an account will first be given of OR in the Department of National Defence (DND) during and after WWII. Then, departing from the chronological order, the origins and development of OR in other Federal departments and agencies and in provincial and municipal governments and agencies will be described. Thereafter an account will be presented of OR in Canadian business and industry followed by the development of OR courses in Canadian universities. Then some comments on the Canadian Operational Research Society will be offered and finally some remarks and a summary will attempt to draw attention to certain interesting facets and relevant observations that have been noted in preparing this account of the early days of OR in Canada.

CHAPTER II

OPERATIONAL RESEARCH IN THE CANADIAN ARMED FORCES DURING WORLD WAR II

INTRODUCTION

It was not long after the introduction of OR in the RAF that information and intelligence concerning its application and usefulness came to the attention of officers of the RCAF. Among the first of these, and the first to do anything constructive about OR in the RCAF, were AVM E.W. Stedman*, Air Member for Research and Development, AVM N.R. Anderson, Air Member for Air Staff (AMAS), and Air Marshal (AM) H. Edwards, Air Officer Commanding, RCAF Overseas.

A brief but comprehensive history of OR in the RCAF during WWII is presented in Ref 10. This document was compiled by Peter M. Millman, Squadron Leader (S/L), RCAF Reserve in 1947 and contains reports by the heads of the several OR sections involved in OR for the RCAF during WWII and by Canadians serving with the RAF and Air Ministry in the UK. Much of the content of this part of the present history is drawn from Refs 8, 10, and 11.

Early in 1942 AVM Stedman brought the work and benefit of OR in the RAF to the attention of the RCAF Air Staff (Refs 8, 10, and 11). From his contacts with the RAF

* AVM E.W. Stedman later (1947) became Air Advisor to the Director General of Defence Research and to the Chairman Defence Research Board.

Coastal Command AVM Anderson was familiar with the OR work there and was anxious to organize OR units to work on RCAF problems in Canada and the UK. In these efforts they were supported by AM H. Edwards and AM L.S. Breadner, Chief of the Air Staff (CAS).

In order to explore the possibility of organizing OR for the RCAF, a meeting was held with Dean C.J. MacKenzie, Acting President of the NRC and representatives from the Air Member Personnel and Air Member Organization Divisions. As a result of this meeting, and subsequent discussions, AVM Anderson made a submission for an establishment to start OR work in the RCAF. The submission noted that NRC would assist in the selection of scientists to complement the establishment and Dean MacKenzie submitted to the AMAS names of scientists who might be approached for recruitment as OR staff.

The submission was approved for action with the understanding that NRC would assist with the selection of staff, and that the AMAS would be responsible for directing the activities of the OR organizations to consist of a central office at Air Force Headquarters (AFHQ), and OR units to work with Eastern Air Command (EAC), and Western Air Command (WAC) in Canada.

Action on organizing the OR services began in August 1942. Dr J.O. Wilhelm, Associate Professor of Physics, at the University of Toronto, was selected to head up the central OR office at AFHQ. He accepted, took charge of the office in September 1942, and remained there until November 1944. He operated under the direction of the AMAS. He also held the appointment of Assistant Director General, Research and Development.

In August 1942 W/C A.C. 'Sandy' Menzies, head of the Operational Research Office at Air Ministry RAF and Major N.B. Leach of the USAAF visited Ottawa to help plan for organizing OR services for the RCAF. This visit represented one of the earliest liaisons between UK, USA, and Canadian OR.

Discussions with these officers at AFHQ resulted in arrangements being made whereby new recruits for OR with the RCAF would visit and serve with OR sections with the RAF for training and practice in the methods and techniques which had been developed in the UK. This agreement turned out to be very beneficial to the development and application of OR in the RCAF, and was a forerunner of similar accommodations provided by the RN and UK Army for Canadian trainees for OR work with the other Armed Forces.

In September 1942, Professor Wilhelm accompanied by Dr Colin Barnes, Associate Professor of Physics, University of Toronto, who had been recruited for OR work with the RCAF, visited the UK to liaise with OR sections there. During the visit the matter of providing Canadian scientists to assist the RAF operational research sections and benefit from on-the-job training was discussed with W/C Menzies and AM Edwards at RCAF Overseas Headquarters.

These deliberations resulted in a formal proposal being made for providing an establishment for OR staff for the RCAF Overseas HQ in addition to the one being set up in Canada. This proposal was for six officers to be attached to RAF OR sections, and two to be attached to the Overseas HQ in London.

The proposal was accepted at AFHQ and the organization was set up to consist of the central office at AFHQ, sections with EAC at Halifax and with WAC at Vancouver, and 8 positions overseas at RCAF Overseas HQ, and OR sections with the RAF. Actually in the UK, Canadian OR scientists were attached to the RCAF Overseas HQ, the DD Science at the UK Air Ministry, RAF Coastal Command, RAF Bomber Command, and with 38 Group of Air Defence of Great Britain.

OPERATIONAL RESEARCH WITH THE RCAF IN CANADA

Introduction

On the acceptance of the proposal for OR services in the RCAF, Professor Wilhelm set about organizing the two OR sections at HQ Eastern Air Command (EACHQ) and HQ Western Air Command (WACHQ). As officer in charge of the Operational Research Centre at AFHQ (AFHQ/OR Centre) his duties involved making all arrangements respecting personnel in the sections at the Commands in Canada and those with OR sections at RAF Commands, RCAF Overseas HQ, and DD Science Air Ministry.

In addition, the Head AFHQ/OR Centre brought to the attention of the Air Staff the activities of the OR units in Canada and UK, and, of course, particularly the findings of OR investigations. Also, he provided scientific advice and assistance to the Air Staff, including the Chiefs of the Air Staff, AMs L.S. Breadner (1940-1943) and R. Leckie (1944-1947) and attended, and contributed to, several senior committees at AFHQ. Although the provision of scientific advice and assistance often involved short term scientific analyses on occasion, no extensive OR projects were undertaken at the AFHQ/OR Centre.

Professor Wilhelm remained in charge of the AFHQ/OR Centre from September 1942 to November 1944. He had built up an effective organization for training OR scientists and for providing OR services to the RCAF in Canada and overseas, and also for assisting the OR sections with the RAF. Through his efforts, and those of the staff he recruited, OR had earned and won extensive genuine credibility with the RCAF by virtue of the many worthwhile findings of their studies.

In December 1944 S/L P.M. Millman succeeded Dr Wilhelm as Head of the AFHQ/OR Centre. He had been with the OR office at HQ RCAF Overseas from September 1943 to November 1944 and continued at the AFHQ/OR Centre until December 1945. Following the cessation of hostilities S/L Millman remained as head of the OR Centre and continued to perform the duties of the post. In addition, he cooperated with other scientists and with RCAF and Army staff officers in planning for military operations in the North. In particular, much attention was given to planning for and arranging to have observations made and data collected on Exercise MUSK OX, the first joint large scale northern exercise by the Canadian Armed Forces.

Operational Research at Eastern Air Command

On his return from the familiarization visit in the UK Dr Colin Barnes reported for duty at EACHQ Halifax in September 1942. It was the first OR field unit set up in Canada. It was called the Eastern Air Command Operational Research Section (ORS/EAC). The first few months there were devoted to setting up methods and procedures for the statistical recording of operational data, observations, and results. However, it was not long until the OR unit was heavily engaged on a variety of operational problems.

In October 1942 to March 1943 the ORS/EAC was strengthened by the addition of Dr J.W. Hopkins of NRC and Dr E.C. Smith. The next scientist to join the staff was Dr J.W. Soper who came to the ORS/EAC in March 1944 following a tour with the RAF Coastal Command ORS since June 1943. Although Dr Barnes was with the Section until August 1944, Dr Hopkins left in December 1943 on attachment to No. 6 RCAF Group, RAF Bomber Command, and although there were other changes, the complement never was more than 3 civilian scientists, or scientists and RCAF officers.

Following Dr Barnes' departure in August 1944, Dr J.W.T. Spinks was put in charge of the ORS/EAC for September 1944. He had been at the Western Air Command Operational Research Section (ORS/WAC) since March 1943. In November 1944 Flight Lieutenant (F/L) J.M. Morton joined the ORS/EAC staff but left in late January 1945 on attachment to the Operational Research Office (ORO) at RCAF Overseas HQ, London, to succeed S/L Millman who had been posted to replace Dr J.O. Wilhelm at the AFHQ/OR Centre. In February 1945 he was replaced at ORS/EAC by F/L W.H. Clarke who remained on staff until the end of the war. In the meantime S/L John Stanley, who had been an Educational Officer with the RCAF, was posted to the Section in December 1944. He had been at the Operational Research Centre, DD Science, Air Ministry, London from October 1943 to November 1944 and remained with the ORS/EAC until June 1945. Thus from December 1944 to June 1945 the complement of the unit was 3 - one civilian Dr Soper, who was the officer in charge, and two RCAF officers (S/L Stanley, F/L Morton, F/L Clarke, the latter replacing F/L Morton in February 1945).

In order to obtain operational data for analysis the ORS/EAC staff first designed appropriate procedures for collecting the data on various aspects of daily operations. Then the nature and purpose of the proposed recordings were discussed with, and explained to, the RCAF staff involved and, on reaching agreement, the data gathering procedures were implemented.

The operational activities and factors concerned included the following:

- a. Flying hours on operational missions
- b. Serviceability of aircraft
- c. Weather as a factor in operational flying
- d. U-Boat sightings and attacks
- e. Estimates of U-Boat densities
- f. Enemy actions, sinkings, etc.
- g. Convoy operations and coverage.

The data obtained were carefully analysed and then presented in a logical and lucid manner and discussed with the Air Staff officers concerned. As a result certain relevant operational forms were re-organized, serviceability was re-examined, the relative efficiency of squadrons was noted, and appropriate remedial action undertaken.

The work just described was largely of a statistical nature and the following up of conclusions and findings therefrom. In addition to this work, which was of a continuing nature, the ORS/EAC staff undertook detailed analysis and examination of a wide range of operational problems, details of which are given in Ref 10.

In his report on activities of ORS/WAC and ORS/EAC for inclusion in Ref 10, Dr J.W.T. Spinks noted that a comparison of the record of successful searches in 1944 with that for previous years gives a good indication of the improvement resulting from the application of scientific principles to the organization of searches for missing aircraft. It may be observed that much research work and practical experimentation have been done on improving search and rescue procedures since 1944 and that these endeavours are continuing. While some advances have been made no great breakthroughs have been found.

In an interesting submission on his wartime experiences in OR, Dr John Stanley recounts some work and problems that he undertook at ORS/EAC where he reported for duty in December 1944 after being at the OR office with the DD Science at Air Ministry Whitehall from October 1943 to November 1944. Details of this work are given in Ref 11. They include investigations leading to the removal of excess weight in aircraft thereby permitting more depth charges to be carried, improvement in the use of binoculars in searching for submarines, adjustments in convoy escort plans, improved flying procedures, and improvements in the general morale and outlook of aircrew personnel.

The formal or informal publications by an OR unit by no means give a good measure of its productiveness. Indeed, the verbal communication of study results to the appropriate decision maker is often the most effective means of ensuring that the results of OR work get into the decision making process in good time. The impact of OR is usually difficult to assess in any meaningful quantitative way.

However, in retrospect the publications of an OR section are often the only available yardstick. And, in any event, the publications of the OR unit provide a quantitative assessment of its output and some indication of its productivity.

A list of titles of ORS/EAC reports issued over the period May 1943 to March 1945 is given in Ref 10. It consists of some 18 formal publications. As these, with others from the original military OR units, were the first Canadian OR publications, their titles are given for information and record purposes in Appendix B.

In addition to these formal publications, periodic progress reports were issued and much information was disseminated in the form of letters on files and by inter-office memos. Briefings and verbal reports were also used to transmit study results.

These publications and the preceding description of the problems and projects studied by the ORS/EAC provide ample evidence of the range and scope of the work done by this OR unit. This work was, indeed, operational research in operation during operations. When it is remembered that there were never more than three OR analysts on the staff including the Head of Section and that the unit was in being for less than three years (September 1942 - Summer 1945) it is remarkable that it accomplished as much as it did. While no long range extensive projects were undertaken, unusually large numbers of projects in a wide variety of study areas were accepted, investigated, and satisfactorily concluded. The record of this OR Section, the first one at an operational

command in Canada, was a very distinguished and productive one. It speaks well for the capability and dedication of the eight OR analysts who were on the staff, at one time or another, and the co-operation, support, and understanding that they received from the RCAF staff of all ranks with, and for, whom they worked.

Operational Research at Western Air Command

On April 15, 1943 Dr Cyril W. Leggatt arrived in Vancouver to set up an OR section at WACHQ. After initial discussion with senior RCAF staff, he first made a familiarization tour, which included visits to radar stations where the problem of "ghost" tracks had been giving trouble and to a site where experimental radar equipment had been emplaced.

At the end of July 1943, Dr Leggatt and Dr J.W.T. Spinks, who had joined the OR Section (ORS/WAC) in June, made a familiarization visit to RCAF bases on the West Coast. Among topics discussed with the appropriate officers were the aircrew assessment board examinations, stick spacing of depth charges, search procedures, and performance characteristics of aircraft and defence equipments. Some interesting WWII experiences of Dr Spinks are described in Ref 12.

The ORS/WAC gradually developed credibility and good working relations with the RCAF staff and was frequently consulted on numerous problems. In this regard the Head of Section and his staff acted largely as scientific advisors and provided much useful advice in this capacity. The section also circulated, or brought to the attention of officers concerned, technical and other reports which were forwarded to them by the AFHQ/OR Centre. A short description of the studies and work undertaken by the Section is given below.

In July 1944 S/L J.W. Abrams was posted to ORS/WAC from the ORS at Coastal Command in the UK. He reported for duty late in August as a replacement for Dr Spinks. He had joined the Navigation Branch of the RCAF in 1940 and was attached to the ORS of the RAF Coastal Command in February 1943. He remained at ORS/WAC until the end of the war and was in charge there after Dr Leggatt left in April 1945.

Other members of the ORS/WAC staff were:

S/L B. Priestman, an ex-RCAF navigator, who joined in November 1944 and was on strength until the end of the war; F/L W.H. Forrest, who joined in March 1945 and remained until the end of the war; and F/L A.D. Dent who was with the Section for a short period near the end of the war.

The strength of the unit accordingly varied from one at the beginning to four towards the end of the war. While never a large section in terms of numbers, it did undertake a wide variety of studies and did much useful work.

The fact that Western Air Command was not in an active theatre of war operations had a strong bearing on the type of studies assigned to the ORS. The main functions of the ORS were to conduct investigations directed towards improving the capability and efficiency of the Command, to gather data to serve this purpose, and provide scientific and technical advice on day-to-day issues as requested.

Arrangements were made for statistics on flying activities of the Command to be collected routinely. These were analysed and a report prepared and distributed each

month. These reports covered the relationship between activity and weather, aircraft availability and serviceability, type of task and aircraft type. The collection of statistical data on flying activities of squadrons was started by Dr Spinks and the first monthly statistical report was issued for the month of June 1943. Thereafter the preparation and issue of this report was a permanent commitment of the Section. Also, a semi-annual summary of flying statistics was prepared and distributed throughout the Command.

Other activities of a continuing nature included the preparation and monthly distribution of charts presenting the density of patrols over the sea approaches, assessments of the relative productivity to the flying effort of the squadrons and the development of a system of air-sea rescue procedures by which the progress of the search could be continuously estimated and the effectiveness of the coverage assessed.

The ORS was represented on the International Joint Committee for the Defence of the Strait of Juan de Fuca. It was consulted in the matter of the quarterly Efficiency Award and worked out procedures for determining the relative standing of stations in the Command.

Beginning in May 1943, considerable effort was put into work on analysing the results of the Second Aircrew Assessment Board (AAB) examinations, in co-operation with RCAF staff (Ref 10). As a result of this early work and discussions at meetings at AFHQ a proposal to set up at AFHQ a permanent committee to study the preparation of examination questions and related matters was accepted by AMAS.

Much of the work of grading the Third AAB examinations was done by the ORS. The analysis of, and report on, the results were completed during November 1943. At a subsequent meeting at AFHQ, the divergent views of the AABs of WAC and EAC were resolved. By April 1944 a regular AAB had been established at both WAC and EAC, and the ORS/WAC, while still consulted, was less closely associated with the work.

The ORS did much work on ways and means of improving search procedures. After preliminary study and discussions with RCAF officers Dr Spinks developed a method of plotting searches for missing aircraft and preparing a cumulative summary of the progress of the search. It proved useful and was later incorporated in WAC Air Search procedure.

As the result of analyses of WAC patrols, memoranda were submitted on their efficiency and on defence of the patrols against aircraft attacks from carriers. In May 1944, the recording of shipping and interceptions by aircraft was initiated, in order to extend the scope of those investigations.

Early in January 1945, trials with a parabolic reflector supported by a meteorological balloon were conducted in the Straits of Georgia, in co-operation with the WAC radar section. The purpose of the trials was to devise a method of providing an additional aid to pick-up by airborne radar for aircrews in dinghies.

A study of the probability of intercepting an enemy surface force by the patrols being flown was undertaken by S/L Abrams. He prepared a series of 'isotects', lines of equal probability, which gave a good picture of the effectiveness of the patrols. This study was extended to devising patrol patterns that would give maximum effectiveness for the available flying effort.

Five other areas of investigation occupied a great deal of the effort of the scientists at ORS/WAC. These were bombing assessment, analysis of navigation logs, coastal radar problems, the analysis of radar logs, and flying statistics. Brief accounts of the associated work and activities are given in Ref 10.

A list of the reports prepared and issued by the ORS/WAC to the end of April 1945 is given in Ref 10 by number, title, and date of issue. It includes some 17 official publications and in addition other reports were issued periodically. The list is given in Annex B.

The preceding account of the activities of the ORS/WAC and the list of publications indicate the high productivity of the unit, particularly when the small size of its personnel (four at the most) and its short duration are kept in mind. The remarks made above about the ORS/EAC apply as well to ORS/WAC. As was the case at EAC the OR analysts at WAC enjoyed the active co-operation, support, and understanding of the RCAF senior and junior staff with whom they worked. They also received help and advice from the OR Centre at AFHQ and co-ordinated their activities with OR work at ORS/EAC.

OPERATIONAL RESEARCH ON AIR PROBLEMS BY
CANADIANS IN THE UNITED KINGDOM

Introduction

It is not easy to sort out relationships concerning OR and the RCAF overseas. The RCAF squadrons in the UK were organized under the RAF. There were relatively few RAF squadrons and groups that did not have Canadian and other Commonwealth aircrews and few Canadian squadrons that did not have RAF and other Commonwealth aircrews. Similarly RCAF officers, such as S/L J.W. Abrams and S/L J. Stanley, worked with scientific organizations operated by the UK Air Ministry or RAF Commands. Some RCAF aircrews took part in various experiments and trials conducted by scientists with the RAF, e.g. trials run by the Coastal Command Development Unit (later designated the Air-Sea Warfare Development Unit). Thus, there was quite an admixture of RAF, RCAF, and Commonwealth aircrews and units, with Canadian and British scientists working on OR problems for various Air Force Units, Commands, and Groups. The RCAF fought overseas as an element of the RAF. Canadian aircrew in a dozen fighter squadrons, at least 18 bomber units, and five of Coastal Command, were in action from the beginning.

During the latter part of WWII quite a number of Canadian OR workers, some RCAF officers, and some civilians were attached to OR sections with the RAF and some to RCAF Overseas HQ in London. The names of the several units concerned with brief accounts of the OR activities and personnel involved are given in following paragraphs.

Operational Research at Royal Canadian Air Force Overseas Headquarters

As already noted the organization of OR services for the RCAF made provision for an Operational Research Officer (ORO) to be located at Overseas HQ, London. The first ORO there was S/L P.M. Millman who filled the position from September 1943 to December 1944. He later was a senior staff member of the Dominion Observatory and the NRC. The second incumbent was S/L J.M. Morton who held the post from February 1945 to the cessation of hostilities. The ORO at RCAF Overseas HQ reported directly to the Director Air Staff, and in addition maintained close liaison with the OR Centre at AFHQ in Ottawa. The Canadian OR Staff attached to units in the UK were administered in a general way by the OR officer at RCAF Overseas HQ and three of them worked at this office on attachment to the Overseas HQ. These were S/L P.M. Millman (September 1943 - December 1944), Flying Officer (F/O) M.M. McEwen (September 1944 - end of war), and S/L J.M. Morton (February 1945 - Summer 1945).

Liaison with Operational Research Sections in the United Kingdom

A large proportion of the work of the ORO was maintaining liaison with OR sections with the British and American Air Forces. The co-ordinating centre for OR activities in the RAF was the DD Science office at Air Ministry. Close contact with, and frequent visits to this office, were the order of the day to discuss problems and keep RCAF OR scientists and the OR Centre at AFHQ informed of work and progress on projects. The OR Sections at Bomber Command, Coastal Command, Fighter Command, Tactical Air Force,

Transport Command, and Flying Training Command were also visited as occasion required. By so doing the general nature of results of studies and projects could be learned, well in advance of their publication in official documents, and passed on to other OR units and interested RCAF authorities. As well, much other information of value resulted from personal conversations and discussions with scientists working on individual projects.

The most important US operational research sections with which good liaison was maintained were at the HQs of the American Eighth and Ninth Air Forces. Contact with these and their OR activities were kept up and also with the Australian and New Zealand Scientific Liaison Office in London.

Certain matters of OR interest concerning airborne forces, ground radar defence, and AA defence were discussed with the British Army Operational Research Group (AORG). There were several Canadian scientists working with AORG and one of the Directors was Dr O.M. Solandt, later Chairman Defence Research Board of Canada.

In addition to the liaison duties the OR Section at RCAF HQ Overseas was responsible for transmitting OR reports and technical information to Canadians participating in committees and for carrying out special research investigations. A list of such studies is given in Ref 10.

Operational Research at Deputy
Directorate of Science

The only Canadian to serve in operational research work with the DD Science at the Air Ministry, Whitehall, London during WWII was F/O (later F/L and S/L) John Stanley. He had been on duty with the RCAF at 5 Initial Training School at Belleville, Ontario as an instructor in mathematics and theory of flight when he was contacted by Dr J.O. Wilhelm and diverted to OR work. The original plan was for him to do a short tour of duty in Canada and then go on attachment for a year to an OR section with the RAF.

As it turned out he reported to DD Science in September 1943 and there worked under S/L A.C. "Sandy" Menzies, who had earlier advised on organizing OR services for the RCAF. F/O Stanley remained there doing OR work for some 14 months till December 1944 when, as noted above, he was posted to ORS/EAC.

Several interesting studies undertaken by Stanley included investigations concerning the V-1 bombs and their launchings, when the first launching site could be expected to be operationally complete, how best to locate where launching sites were, and methods of destroying enemy radars. It is interesting to note that his prediction of when the first U-1 launching base would be finished was correct to the very day! Further details on his work there are given in Refs 11 and 13.

Operational Research by Canadians at
Royal Air Force Bomber Command

Early in July 1943 arrangements were completed for Canadian scientists to serve with OR units in the RAF. In July 1943 Dr Gordon H. Harris arrived in London. After discussions at the OR office at RCAF Overseas HQ and consultation with G/C Menzies at DD Science, Air Ministry, he was posted to the ORS at Bomber Command (ORS/BC) under Dr B.G. Dickins. He was assigned to a section headed by Dr J. Thewlis which was concerned with problems in airborne radar target finding devices and air navigation in general.

His primary responsibility was to deal with all OR problems arising in Bomber Command from the use of equipment designated H2S which was a self-contained airborne blind bombing device and navigational aid. This was an area of research for which his earlier training and experience made Dr Harris particularly suitable. The main problems were associated with the interpretation of difficulties encountered in using H2S and devising remedial action to improve its operational effectiveness.

Other work in which Dr Harris and other Canadians at Bomber Command participated included development trials of H2S (MkII), investigating training problems, assessment of the operational use of H2S, and interpreting aerial photographs. Further details and relevant publications can be found in Ref 10.

Personnel

In addition to Dr Gordon M. Harris whose participation in and contributions to the work and projects of the ORS/BC are described above, two other Canadian OR analysts worked with the Section. These were S/L A.P. Guinand and F/L E.M. Kershaw. S/L Guinand worked on several problems at Bomber Command and also at the OR Section at Coastal Command. He later joined the staff on the Air and Armament Experimental Establishment, Martlesham Heath, England on a special mathematical study involving navigational aids. He served at the Bomber Command OR Section from February 1943 to May 1943.

In March 1945 F/L E.M. Kershaw, an Education Officer with the RCAF, joined No. 6 RCAF Group of Bomber Command as an OR analyst. He remained there in OR work until the end of the war and participated in several problems studied by ORS/BC.

Operational Research by Canadians at Royal Air Force Coastal Command

More Canadian OR workers served with the OR Section of the RAF Coastal Command than at any other RAF Command. A total of four Canadians was so employed, 2 civilian scientists and 2 scientists in RCAF uniform.

The first Canadian scientist to join the Coastal Command Operational Research Section (ORS/CC) was F/O J.W. Abrams who later was promoted to S/L rank. He joined the RCAF Navigation Branch in 1940. In February 1943 he

was detached from RCAF Overseas HQ and attached to the ORS/CC. After a conference with Mr H. Larnder, the father of OR*, who by then was Scientific Advisor to the Commander-in-Chief, Coastal Command, he was assigned to a rather loosely defined section dealing with the tactics of anti-submarine attacks and with anti-submarine weapons. The head of the Section was Mr W. Merton.

In June 1943 Dr A.G. Nickle and Dr J.H. Soper arrived from Canada for indoctrination in OR work and methodology and both were posted to the ORS/CC to work with S/L Abrams. Also in that month S/L A.P. Guinand came to the ORS/CC from Bomber Command OR Section but remained only until September 1943.

As already noted Dr Soper, a biologist, was posted to Canada to join the ORS/EAC in March 1944. Dr Nickle, a physical chemist and graduate of Queen's and Harvard Universities had been a member of the National Research Council before joining the RCAF as an OR analyst. He remained at ORS/CC until the summer of 1945 when the war ended. Following the departure of S/L Abrams in June 1944 to join the staff of ORS/WAC in Canada Dr Nickle took over his duties at ORS/CC. In March 1943 Mr Merton joined the staff of the Scientific Advisor to the Prime Minister (Lord Cherwell) and was succeeded in his post by S/L Abrams.

* See comments on who originated the term 'operational research' and who the 'fathers' of OR were under the REMARKS Section at the end of this Chapter.

The first project undertaken by S/L Abrams, following a short indoctrination period, concerned the improvement of a projector designed to remove the distortion from mirror camera photographs used in attacks on submarines so that the errors of attack could be more accurately determined. A method of improvement was developed and constantly bettered until the projector became a satisfactory working device. It was accepted by the Senior Naval Staff Officer at Coastal Command as the standard method of analysing U-Boat attack and the analysis sheets, whenever available, were submitted to the Admiralty Assessment Committee as an aid in evaluating attacks. Other projects in which S/L Abrams participated were the determination of the effect of sunlight on the visibility and detectability of U-Boats from aircraft, the examination of the spacing of depth charges in a stick, the lethality depth charge attacks, and loss rates of aircraft from U-Boats and anti-aircraft fire.

By May of 1943, emphasis in the section became directed towards weapon development and the study of new anti-submarine tactics. When Drs. Soper and Nickle joined the unit in June they were put to work on photographic interpretation problems, and the analysis of aircraft attacks on U-Boats, respectively.

In December 1943 Mr H. Larnder became Scientific Advisor to the Air Officer Commander-in-Chief, Allied Expeditionary Air Force and his position at Coastal Command was assumed by Dr C.H. Waddington. The OR Section was then reorganized. A weapons and attack section dealing with both anti-U-Boats and anti-shipping attacks was set up with S/L Abrams in charge.

The attack-effectiveness work was continued under Dr Nickle when S/L Abrams returned to Canada. Data obtained from photographs and from attack reports on the card filing system which Dr Nickle had improved, were used in these studies. In particular, after the general use of schnorkel equipment by enemy submarines considerable help and advice were given concerning bombs, bomb spacing, and fuses.

The anti-shipping projects were usually handled by RAF members of the OR Section and details of the work are given in Ref 10. However, aspects of shipping attacks in which bombing problems were involved were frequently examined by Dr Nickle. Incidentally, all OR personnel involved, mutually and individually, agitated for more photographs as a prime source of accurate factual up-to-date data and towards the end of the war the extreme value of adequate photographic records for both operational and training purposes was being appreciated by the Command and elsewhere (Refs 10 and 14).

It was realized during the winter of 1943-1944, that on the basis of operational data, night attacks against submarines were not getting as good results as was hoped, and interest increased in methods of obtaining night photographs to help determine what was not going right. A simple technique for assessing night photographs was devised and submitted to operational squadrons, was used successfully, and was in fairly wide use by the end of the war (Ref 10).

Another problem on which Dr Nickle worked was the use of sonobuoys in anti-submarine operations. Investigations and liaison were carried out with Signals Corps and anti-U-Boat personnel in determining the reliability of contacts and the best methods of utilizing them.

As has been the case with all military OR sections such papers as visit reports, minutes of meetings or comments on staff papers, and many other memoranda were intended for internal use and are not generally available outside the Command or military organization directly concerned. In any event a listing of ORS/CC publications would not be directly pertinent to the present document. Some of the Coastal Command publications that Canadians prepared or collaborated in preparing are given in Ref 10.

The preceding paragraphs provide a brief account of the work undertaken by Canadian OR workers in the RCAF under wartime conditions. This record speaks for itself showing the extensive contributions made by a few dedicated scientists given the stimulus and right environment. However, there would have been no such record had not the senior RCAF officers and scientists already mentioned had the foresight and wisdom to plan for and initiate OR in and for the RCAF. To them and to the senior OR scientists in the UK and USA who helped get OR services organized in the RCAF and to the OR scientists in the UK who provided training and experience in OR with Operational Commands much credit and appreciation are due for OR achievements for the RCAF during WWII.

By way of a summary a list of Canadian personnel, civilian and military who served in operational research on behalf of the RCAF in WWII is provided in Annex C. It will

be noted from this Annex that a total of 9 civilian and 12 military scientists were engaged in OR for the RCAF in WWII. Of these 21 scientists five continued in military OR after WWII in one way or another. These were Drs. Colin Barnes, C.W. Leggatt, J.W.T. Spinks, J.W. Abrams, and John Stanley. Some details of their post-WWII work in OR are given in Ref 8.

OPERATIONAL RESEARCH IN THE ROYAL CANADIAN NAVY IN WORLD WAR II

Introduction

A short account of the beginning of OR in the RCN is given in Refs 7 and 11. In those references it is noted that depending on how one defines OR, the beginning of the activity in the RCN might be traced to 20 February 1940 when Captain (later Vice Admiral) H.E. Reid, Commanding Officer Atlantic Coast, requested help from Professors J.H.L. Johnstone and G.H. Henderson of the Physics Department of Dalhousie University. Assistance was needed in providing ships on this side of the Atlantic with protective devices before entering the mined waters of the British Isles.

The information available in Canada, at the time, on this subject was very scanty, being to the effect that a degree of protection could be obtained by a coil of wire around the perimeter of the ship energized by direct current, with the ampere turns given by a rough and ready rule. In addition to developing the coils a method of measuring the magnetic field beneath the ship was required. Captain Reid was convinced that trained scientists like Professors Johnstone and Henderson could help solve such problems and,

accordingly, sought their assistance. Indeed, such help was forthcoming and the first ship coiled in Canada was the Fleur de Lys on 21 March 1940.

The type of work outlined above continued vigorously under Dr Johnstone and research was done in related areas such as magnetic minesweeping, calibration of ships, defence against magnetic and acoustic torpedoes, and the development of noise makers for use in acoustic minesweeping. Drs. Johnstone and Henderson and others working on these problems were, at the time, on the staff of NRC.

By the middle of 1942 the NRC staff doing naval research at Halifax had grown to about thirty, most of whom were young physicists and engineers recently graduated from Canadian universities. Later, naval scientific research was continued at Halifax by a unit designated HM Canadian Naval Research Establishment (NRE) under the direct control of the RCN and official connection with NRC terminated in January 1944. Needless to say, the Establishment continued to have available the advice and assistance of the NRC when required, on a contract basis.

Origin of Operational Research in the Royal Canadian Navy

Whether or not this valuable research work should be called OR is not vital to the present report. It is sufficient to note that it involved Dr J.H.L. Johnstone and Dr G.H. Henderson who later formed the nucleus of the first OR units that worked with the RCN. By 1943 Dr Johnstone was the joint superintendent of the NRE,

Halifax, and on 1 July 1943 was appointed Director of Operational Research (DOR) and charged with organizing an operational research group for the RCN.

As a first step in his new job Dr Johnstone made a visit to the Department of the USN, Washington, D.C. where the organization and operating methods of the Anti-Submarine Warfare Operations Research Group (ASWORG) were studied. He spent the month of August 1943 at the UK Admiralty where he acquired familiarity with the Royal Navy OR organization and its method of working. In addition, arrangements were made for the new Canadian unit to receive reports of naval OR work done in the UK and USA. For example in September 1943 some thirteen OR papers were forwarded to Naval Services Headquarters by the Naval member in Washington and three more in January 1944. Access to such papers played an important part in developing military OR capability in Canada. A second visit was made by Dr Johnstone to ASWORG in early January and to the Massachusetts Institute of Technology (MIT) on 15 January 1944 to learn more about various anti-submarine problems. Such exchanges of information and visits have continued down to the present. They have been very valuable, particularly to the Canadian OR workers.

On his return Dr Johnstone set about organizing staff and a program of work for them. The original RCN operational research staff, as finally established consisted of:

Director of Operational Research - Dr J.H.L. Johnstone.

Operational Research Staff Officer - Dr G.H. Henderson.
Atlantic Command

Operational Research Advisors - W.R. Christmas, B.Sc., F.A.S.,
Andrew McKellar, Ph.D., R.M. Petrie, Ph.D., H.L. Welsh, Ph.D.,
B.N. Moyls, B.A., and E.B. MacNaughton, B.A.

One officer, Lt B. Sutton, (Womens Royal Canadian Naval
Service) and one secretary stenographer, Miss M. Sarazin,
completed the group.

The question of status of the OR scientists with the
RCN took some time to solve. Briefly the solution to the
status question was that all of the OR staff other than
Dr Henderson became active service officers as members of the
Royal Canadian Volunteer Reserve. They were thereby authorized
to wear naval uniform while on duty or travelling in dangerous
zones and if captured by the enemy would be treated as
Service personnel rather than as civilians.

Organization of Operational Research in the Royal Canadian Navy

For the greater part of the time there were five
scientists (including the Director) stationed at Naval Services
Headquarters (NSHQ) and three at Atlantic Command Headquarters,
Halifax. This appeared to be a satisfactory distribution,
but a larger staff at both places would have been required
to handle the volume of work adequately. Occasional visits,
only, were possible to St. John's, Newfoundland. A larger
staff would have made it possible to have at least one
scientist continually stationed at this important focal
point of North Atlantic operations.

Although there were only two small OR units with the RCN during WWII, members kept closely in touch with naval OR units in the UK and USA, by visits and exchange of documents. It was found that suitable liaison with the OR groups at Admiralty and with the USN was most important both in stimulating the activity of the RCN group and in making the results of the other groups available to the RCN and vice versa. From January, 1945 until the end of the Japanese war, a Canadian scientist was stationed in the Directorate of Naval Operational Research at Admiralty, UK. The benefits of this arrangement were considerable and, if they could have been foreseen, would have justified the continuous existence of this form of liaison from the beginning. Operational records, even of RCN ships, were always more complete and up-to-date at Admiralty than at NSHQ, and the presence of a Canadian scientist at Admiralty meant that these records, as well as much other operational information, were then available to the Canadian group with a minimum of delay.

Liaison with ASWORG in Washington was on the whole very satisfactory, and was maintained by regular visits of varying duration by different members of the RCN groups at Ottawa and Halifax. By this means much information was exchanged, not only on OR matters, but also on technical subjects. It would have been of considerable advantage to have a Canadian scientist continually stationed in ASWORG but the shortage of personnel made this impossible. It might be pointed out that such an arrangement would have been welcomed by the USN authorities (Ref 11).

Operational Research Activities

Due to the relatively few professionals engaged in OR for the RCN during WWII their activities were not as extensive as those of OR scientists serving with the RCAF and Canadian Army during the same period. However, the scientists employed with the RCN were challenged by a wide variety of problems to which they responded effectively and in timely fashion.

The staff of the Directorate of Operational Research at NSHQ acted as both a HQ administrative and support unit and as a working OR section. The director, Dr J.H.L. Johnstone, and some of the Directorate of Operational Research (Navy) (DOR(N)) staff frequently provided advice and information on scientific and engineering problems on request. Indeed, Dr Henderson did so, as well, at HQ Atlantic Command. In particular much assistance was provided by Dr Johnstone and his staff on mine warfare and measures against the German Naval Acoustic Torpedo (GNAT) and in initiating and contributing to the Canadian Radio Wave Propagation Committee.

Much vital information on the performance of friendly and enemy weapons and submarine detection systems, and on OR techniques and methodology were obtained through visits to, and exchange of information with, naval OR units in the UK and USA. Many relevant reports on anti-submarine (A/S) studies came from the British OR section with the RAF Coastal Command. The Naval Member, Canadian Joint Staff, Washington forwarded many documents on naval OR and related matters to the Directorate of Operational Research at NSHQ.

Like his counterparts with the Army and RCAF the Director, Operational Research for the RCN acted on several committees including those dealing with inter-service research and for the exploitation of enemy science and technology. He also acted as an unofficial technical and scientific advisor. Amongst the other matters he advised Naval Staff on mine warfare and OR anti-GNAT measures, and attended meetings of the Naval Staff.

As was the case with the OR units at Army and Air Force HQs in Ottawa, the Directorate of Operational Research with the RCN enjoyed the confidence and support of the Naval Staff. Likewise the Section at Halifax had high credibility and excellent co-operation with the staff of the Commander-in-Chief Canadian Northwest Atlantic.

Considerable work was done by the OR Sections at both NSHQ and Halifax on aspects of mine warfare including characteristics and expected performance of German and Japanese mines. Much information about enemy mines was received from the Mine Warfare Operational Research Group USN in Washington.

A visit to Washington and Boston was made by Dr Johnstone on 12-15 January 1944 to explore sources of information on the subject of tropicalization of ships. He submitted a trip report covering such topics as fire hazard, fire fighting, ventilation, refrigeration, insulation, clothing, supplies, facilities for personnel, cold water drinking machines, etc.

During the same visit Dr Johnstone obtained information from the Acoustic Laboratory of MIT. On his return he reported on radar ranges of known and probable U-Boats, German listening equipment, USN anti-acoustic torpedo devices, and on experiments on covering submarines with rubberlike material to decrease the reflection of supersonic waves from ASDIC or QC equipment. The latter was a depth finding modification device for attachment to ASDIC equipment for listening to submarine noise. ASDIC was named for the British Anti-Submarine Detection Investigation Committee.

A summary of the more important topics with which the Directorate dealt at more or less greater length is given below:

- a. Analyses of anti-U-Boat operations in Canadian coastal waters. These analyses were carried out mostly by the Halifax group and were useful in indicating how future operations could be improved.
- b. Statistics of the factors affecting the success of anti-U-Boat activities of the RCN for the period 1940-44.
- c. Countermeasures to the acoustic torpedo. In association with NRE at Dartmouth, N.S., successful countermeasures were developed shortly after the advent of this torpedo.

- d. Countermeasures to the German Type XXI U-Boat with high underwater speed. This boat was a grave threat but never became an actual danger to Allied shipping, because the enemy was unable to bring Type XXI into operation to any extent before the end of the war.
- e. Estimation of the improvement in the RCN anti-submarine effectiveness if certain new weapons were introduced. Thus, the installation of Squid¹ in RCN ships, stabilization of Hedgehog¹ mounting, and the use of Carrier Vessel Escorts (CVEs) in Canadian coastal waters were studied.
- f. Since the ships of RCN were used to a great extent for convoy protection this phase of operations was given full attention in operational research. The reports included the effect of weather on North Atlantic convoys, the effectiveness of convoy radar screens, the value of middle-ocean escorts in saving merchant ships, etc.
- g. Possible countermeasures to Schnorkels.
- h. After the collapse of Germany, assistance in the interrogation of prisoners of war from U-889 was given and a technical examination of the U-Boat was made. During this immediate post-war period, DOR's representative in Admiralty was able to transmit to NSHQ with a minimum delay much information on captured German weapons and devices.

¹A type of depth charge

By far, the most important concern of the RCN and its OR units during WWII was ASW in connection with convoy operations. Almost all of the OR work was devoted to one aspect or another of ASW operations. Some interesting OR findings of ASW operations are mentioned in Ref 11.

It is worthy of note that on 1 November 1943 at the request of Dr Johnstone, the Director of Naval Intelligence wrote to the Staff Officer (Intelligence) Halifax to the effect that the OR Staff Officer there, Dr G.H. Henderson, was to receive all available information about the enemy. The necessary arrangements were made to this end and the two OR Sections at NSHQ and Halifax were henceforth kept fully in the operational picture from both the operational and intelligence points of view.

During the period from August 1, 1943 to August 31, 1945 OR reports and memoranda on a wide variety of subjects were prepared and circulated to the operational authorities at NSHQ and Atlantic Command. A list of reports and memoranda is given in Ref 11 and included in Appendix B for information. This list represents in reality only a portion of the work of the group. Much advice was given to operational staffs conversationally or as minutes on files and did not require formal reports or memoranda. It may be of interest to note that the first anti-submarine OR report dealt with the analysis of 49 hunts by A/S ships in the Atlantic Coast Command in 1942.

The list of reports and memoranda contains the titles of 26 reports and 45 memoranda published by the Directorate at NSHQ and 11 by the Halifax unit. These titles (Appendix B) indicate the wide scope and variety of OR studies undertaken by

these units. These publications represent a great amount of analysis and work and attest to the productivity of the relatively small number of dedicated staff members who were employed on OR work with the RCN in WWII.

This list shows that, among other projects, the OR unit at Halifax worked on analyses of naval operations in the St. Lawrence River and Gulf of St. Lawrence, on studies of convoy operations in the North Atlantic and high speed U-Boats, on the effects of weather on convoy movements, and on escort requirements in the North Atlantic. They also assisted in evaluating countermeasures to German acoustic torpedoes and the newer types of depth charge, Hedgehog and Squid. A good deal of consideration was also given to countering the German submarines use of Schnorkel equipment.

In personal correspondence with Dr H.L. Welsh he has noted that in May, 1945 a German U-Boat surrendered off Shelburne, N.S. and as the Intelligence people who spoke German had all gone from Halifax to Newfoundland to help accept the surrender of a U-Boat there, he was called on to go to Shelburne. Having studied in Germany 1931-1933, he spoke German fluently and interviewed each member of the German crew as they came off the submarine.

Considerable effort was devoted by the OR unit at NSHQ to perusing intelligence reports about enemy submarine activity and A/S actions. These reports were of Canadian, UK, or US origin and were summarized and circulated to interested agencies. This work was one of the main responsibilities of W.R. Christmas. A further short term form of work that involved quite a lot of time and effort

at both NSHQ and Halifax was answering questions that arose out of situations and decision making originating in the operations rooms.

Personnel

The three OR scientists working in the Halifax OR unit were Dr G.H. Henderson, Dr R.M. Petrie, and B.N. Moys. The remainder of the naval OR staff (Dr J.H.L. Johnstone, Dr A. McKellar, Dr H.L. Welsh, W.R. Christmas, E.B. McNaughton, J.D. Barber, G.D. Scott, and Lt. B. Sutton, WRCNS) worked at the DOR in NSHQ. Both Drs. McKellar and Welsh served short postings at DOR Admiralty. E.B. McNaughton was not in OR for very long; he joined the RCN earlier and on coming into OR work specialized on radar problems. None of the OR workers continued in OR after the end of WWII.

Concluding Remarks

From Dr Johnstone's final report (Annex E of Ref 11) and the preceding summary of work undertaken it is clear that the OR units under Dr Johnstone were of great assistance to the naval staff during the three years that they were serving the RCN. In the light of later events it is interesting to note that Dr Johnstone's report reads in part, "Even in peacetime one or more operational research scientists would be found very useful to the Navy". It was not until after the Defence Research Board was established in 1947 that OR staff again became available to the RCN. An account of how OR was provided to the RCN and the other Canadian Armed Services in WWII is described in more detail in Ref 11.

OPERATIONAL RESEARCH IN THE CANADIAN ARMY
IN WORLD WAR II

Introduction

Shortly after the introduction of OR in the UK Armed Forces and in the RCAF discussions and plans were underway for providing OR resources for the Canadian Army. General A.G.L. McNaughton, General Officer Commanding-in-Chief (GOC-in-C), First Canadian Army Overseas, who had been President of the NRC, was greatly interested in the possible contributions of science to the conduct of WWII and was aware of the OR work of the British AORG. He strongly supported the idea of having OR done for the Canadian Army (Ref 11).

Following discussions at Army Headquarters (AHQ) in which NRC took part, on 1 May 1943 Colonel (Col) W.W. Goforth Director Staff Duties (Weapons) (DSD(W)) proposed a policy and plan for OR in the Canadian Army. The proposal covered the carrying out of operational, general, and tactical research in the Canadian Army.

In September 1943 at the instigation of Col W.W. Goforth at National Defence Headquarters (NDHQ), Dr D.C. Rose of the NRC and Lieutenant Colonel (Lt Col) C. Sanford of the Directorate of Signals visited the AORG in the UK. The visit was based on a felt need for an Army OR system as mentioned by Lt Gen A.G.L. McNaughton, GOC-in-C, First Canadian Army, in August 1943 (Ref 11) during a meeting with Dr Rose, Col F.F. Fulton (Canadian Military HQ, London), and Lt Col C. Sanford. The visit was supported by the Brigadier T. Earnshaw, Deputy Chief General Staff (C).

As a result of this visit and a report thereon a submission was made to the Minister of National Defence on 11 October 1943 based on a proposal by Lt Col Sanford. The report contained three parts: Recommendations, Army Research System in Canada; Observations on the British Army Research System; and Operational Research in First Canadian Army. On 11 October the Chief of the General Staff (CGS) forwarded a covering recommendation to the Minister. On 12 November 1943, the proposal was approved with effect from November 1943. It provided for a System of Army Operational Research to include a civilian Scientific Advisor to the Canadian Army Council and a Directorate of Operational Research (DOR). The System was to function within the General Staff Branch under the Deputy Chief of the General Staff with the provision that the Scientific Advisor (SA/CGS) had access to the CGS on certain matters. In addition an Army Operational Research Group was established for the conduct of research in the field. It was named the Canadian Army Operational Research Group (CAORG).

Functions and Terms of Reference

The functions of the System were:

- a. To advise the CGS on any subject susceptible of scientific study on which he might request advice;
- b. To examine equipments and methods from a statistical and scientific point of view and to provide data to assist in assessing their value in operations and training.

The terms of reference of the CAORG and of the Director of Operational Research (D Res) were based on those of the SA/CGS as the three branches were closely related and worked in collaboration. The terms of reference of the SA/CGS were very general and defined as follows (Ref 11):

"To advise the Chief of the General Staff on any matters susceptible of scientific study, on which his advice is requested".

The SA/CGS was also responsible for directing the research work of the CAORG.

The functions of the Directorate of Operational Research (DOR) were:

- a. To provide the liaison and the Service knowledge and experience necessary for directing the research work along the lines most profitable to the Army;
- b. To relieve the SA/CGS and CAORG of as much detail as possible.

In short, the Directorate was a military staff directorate which was the organ of day-to-day administration and liaison in support of the SA/CGS and CAORG. Within the Directorate the functional organization provided sections for routine matters and administration, and technical liaison. The internal organization of the sections varied from time to time in response to requirements of the research program.

The function of the CAORG in very brief terms was to provide the SA/CGS with data on which to base his advice. In general these data were supplied as the result of detailed quantitative analyses in the form of reports and memoranda based on data obtained from trials and operations.

Organization of Operational Research in the Canadian Army

Soon after the OR System was set up with the three collaborating branches (SA/CGS, D Res, CAORG) the existence of certain training problems was recognized. Following informal discussions at AHQ, particularly with the Directorate of Military Training, it was decided to set up detachments of CAORG at the Canadian Signals Training Centre (CSTC) at Barriefield (Kingston), Ontario, and at the Armoured Corps Training Centre, Camp Borden, Ontario. Later a small detachment of 2 officers was established at HQ Pacific Command, Vancouver, B.C.

Although OR work was done at Camp Shilo, Manitoba, a detachment was not formally established there for conducting the work, as OR personnel were attached for temporary duty as required. Also, Canadian OR analysts were posted to the Australian and Indian Armies for duty, to CMHQ, London, England, and to the British AORG. Later a Field Research Section was established with effect from 15 April 1945 to work with First Canadian Army in North West Europe.

Operational Research Activities - General

By November 1944 a large number of study projects had been recognized including several large-scale projects such as Exercise POLAR BEAR, Project STORMY WEATHER, and projects initiated in co-operation with Pacific Command, Camp Borden A-7 Canadian Signals Training Centre (CSTC), several Directorates at AHQ, and NRC.

A few examples of OR projects undertaken in Canada serve to indicate the scope and diversity of the work which will be described in more detail in the sequel. These included large scale trials, training problems, applications of radar and meteorology for the detection of rain and snowfall, the effectiveness of weapons, comparison of visibility of various materials used for panel-signalling to aircraft, development and application of a water-proofing compound for maps, and the technological implications of, and probable reasons for, a sudden increase in certain types of imports into a neutral country.

Personnel - General

Although the Operational Research System lasted for only a few years, there were many changes in personnel during its lifetime. The interim establishment consisted of 16 Officers and 17 Other Ranks; it was increased to 19 Officers and 23 Other Ranks effective 15 May 1944. Col J. Tuzo Wilson was appointed D Res with effect from 24 December 1943. The position of Scientific Advisor (SA/CGS) and Deputy SA/CGS were established by Order in Council dated 15 December 1943. The first and only wartime SA/CGS was Dr D.C. Rose who had been a prominent scientist with the NRC.

The combined strength of the System at 31 December 1944 was 33 officers (military and civilian) and 22 other ranks. By the end of February 1945 it was 36 officers and/or civilian scientists and 22 other ranks. At the end of September 1944, 18 officers were members of CAORG and 13 of these were detached as follows: India 2; Australia 2; Exercise POLAR BEAR 2; Exercise ESKIMO 1; Exercise LEMMING; Camp Borden 2; CSTC 2; University of Toronto 1.

The DOR, and the System of Operational Research, in general, worked closely with NRC, the Departments of Munitions and Supply, Mines and Surveys, Agriculture, Pensions and National Health, and Transport. The nature and extent of the collaborative work with these agencies, and also with Canadian Universities, depended in large measure on the type of projects and studies that were being investigated.

In late 1944 and early 1945 there was growing interest in arctic research and army exercises and possible operations in the North. These initiatives eventually led to much work by DOR and CAORG in connection with several military exercises.

As an example of the nature of DOR and CAORG involvement in these exercises a brief description of one of the involvements follows. Exercise POLAR BEAR, a winter and spring manoeuvre, was conducted during February-April 1945, under the direction of HQ Pacific Command. The Army DOR was charged with co-ordinating observations during the trials and with writing a report. It contained 28

suggestions for future research. One of these was the recommendation that smaller scale exercises, scientifically controlled, be conducted to investigate problems of winter living and winter mobility on foot and in vehicles. A pamphlet called Zero Warfare prepared by D Res and the DOR staff, was issued to all personnel taking part in this exercise.

Organization of Canadian Army Operational Research Group

The CAORG consisted of a central unit in Ottawa, housed in a hut on the old Cartier Street school grounds along with the SA/CGS and DOR offices, and detachments in Canada and overseas. All these detachments submitted regular periodic reports to D Res and SA/CGS.

A common feature of the work of the CAORG detachments was the relatively large number of projects that were undertaken by rather few personnel. There were generally more staff members in the DOR than there were doing OR in the CAORG detachments. Indeed the number of problems investigated and reports published argues that the CAORG was a very productive organization.

The CAORG in Ottawa was organized into project teams whose personnel varied from time to time with requirements of the work. Since many projects were undertaken, there were many changes in the work assignments of the CAORG staff and some of them worked on several projects at the same time. They also worked closely with the DOR staff on some projects. D Res directed the program of work of the whole system. In

addition to working on over 70 different projects during the period of its existence the CAORG staff co-operated with the DOR staff in participating in meetings and liaison activities with other Government Departments and OR units in the UK and USA. A list of the titles of the CAORG projects given in Ref 11 contains the projects worked on by CAORG and DOR staff.

One of the major projects of CAORG was titled STORMY WEATHER which was a study of the detection of rainfall and snow by means of radar equipment. The objective was to determine to what extent, with what reliability, and under what conditions rainfall and snow could be detected within the operating range of the radar. Work on this project started in June 1944 and continued till after CAORG was disbanded. Thereafter the project became the responsibility of the recently appointed Director General of Defence Research (later Chairman Defence Research Board) in 1947. CAORG project leaders for this work were Dr J.S. Marshall, Lt Col L. Guy Eon and Dr R. Langille. As a specific project this work was terminated in 1947. It made a very worthwhile contribution to scientific knowledge.

It may be noted that of the 151 proposals submitted to DOR and CAORG for consideration by April 1945, 43 were studied in projects, 24 were answered directly, and the remainder not activated. The emergence of so many suggestions and the early action taken on so many of them indicate the interest and credibility in OR shortly after its inception in the Canadian Army and the responsiveness, alacrity, competence, and versatility of the OR system. Further information on projects undertaken by CAORG can be found in Ref 11.

The Kingston Detachment

The Detachment of CAORG at Kingston, Ontario, sometimes referred to as Detachment Barriefield, was attached to and worked with the A-7 CSTC at Vimy Barracks. The Detachment was never a large one with at most 3 professional members, supplemented by consultants and summer assistants. The major part of the OR work was devoted to problems associated with signals training and equipment. This Detachment at one time or another employed a total of 6 persons: Dr J.E. Morsh, Capt A.F.B. Stannard, Mr H.H. Potter, Mr A.H. Shephard, Sgt A.B. Colpitts, and Miss F. Coggins. In addition, consultants and summer assistants worked for the Detachment.

The first formal project undertaken by the Detachment concerned training in Morse Code operating. The titles of the first two projects were Morse Operating Achievement Test and Selection of Morse Operators. Indeed by February 1945 the Detachment had several projects related to teaching Morse Code keyboard and line operators

Other project titles included: Remedial Tape for Operators, Sample Lesson Plans and Tests (on Telephones), Laying-Out Course in Morse Operating, Training in Morse Sending, Training in Morse Code Reception, Reliability of Trade Test Operators Wireless and Line, Standard of Morse Code Reception, Telephony Training (Preliminary Study), Selection Tests, Signals Trades (Preliminary Study), and Wire Recording in Instruction at CSTC.

The Camp Borden Detachment

The Camp Borden Detachment was organized to work with A-33 Canadian Armoured Corps Training Establishment at Camp Borden, Ontario. A major part of the OR work of this detachment was concerned with assisting instructors at Camp Borden in determining the best methods of selecting, training, and grading tank gunners and with related studies relevant to armoured warfare.

This detachment was never very large in terms of personnel. The head of the detachment was Dr Kenneth C. Fisher, (1944-1946), a physiologist from the University of Toronto. Other early members were Dr Thomas W. Cook, a psychologist from Acadia University, and Capt J.S. Vigder, a mathematician from the University of Saskatchewan who had joined the Army as a 2nd Lieutenant in Artillery. After Capt Vigder left to go to Australia in October 1944, Capt J.S. McBride worked for a period with the Camp Borden Detachment. Other short-term members were Lieutenants K.P.R. Hodges, and W.C. Woods who served with the Detachment in 1945. Miss Annette Johnston was employed with the Detachment during 1945 as a summer assistant and continued on a full-time basis.

Projects undertaken by the Detachment included studies of the accurate sighting of tank guns on target and the optimum number of rounds required in tank gunnery training, assessments of rifle training, and the development of an aptitude test for Canadian Armoured Corps operators. Work of the Detachment also included the preparation of

reviews and comments on OR publications from the UK and USA dealing with ATK gunnery and the training of tank crews and compiling and analysing the results of investigations, trials and experiments. Liaison was maintained with CAORG, other Canadian Detachments, and Army OR services in the UK and USA.

Camp Shilo and HQ Pacific Command Detachments

For a short period near the end of WWII there was an OR unit stationed at Camp Shilo, Manitoba. It was a small unit of one or more officers, one of whom was Lt K.P.R. Hodges. Among projects investigated were manipulation training for ATK gunners, the evaluation of skill in ATK gunners, and work on guns and gun drill (Ref 11).

Early in 1944 an OR detachment was set up at HQ Pacific Command. Two officers who worked in the unit were Captains H.H. Clayton and G.H. Charlewood both of whom later served in OR overseas. Studies undertaken by the detachment were the analysis of AA fire and small arms shooting, the reduction of paper return, and an investigation of rifle sights in poor light. The detachment also assisted in the mosquito surveys conducted by CAORG.

Army Operational Research Overseas

By August 1944 consideration was being given to forming a Canadian OR section with the First Canadian Army in Northwest Europe and to providing Canadian officers with OR experience to assist in getting work started in the Australian and Indian Armies. It was thought that the latter would prove mutually beneficial as indeed was the case.

The purpose of the OR team with the Canadian Army in the field was to collect and record data on Canadian operations with particular reference to purely Canadian aspects of operations. The team was instructed to work in close conjunction, and co-ordinate its progress, with the UK No. 2 Operational Research Section, HQ 21 Army Group.

The work done by the Canadian Officers in the Australian and Indian Armies included field gun evaluation, assessment of artillery smoke in the New Guinea jungle, the effectiveness of a man packed flame thrower, tests of illuminating smoke screens, and the study of tank problems in jungle warfare in the case of Capt. Vigder and Charlewood with the Australian Army. The Indian Army research was done on supply dropping, signals and medical corps problems, the wastage of war materials in jungle warfare, and transport problems among others. The Canadian officers were Lt Col C. Sanford and Captain G.W. Haug.

The OR team with First Canadian Army consisted of Lt Col L.S. Lauchland and Majors F.G.B. Maskell and H.H. Clayton. As they arrived in the active theatre the first week in May 1945 and VE day occurred on 8 May they did not have much time to do effective OR work and the cessation of hostilities tended to dampen enthusiasm for research work.

The OR team ceased operations in August 1945 when Major Maskell left the theatre to return to Canada. During their active period in the field (May-August 1945) team members worked mainly on two projects, an investigation of

the effectiveness of rockets and a survey of mine casualties. Having collected and analysed the relevant data, reports on these projects were written by Major Maskell as Major Clayton had departed prior to August to join the Canadian force being prepared for the Pacific theatre.

Exchange of Army Operational Research Staff

After OR got started in the Canadian Army there was an exchange of officers between AORG and CAORG. There were also Canadian officers with AORG who were not members of CAORG. Two of them were Capts. R.B. Bromiley and G.R. Lindsey. The latter however, did join CAORG in 1945. They both worked on radar and associated problems. Capt Bromiley was a psychologist and machine gunner. He worked mainly on human aspects of radar tracking. Later he went to Italy with a Section of AORG and became a prisoner of war while working with front line troops. Capt Lindsey was concerned mainly with radar and AA fire control problems. Amongst other projects he did a study on the susceptibility of army radars to 'window' and one on the operational performance of radars with 40 mm guns. It is worthy of note that a member of AORG, Mr G.D. Kaye who worked on AA and weapons lethality projects later came to Canada and has been for many years an outstanding contributor to OR in the Canadian Army and RCAF. One of his fellow workers on lethality problems at AORG, who shared an office with him for a time, was Capt F.G.B. Maskell of CAORG. Later these two capable and experienced OR scientists again worked together in the post-WWII Canadian Army Operational Research Establishment.

Several other officers served with AORG for varying periods of time and participated in on-going projects in one or more of the several sections or field units. They were both learners and workers who benefited from their tours of duty and on their return to Canada or to Canadian OR units were more effective and experienced OR analysts.

It should be observed that although more Canadian officers served with AORG than British officers did with CAORG, there was a useful and mutually beneficial exchange of staff between the two Groups. For example, on 4 June 1944 Major T. Verschoyle from AORG reported for duty with CAORG to work on large scale smoke trials carried out in July by the 14th Canadian Infantry Brigade at Wainwright, Alberta. The UK Army was interested in this trial which was associated with the CAORG Project Fighting in Smoke Fog (Ref 11). Also, on 14 August 1944 two AORG representatives, Dr Whitney and Mr Harrison arrived in Ottawa to work with CAORG.

Publications

The list of CAORG publications, which appears in Ref 11 and is repeated here in Annex B for information, shows some 45 reports and 40 memoranda. These were produced over the period February 1944 to July 1946 with one outlier dated 5 May 1948. The work covered a very wide range of projects most of which were successfully completed and the findings published. These publications received wide distribution in Canada and abroad. For example CAORG Report No. 40 (Radar Weather Messages) was sent to 101 addressees in Canada, Australia, India, UK, and USA.

Observations on Army Operational Research

Prior to leaving CAORG and the Canadian Army, Dr J.T. Wilson submitted to the Deputy Chief of the General Staff (C) a memo on lessons learned on operational research during the war (Ref 11). Among other points it noted the following observations which are worth repeating here:

- a. It was soon realized by the Army that theoretical methods and field trials could not provide all the answers that were sought to problems that arose;
- b. As a result OR sections were established as a part of the field forces;
- c. It was appreciated that OR in the field could not be undertaken successfully by regimental officers in addition to normal duties;
- d. Post-mortem investigations making use of information from routine sources such as war diaries are of little value and cannot replace investigations made during the course of a battle in which trained investigators collect quantitative data;
- e. It is important that OR be carried out at training centres or with a unit and not in a university laboratory;

- f. It does not appear that the work of CAORG could have been done by other development agencies.

Personnel

A large number of officers, other ranks, and civilians were on the staff of the Army System of Operational Research during its lifetime. Mention of those at the field establishments and on overseas duty have been made above. A list of the officers and civilians of officer equivalent ranks on the staffs at the DOR and CAORG is given in Annex C. This listing also includes the names of many of the other ranks and civilians on the support staff of the DOR. A more complete listing of personnel serving in Army OR work during WWII is given in Ref 11, Vol. II.

Of the many scientists employed in OR work with the Army in WWII only a few continued in OR work after the reactivation of OR support after the War. Those who did, either as full-time or part-time staff members, were Drs. T.W. Cook, K.C. Fisher, G.R. Lindsey, J.S. Vigder, Messrs J.E.D. McCord and A.F.B. Stannard, and Major (later Lt Col) F.G.B. Maskell. Their experiences, capabilities, and dedication were vital to the success of the post-war OR organization. Accounts of their contributions will be found in Ref 6, 7, 8, and 11.

Mention has already been made of many of the Army officers whose foresight, assistance, and co-operation made the adoption of OR in the Canadian Army possible and successful. These include General A.G.L. McNaughton,

Brigadiers T. Earnshaw, M.H.S. Penhale, and S.F. Clark, and Colonels F.F. Fulton and W.W. Goforth. Others deserving mention are Lieutenant Generals C. Foulkes and K. Stuart, and Brigadier G.P. Morrison (Ref 3). To these officers and many others not named here, credit must be given for their faith in, advocacy of, and support for OR as a valuable aid to decisions concerning Army operations and plans. Without such help and active co-operation OR could not have been successfully introduced into the Canadian Army.

REMARKS ON MILITARY OPERATIONAL RESEARCH
DURING WORLD WAR II

This short account of operational research in the Canadian Armed Services during WWII does not attempt to assess the value of the contributions of the OR activities to the pursuit of the war. However, the account of projects undertaken and completed in Canada and several theatres abroad, speaks for itself. To attempt to determine the impact of the findings of these studies, and of the assistance and support provided in less formal forms, would be very time consuming and, in most cases, highly subjective. Since, irrespective of its definition, OR does provide input to decision making, but is normally only one of several inputs, the assessment of the direct influence of an OR project on a particular decision is almost indeterminate and usually very difficult to estimate with any confidence.

Despite this general caveat some authors have been prepared to make statements, quantitative or otherwise, about the general value of OR in WWII situations. For example, in Ref 2, Sir Charles Goodeve states that "the

analyses of the half dozen OR scientists at HQ Fighter Command formed the basis for the operation of the whole defence organization of Britain. It is estimated that radar itself increased the probability of interception (of enemy aircraft) by a factor of about 10, but that, in addition, this small operational research team increased the probability by a further factor of about 2, which together meant that the Air Force was made twenty times more powerful".

Another supportive statement is made by Sir Robert Watson-Watt in the Foreword to Ref 15. He says that "the title of this 'Three Steps to Victory' is an over-condensation of 'Three and a Half Steps to Victory'. The three steps in chronological order of conception are the Instantaneous Visual Radio Direction Finder, Radar, and Operational Research. He adds that the remaining half step was his acceleration of very high frequency radiotelephony for Fighter Command".

In Ref 16, Len Deighton states that "the name 'Operational Research' was coined by Watson-Watt. He defined this as 'investigation by scientific method on actual operations - current, recent, or impending - and explicitly directed to the better, more effective, and more economical conduct of similar operations in the future'. Although it never got the public attention that radar attracted, Operational Research eventually became just as important to the progress of the war".

There is some disagreement about who originated the term 'operational research'. Credit has been given to Harold Larnder (Ref.8), to A.P. Rowe (Ref.1), and to Sir Robert Watson-Watt (Refs.15 and 16). In a presentation to the Eight IFORS International Conference on Operational Research, Larnder mentions that the term 'operational research' was coined during discussions between A.P. Rowe, E.C. Williams, and himself in 1938. In Ref.17 Sir Solly Zuckerman states that P.M.S. Blackett, "if anyone deserved the description, was the father of operational research" and also says that he himself was "regarded as one of the founding fathers" of OR. But there is no real disagreement between reviewers of OR work in WWII about the value of the OR contributions. Indeed, a major contribution may be said to be the impetus and stimulation that OR gave to quantitative thinking and the appreciation of scientific analysis on the part of senior and junior officers of all military services.

It must also be realized that despite its inherent potential and the dedication and skill of its practitioners, OR in WWII, and military OR in general since then, would not have contributed very much without the assistance, co-operation, encouragement, and support of the military staffs which it sought to serve. There is in all human organizations some opposition to change, innovation, and the acceptance of new approaches and ideas. That such opposition or antipathy did not exist to any great extent in respect of OR in WWII attests the foresight, acumen, and willingness to improvise and adopt new procedures of the many military officers who came in contact with OR, and perhaps a ready recognition of their need for help on their part. An attempt has been made in the foregoing to mention many of these forward-looking officers particularly senior ones but the great majority of them must remain anonymous.

In Canada the helpful and contributing role of the NRC in the introduction and development of OR in the Canadian Armed Forces during WWII was essential. Insufficient recognition of, and credit for, the NRC contribution to OR have been given in this brief history. Similarly, the indispensable part played by OR and other scientists from the UK and USA in the development of OR in the Canadian Armed Forces during and after WWII has not received the attention and credit that it deserves. Hopefully, enough has been said about these contributions to give the reader some idea of their intrinsic and fundamental nature insofar as initial Canadian OR work was concerned.

It may be of passing interest to note the relative numbers of OR professional staff employed with the three Armed Services in WWII. Very roughly the numbers of OR personnel (officers and civilian scientists) with the RCN, RCAF, and CA were 10, 20, and 30 respectively, although they varied considerably from time to time. But the OR system with the Army had a relatively large support staff of other ranks, as compared to the OR units with the RCN and RCAF. The maximum strength of the Armed Forces during WWII occurred in 1944 and the figures as provided by the Directorate of History were approximately RCN 81,600, RCAF 210,000, and CA 495,000. These numbers are in the approximate ratio of 10:25:60. If all ranks are considered the OR staff with the RCN, RCAF, and CA were approximately in the ratio 10:20:60. The similarity in these ratios is interesting but, of course, not of any particular significance.

Mention has been made of the encouragements and support given by military officers to those initiating OR services in the Canadian Armed Forces. The names of these officers have been cited and their valuable contributions noted. This support occurred at all ranks in the Forces but approval for establishing OR services had to be obtained at the highest level. For this support and endorsement credit must go to the Chiefs and Vice Chiefs (or surrogates) of the Services during the relevant period (1942-1944).

CHAPTER III

CANADIAN MILITARY OPERATIONAL RESEARCH AFTER WORLD WAR II

INTRODUCTION

Within the Department of National Defence OR activities came temporarily to a close shortly after the end of WWII. In the RCAF the activity ceased around the end of December 1945, in the RCN at about the same time; Dr Johnstone's final report was dated August 1945 (Ref 11). In the Army OR work continued until mid-1947 but latterly with a very reduced complement of personnel.

There was a hiatus of from three to four years between the disbandment of OR in the Canadian Forces after WWII and the re-activation of military OR units following the establishment of the Defence Research Board (DRB) in 1947 (Ref 3). This lapse in continuity gave rise to many problems in recruiting staff, reviving interest, and developing and organizing working relations between the scientists and the military. However, due to the efforts of the Chairman Defence Research Board, Dr O.M. Solandt, who had been Director of AORG during part of the war, Dr N.W. Morton the first director of the post-war OR services in the Department, and many concerned Service Officers, an OR organization was formed early in 1949.

An agreement was reached between the DRB and the Armed Services that an OR team would be set up in each Service and within the Board, and that these would be staffed

largely by DRB scientists, with provision for the assignment of qualified Service officers at the discretion of each Service. The DRB, through an establishment specially set up for the purpose known as the Operational Research Group (ORG), was to give general technical supervision and support to the work of the Service Sections, whose civilian members belonged to the ORG, and plan their individual postings and careers. The program of each of the four units was the responsibility of the RCN, Army, RCAF, and DRB respectively but a committee called the Joint Operational Research Committee was set up to review programs periodically with a view to balance of effort, avoidance of duplication, and a reasonable apportionment of resources relative to need.

This scheme was successfully applied and gradually OR staff was recruited to work with the four sections. As the development of OR resources grew OR units were set up at Service Commands 'in the field' as well as at NDHQ and DRBHQ.

SCIENTIFIC ADVICE AND DIRECTION

As noted, the formation of OR units within the Armed Services was done with the understanding that OR in the Services would be a service rather than a DRB responsibility. In practice this agreement meant that the programs of work of the OR units were not the responsibility of DRB officials. However, the resources of DRBHQ which included at one time or another seven scientific directorates concerned with weapons research, engineering research, atomic research, personnel research, scientific and technical intelligence, and scientific information were available to the OR scientists

at DRBHQ and those seconded to the Armed Services. As well, the resources of the DRB Laboratories (or Establishments as they became later) were available to them. In addition, DRB published the formal reports, memoranda, and periodic progress reports of the OR units.

DRB staff were also available for consultation, advice, and providing technical information upon request. A further valuable link with DRB existed in the offices of the Scientific Advisors to the Service Chiefs. These Advisors were Senior DRB scientists stationed with the respective Services HQ at NDHQ in Ottawa. The Scientific Advisors were ever ready to assist the OR units and personnel in providing advice, scientific direction, and in 'opening doors' to senior military officers and to defence scientists in other countries, both North Atlantic Treaty Organization (NATO) and Commonwealth. During the period of this report the Scientific Advisors were: (i) To the Chief of the Air Staff: Dr J.J. Green 1949-1954; Dr J.W. Abrams 1954-1958; Dr J.C. Arnell 1958-1963; and Mr J.W. Cox 1963-1964; (ii) To the Chief of the Naval Staff: Dr G.S. Field 1948-1954; Dr F.H. Sanders 1955-1957; Dr Wm Ford 1958-1963; and Dr J.C. Arnell 1963-1964; (iii) To the Chief of the General Staff: Dr N.W. Morton 1954-1959; Mr G.D. Watson 1959-1961; Dr L.J. L'Heureux 1961-1963; Mr H.H. Watson 1963-1964.

ORGANIZATION AND PROCEDURES

Organizationally the OR units attached to the Services normally appeared as part of the military staff, usually reporting to the senior officer responsible for operations. The links between the field units and the ORG (or its successors) of DRB, and with DRB generally, were flexible and used for personnel, scientific, or technical purposes as required.

Due to the many organizational changes in OR units that took place from time to time they are described in the following sections in chronological order as far as conveniently possible. The general picture, however, exhibits a DRBHQ 'holding unit' of OR scientists which not only provided personnel for OR units in the Armed Services but also conducted OR and systems analysis studies of interest to more than one Service, with, in the case of the RCAF, first one then later two OR units at AFHQ, and up to seven field units. The other Services have had only one OR unit at NDHQ and one or two in the field. In addition Canadian OR scientists filled exchange postings with corresponding British organizations and served with the Canada-US Scientific Advisory Team (CUSSAT) in Washington and with various NATO formations such as Allied Forces Central Europe, Supreme Headquarters Allied Powers Europe (SHAPE), SHAPE Air Defence Technical Centre (SADTC), Supreme Allied Commander Atlantic (SACLANT) and the Anti-Submarine Warfare Research Centre in La Spezia, Italy.

In general, projects to be undertaken on behalf of the Armed Services were proposed by senior military officers, or were suggested to senior Service staff after discussions and negotiations between the OR staff within the Service and senior or "working level" staff officers. Similarly, projects undertaken by the ORG/DRB were agreed after discussions and consideration between members of that unit and the Armed Service concerned or with two or more Services as appropriate. In some cases the OR staff first prepared proposals for studies and then discussed them with the proper military authorities. In addition the OR units were, of course, available for tasking on short notice on

"quick-and-dirty" investigations, for assistance on mathematical and statistical problems, and for advising on technological matters as well. In pursuing the latter the OR staff could readily refer for assistance to the DRB Laboratories or specialists at DRBHQ Directorates and through them, or directly, to other scientific research agencies such as the NRC, if necessary.

Reporting on OR work done for the Armed Services has taken several forms. Sometimes the results were and are presented informally and verbally, in the form of inter-office memoranda or letters on files; sometimes they are given at formal or informal briefings; on other occasions published reports appear as documents controlled by the Armed Services concerned. But most frequently reports on OR work were presented first in briefings to interested senior Service staff and later appeared as publications in the DRB series of scientific reports.

For the sake of brevity details of OR studies undertaken for the Canadian Armed Services over the years since WWII and of OR personnel involved are not given in detail in the present report. Such details can be found in Refs 6, 7, and 8.

OPERATIONAL RESEARCH AT HEADQUARTERS
DEFENCE RESEARCH BOARD

General

Further changes in the organization of the ORG at DRBHQ resulted in two OR Sections being formed. One called the Weapons Systems Evaluation Section (WSES) under

Dr G.R. Lindsey, who had worked with the British AORG under Dr O.M. Solandt, was set up in 1951. The other turned out to be a double arrangement called the Statistical Analysis and Northern Operational Research Section. It was headed by J.W. Mayne and organized in 1951 as well. In addition the ORG had for a time a Human Resources Research Section under Dr T.W. Cook and later under Mr Craig Mooney. Also briefly there was in the early 1950's a small section working on atomic problems under Mr T.K. Groves.

The two OR Sections continued in being for a number of years under different heads and with many changes in staff. The WSES carried out evaluations of weapon systems of interest to the Canadian Armed Forces, particularly those of joint or individual concern to the Army and Air Force. Its second leader was Mr E.L. Leese, an experienced OR analyst from the United Kingdom, who originally worked with the RCN and took over the Section in 1952. The WSES was a highly productive OR unit with a very competent staff. It ceased to exist as of 14 December 1955 and was replaced by the DRB Operational Research Section (DRB/ORS) with Mr G.D. Kaye as Chief. He too joined the DRB from the UK where he had worked with the AORG. On coming to Canada he first was on the staff of the Canadian Army Operational Research Establishment (CAORE) which was set up originally at the Royal Military College in Kingston, Ontario in January 1950.

The WSES carried out studies and issued reports on such subjects as the effectiveness of surface-to-air missile (SAM) systems, the comparative cost of fighter and SAM air defence, the effectiveness of various air defence tactics,

detection probabilities of the Canadian air defence radar system, requirements of Canadian interception defence systems, the reaction of AA defences to attacks by more than one aircraft, etc. Its staff consisted of both DRB scientists and Service officers.

The Statistical Analysis and Northern Operational Research Section worked on two quite different types of studies; first the design and analysis of field trials and laboratory experiments and, secondly, the investigation of operational problems related to the Mobile Strike Force. The Northern Operational Research Section (NORS) was disbanded in October 1953 when Mr Mayne was posted to the Joint Services Operational Research Team in Edmonton. Studies on northern operations were conducted from there in collaboration with the Operational Research Section of the Defence Research Northern Laboratory at Churchill, Manitoba. For about one year the NORS had an OR scientist from the US Army ORO, Mr N. Hitchman working with it.

From 1955-1958 OR work at DRBHQ of interest to more than one Service was conducted by the DRB/ORS. It was a period of increased interest concerning the air defence of Canada and North America. The analyses undertaken were concerned mainly with defence against enemy bomber and missile attack and the effectiveness of civil defence measures.

A further reorganization in June 1958 (Ref 8) resulted in the DRB/ORS continuing under that name with Mr H.H. Watson as Head. Work was done on defence against intercontinental ballistic missiles, satellites and defence

systems of the future. The Section was disbanded on 1 June 1959 to permit the formation of a combined evaluation and analysis staff originally designated the Defence Systems Evaluation Group but soon renamed the Defence Systems Analysis Group (DSAG). The purpose of this Group was to provide an integrated approach in analysing and evaluating major defence systems. The DSAG's first Head was Dr G.R. Lindsey. Its original strength was 8 OR scientists and 3 Service officers, one from each Service.

The Computation and Analysis Section (COMANSEC) organized in 1958 continued in being until the major reorganization of the OR services in 1965 following the integration of the Armed Services. It conducted specialized defence studies (prior to establishment of DSAG), provided a consulting service to DRB in the field of computation, advice and assistance in mathematical and statistical analysis to DRB and to the ORG sections attached to the Services, and also served for training and indoctrinating newly appointed ORG staff.

The Defence Systems Analysis Group

The major work on DSAG was concerned with defence against ballistic missile attack. Related work continued from 1959-1964. In addition studies were done on arms control problems, on surveillance and communications satellites, and on the capabilities of hydrofoil craft and other maritime projects.

In the summer of 1961 Dr Lindsey was posted to the SACLANT Anti-Submarine Warfare Research Centre and was succeeded by Dr J.W. Abrams on his return from a posting at

SHAPE, in Paris. He remained in the position until his retirement from DRB in November 1962. During the period January 1962 - November 1962 he held the dual posts of Director Systems Analysis Group (the new name for DSAG) and Chief of Operational Research. In the latter appointment he was succeeded by Dr R.J. Sutherland with effect from 1 January 1963. Dr Sutherland had been the DRB representative on the Joint Ballistic Missile Defence Staff which was responsible to the Chiefs of Staff Committee for all anti-intercontinental ballistic missile matters. In the 1962-63 period DSAG was organized into two sections headed by G.D. Kaye and J.W. Mayne and its name was changed to the Systems Analysis Group (SAG).

The SAG continued its work on the types of studies described above and on other similar problems. It disappeared as a separate entity on the reorganization of the OR resources in the Department effective 1 February 1965. It had on staff, at one time, for on-the-job training two NATO defence scientists.

Summary of Units and Personnel

Pertinent data on OR units at DRBHQ, their Heads, Chiefs, or Directors with relevant dates are presented in Table I below. Further details on the OR units, programs, and personnel that functioned at DRBHQ prior to 1 February 1965 may be found in Ref 8.

TABLE I

OPERATIONAL RESEARCH UNITS AT HEADQUARTERS
DEFENCE RESEARCH BOARD AND THEIR DIRECTORS
(1948-1965)

| <u>UNITS</u> | <u>HEAD, CHIEF OR DIRECTOR</u> | <u>DATES</u> |
|--|--|---|
| Directorate of OR | Dr N.W. Morton | 1948-1952 |
| Operational Research Gp DRB | Dr J.W. Abrams | 1952-1954 |
| Chief Operational Research (COR(DRB)) | Dr Wm. Petrie Dr J.W. Abrams | 1954-1962 1962-1963 |
| Operational Research Corps | Dr R.J. Sutherland | 1963-1965 |
| Operational Research Establishment | Dr R.J. Sutherland Dr G.R. Lindsey | 1965-1967 1967-1967 |
| Defence Operational Research Establishment | Dr G.R. Lindsey | 1967-1968 |
| Defence Research and Analysis Establishment | Dr G.R. Lindsey | 1968-1974 |
| Operational Research and Analysis Establishment | Dr G.R. Lindsey | 1974- |
| Weapons Systems Evaluation Section | Dr G.R. Lindsey Mr I.H. Cole Mr E.L. Leese Mr G.D. Kaye | 1951-1953 1953-1953 1953-1955 1955 |
| Statistical Analysis Section | Mr J.W. Mayne Mr G.D. Kaye | 1951-1953 1953-1955 |
| Northern Operational Research Section | Mr J.W. Mayne | 1951-1953 |
| DRB/ORS | Mr G.D. Kaye Mr H.H. Watson | 1955-1958 1958-1959 |
| COMANSEC | Mr G.D. Kaye Mr J. Laskoski Mr J.H. Morgan | 1958-1959 1959-1960 1960-1965 |
| Systems Analysis Group | Dr G.R. Lindsey Dr J.W. Abrams Dr R.J. Sutherland | 1959-1961 1961-1962 1963-1965 |

OPERATIONAL RESEARCH AT AIR FORCE HEADQUARTERSIntroduction

The first OR unit with the Armed Services organized after WWII was set up at Air Force HQ (AFHQ) in November 1948. This OR unit was originally designated the Directorate of Air Staff Services Operational Research Section (DASS/ORS). The DASS was a directorate under the Chief of Air Operations (CAOps).

Operational Research Sections and Directorates at Air Force Headquarters

The first Head of DASS/ORS was Mr J.E.D. McCord who had served with the CAORG in Ottawa during WWII. Two other DRB/ORG scientists joined the unit in 1950-1951. Assigned to the unit was S/L A.B.C. Weatherwax as the Air Force member.

In 1950 the DASS/ORS included one OR scientist (J.F. Ruddell) who was attached for OR duty to the RCAF Maritime Squadron of Maritime Air Group at Station Greenwood, N.S. This was the first post-WWII OR field unit with the Canadian Forces. His work was concerned with analysing problems related to Air Force operations in ASW.

In 1952 the AFHQ Section was headed by Mr I.H. Cole as Senior Operational Research Officer (SORO). Both Mr Cole and his successor Mr H.D. Poole were experienced and very capable OR scientists who were recruited in the UK (as were Messrs. Kaye and Leese) to assist DRB in

establishing an effective and productive OR staff for the study of Canadian defence problems. Mr Cole was a member of the original Operational Research Section at HQ RAF Fighter Command, Stanmore, UK. Mr Poole returned to the UK in 1965 but Mr Cole remained in Canada with DRB.

The work program of this OR unit included such projects as fighter aircraft tactics and control, aircraft armament, assessments of proposals for the air defence of Canada, electronic countermeasures, Air Force training, effectiveness of fighters and SAMs, analysis of air defence exercises and trials, and the cost effectiveness of various air-to-surface weapons. Other studies included the vulnerability of aircraft, effects of terrain masking, selection of tactical aircraft for the RCAF, and aircraft maintenance.

By 1955 the AFHQ operational research section was formally designated the Chief of Air Operations Operational Research Section (CAOps/ORS). Following Mr Poole's departure that year the Section was headed by E.L. Leese who had been Chief WSES. Mr Leese remained as Chief CAOps/ORS until 1956 when he was posted to the newly formed Directorate of Systems Evaluations as Deputy Director (Scientific). He in turn was succeeded by J.H. Morgan and he by J.F. Ruddell.

In April 1957 Mr Ruddell left to be SORO at 1 Air Division RCAF in Metz, France and R.P. Hypher took over the Section. He was followed by T.W. Fairlie and he by Dr Sidney Hellyer in January 1958 who had returned from an OR posting at SADTC, The Hague, Netherlands. In May 1958

the status of the Section was raised to that of a Directorate at AFHQ and renamed Chief of Operations ORS (COps/ORS). Again in April 1960 the unit was officially redesignated the Directorate of Operational Research Services, Air (DORS(Air)) a name which had been used earlier but not officially.

As DORS(Air) this directorate remained in being until after the integration of the Armed Services in 1964. During the period 1960-1965 the Director was E.L. Leese and his deputy was J.F. Ruddell. The Directorate was rather few in staff with at most 7 members.

It should be noted that this Directorate and its predecessors included the AFHQ Section of OR staff and the staff of the several field units with the RCAF. The HQ Section provided scientific and technical support as required by the field units and acted as a link to DRBHQ and the Superintendent ORG or as he was later called Chief of Operational Research (COR).

Directorate of Systems Evaluation

In November 1955 a new OR unit called the Directorate of Systems Evaluation (DSE) was set up at AFHQ to be responsible to the Chief of Operational Requirements for the evaluation of all future and proposed RCAF systems, and, where necessary, current RCAF systems insofar as they affected future and proposed systems. A joint DRB/RCAF Advisory Committee was established (effective 15 January 1956) to assign priorities to projects proposed for study and to ensure that the necessary assistance and expertise were made available to the new Directorate.

The first Director appointed was Mr H. Larnder who was posted to DSE late in 1955 from his previous appointment as Executive Director of CUSSAT in Washington, D.C. The Deputy Director Air was Group Captain G. McKenna and the Deputy Director Scientific was E.L. Leese as already noted. Personnel of the Directorate included 6 other scientists and 7 other RCAF officers.

During the life of DSE (November 1955 - February 1965) it undertook a large variety of major studies. To mention a few, evaluations were done on armament for the CF-105 aircraft, ballistic missile defence systems, the simulation of the operation of manned interceptors and BOMARC SAMs in a semi-automatic ground environment (SAGE), guidance requirements of an anti-missile missile, satellite reconnaissance networks, electronic countermeasures (ECM) trials, detection of submarines in barriers, and sonic devices for detecting submarines. Other studies were concerned with the coverage of ballistic missile early warning systems and forward acquisition radars, passive tracking procedures, ocean area surveillance, the performance of an explosive echo ranging system for detecting submarines, and of a moored-buoy ocean area surveillance system, the tracking of space vehicles from satellites or airborne platforms, orbital rendezvous of satellites, maritime warfare operations, and air transport requirements of the RCAF.

In March 1958 Mr K.J. Radford became Director DSE and he was succeeded in 1963 by Mr E.J. Bobyn who left in 1964 to become Superintendent of DRB's Suffield Experimental Station. On his departure DSE was directed by two acting

directors Mr J.L. Hudson and Wing Commander J.K. Young both of whom had been on the DSE staff for some years. In July 1964 DSE became responsible to the Assistant Chief of Defence Staff in the newly integrated defence HQ and the name DSE was changed to the Directorate of Systems Analysis (DSA). This unit in turn was disbanded as of 1 February 1965 when the OR resources at NDHQ were reorganized.

Throughout the course of its existence DSE (later DSA) was a highly productive unit which enjoyed very close and co-operative working relations with the senior RCAF officers at AFHQ and NDHQ. It was a relatively large directorate and the mix of DRB scientists and RCAF officers on its staff worked harmoniously and effectively together on a wide variety of challenging projects relating to future defence systems in both space defence and ASW. Further details of its personnel and work will be found in Ref 8. A brief account of OR at NDHQ following the integration of the Armed Services is given later in this Chapter.

Summary of Units and Directors

In view of the rather frequent changes in the names and heads or directors of the several OR units directly serving the RCAF at AFHQ during and after WWII, it may be helpful to summarize these. Such a summary is presented in Table II.

TABLE II
OPERATIONAL RESEARCH UNITS AT AIR FORCE
HEADQUARTERS AND THEIR DIRECTORS
(1942-1965)

| <u>NAME OF O.R. UNIT</u> | <u>HEAD, CHIEF, DIRECTOR, ETC.</u> | <u>DATES</u> |
|------------------------------|---|---|
| AFHQ/ORS | Prof. J.O. Wilhelm S/L P.M. Millman | 1942-1944 1944-1945 |
| DASS/ORS | J.E.D. McCord I.H. Cole H.D. Poole | 1948-1952 1952-1953 1953-1955 |
| CAOps/ORS | E.L. Leese J.H. Morgan J.F. Ruddell Dr T.W. Fairlie Dr S. Hellyer | 1955-1956 1956-1956 1956-1957 1957-1958 1958-1960 |
| DORS (Air) | Dr S. Hellyer E.L. Leese | 1960-1960 1960-1965 |
| COR/DSE | H. Larnder K.J. Radford E.J. Bobyn J.L. Hudson (co- director)* | 1956-1958 1958-1963 1963-1964 1964-1965 |

* With W/C J.K. Young

OPERATIONAL RESEARCH AT NAVAL HEADQUARTERSIntroduction

On 20 January 1949 the Vice Chairman DRB notified the Chief of the Naval Staff (CNS) that DRB was prepared to assign civilian OR officers to the RCN and suggested that a suitable RCN officer should be provided to work with the OR staff and assist in the definition of OR problems. In reply the Naval Board approved the establishing of a Directorate of Operational Research under the Vice Chief of the Naval Staff (VCNS) and recommended that a scientist rather than a Naval officer should head this Directorate. A RCN officer was not allocated at the time, nor later, although from time to time RCN officers were assigned temporarily to the RCN OR Directorate to work on specific projects.

Work started in OR for the RCN in the post-WWII period in March 1949, when one scientist Dr J.A.H. Duffie, was made available. Early in 1951 Mr Henry Montgomery reported for continuing employment on OR work for the RCN but Dr Duffie had already left. In May 1951 Dr J.S. Vigder joined the unit for summer work only but E.L. Leese joined on 15 June 1951 as a permanent employee and Head of the Directorate.

Although the original post-WWII OR unit with NSHQ was few in number several useful studies were completed in the period 1950-1952. These included a comparison of effectiveness of several naval guns, the effectiveness of certain torpedoes, and comparisons of destroyer escorts with aft and forward mounted guns.

General

Operational research work continued at NSHQ on a variety of problems despite the rather few scientists available to undertake studies. There were changes in the Naval Services organization at NDHQ and changes in OR staff from time to time. One noteworthy change was in the appointment of the head of the OR unit. In 1952 the unit became known as the Directorate of Operational Research (Navy) (DOR(N))* and the senior OR scientist was designated Director of Operational Research (Navy). He attended meetings of the Naval Staff and frequently presented findings by OR studies at these meetings as well as discussing agenda items as appropriate. The names and periods of service of these directors from then until the time of integration were:

| | |
|-------------|----------------|
| 1952 - 1955 | P.B. Wilson |
| 1955 - 1958 | J.W. Mayne |
| 1958 - 1965 | Dr J.S. Vigder |

The Period 1952-1955

During the period 1952-1955 the Director of DOR(N) was P.B. Wilson, an experienced OR analyst who came to DRB from the Directorate of Operational Research Admiralty, UK. DOR(N) reported to the Assistant Chief of Naval Staff (Air and Warfare).

* This abbreviation was used for both the Directorate and the Director.

The type of work undertaken during this period is indicated by the following subjects: air threat to Atlantic shipping, anti-submarine warfare, minesweeper operations, gunnery assessments, A/S requirements against modern submarines, improvement of air-to-air armament for naval fighter aircraft, radio warfare in the RCN, and the optimum utilization of merchant ships.

During this period it became clear that there was a need for more OR support at NSHQ. Gradually progress was made in this respect and by 1955 DOR(N) had a total of 6 scientists. One of these (K.R. Kavanagh) was detached with the RCN Operational Evaluation Organization (OPVAL) in Halifax. During 1954 DRB appointed an advisor to the Director of Naval Training. The first and only incumbent of the appointment was Mr F.H. Morrow who joined the DOR(N) staff in this capacity on 30 April 1954.

The Period 1955-1958

In October 1955 Mr Wilson was succeeded as Director DOR(N) by J.W. Mayne who had been at the Joint Services Operational Research Team (JSORT) in Edmonton. Both of these scientists later became Director of the Canadian Army Operational Research Establishment.

One of the most important investigations underway at the time was the development of the characteristics for a new class of destroyers referred to as the Improved Restigouche Class. Considerable time and effort was devoted to the study group on this subject by DOR(N) and his staff. Another investigation to which the DOR(N) staff made valuable

contributions was the development of tactics for defeating ballistic missile launching submarines by using available maritime forces. Concepts and tactics for this purpose were developed from theoretical considerations and tried out in exercises.

One of the major undertakings early in this period was a comparison of medium and close range AA guns to be fitted to the various classes of destroyers. Another was the determination of the requirements of a missile system for convoy defence. These projects were completed satisfactorily and in timely fashion.

A study of the estimated effectiveness of various force systems in support of an anti-submarine barrier was completed in July 1957. The report was a comprehensive cost/effectiveness analysis involving some twelve detection systems and various force systems providing the barrier. Another major study conducted later was the determination of the air defence requirements of the fleet on a study group basis which was done in conjunction with naval air staff officers. A statistical analysis and summary was made of the probable effects of weather and sea conditions on maritime operations in the North Atlantic. The results have been widely used in planning exercises and operations and in determining the sea and weather conditions which helicopters can be safely accepted on the decks of destroyer escort vessels.

Other studies that were conducted in this period were concerned with such topics as force requirements for the support of submarine detection systems, future requirements

for A/S ammunition, torpedo armament for RCN fixed and rotary wing aircraft, effectiveness of support systems in support of an anti-submarine barrier, effectiveness and requirements for air defence systems for the RCN, and the analyses of a super-sonic interceptor with an infra-red homing air-to-air missile. Still other subjects that were studied included early warning requirements and radio warfare aspects of the air defence of shipping, radar silence policies in the defence of shipping, and the possible use of radars mounted on transatlantic commercial and military aircraft as an anti-submarine confusion device, bearing accuracy requirements of shipborne sonars used with medium and long range attack systems, and the effectiveness of Mk 44 torpedoes used by surface ships. Toward the end of the period much work was done with the naval staff in developing and analysing the concept of operating A/S helicopters from the decks of Canadian frigates and destroyer escort vessels.

The staff of DOR(N) increased slightly during this period. By 1958 the total strength was 7 scientists including the Training Advisor and one scientist (D.M. Murray) who was attached to the Joint Maritime Warfare School in Halifax. Also Mr Kavanagh remained at OPVAL in Halifax.

The Period 1958-1965

During this period the Director of DOR(N) was Dr J.S. Vigder whose name has appeared previously in this paper. He was a competent mathematician and an experienced OR scientist who had recently been Deputy Director Canadian Army Operational Research Establishment (1957-1958). He succeeded J.W. Mayne in July 1958 on the latter's posting to the SADTC.

Examples of the type of work being done by DOR(N) in the late 1950's were three studies completed in the Fall of 1958 by Mr J. Langis under the direction of Dr Vigder, DOR(N), on fitting frigates with helicopters, fitting St. Laurent class destroyers with helicopters and long range sonar, and on the modernization of the vessels SIOUX and CRUSADER. A further specific study requested in August 1958 by Captain P.F.X. Russell, Director Undersea Warfare, concerned the usefulness of ASW helicopters operated from escort vessels.

Other OR work conducted during the latter part of the 1950-1960 decade included studies in the following areas: modernization of the CS2F Tracker aircraft; the use of homing torpedoes rather than depth charges; the RCN requirement for submarines; the air defence of escort vessels; equipment for escort vessels; the possible use of hydrofoils in ASW; and the potential of ship-borne sonobuoys. The nature and scope of other studies can be had from the titles of the publications given in Ref 7.

About half of DRB operational research staff in Naval Headquarters was engaged in studying systems to meet long-term requirements. This group worked in the analysis and evaluation division of the Director of Naval Operational Requirements (DNOR). Because future roles cannot be predicted with certainty, a broad range of requirements had to be examined. Some unconventional systems were being studied, with a view to obtaining the best cost-effective results for a number of specific roles.

The remainder of the staff worked in the weapons requirements division of the DNOR. This group was engaged in evaluating present systems and proposals for new weapons. Most of this work was in the anti-submarine field, and an extensive study of the effectiveness of modern escorts was done. Other studies included airborne systems, harbour defence, and the capabilities of the 3"/70 naval guns.

In the latter part of this period (1963-1965) the activities in naval OR work at NDHQ ranged over a great variety of projects. Among these were: war gaming ASW operations, planning exercises for testing the use of moored sonobuoys, operational use of hydrofoil craft, performance of towed ultra deep sonars, ammunition requirements, maritime requirements for peacekeeping, and ASW in the Arctic.

The DOR(N) staff also participated in a number of important studies on a joint or contributory basis. These included a re-examination of RCN objectives, the composition and cost of a mobile force, the size and composition of the future RCN, and the major alternatives available to Canada in the field of maritime warfare systems during the next decade (1964-1974).

The record shows that the authorized establishment of DOR(N) in 1962 was eight DRB scientists and no naval officers. But the RCN always provided officers to assist with the special studies on an as and when required basis. However, the number of OR scientists on strength even in 1964 was only seven including the Director. In November 1964, the DOR(N) staff members were: Dr J.S. Vigder (Director),

J.E.D. McCord, Dr A.C. Lauriston, J.G. Jones, R.D. Wilmot, R.S. Keir, and W.S.P. Ward. Further details on personnel and projects are presented in Ref 7.

OPERATIONAL RESEARCH AT ARMY HEADQUARTERS

Introduction

The date of the post-WWII beginning of OR for the Canadian Army was 17 November 1949 when authorization was issued for setting up the Canadian Army Operational Research Establishment (CAORE) at the Royal Military College in Kingston, Ontario, with effect from 22 December 1949. The Directorate of Weapons Development at Army Headquarters (AHQ) was made responsible for coordinating all staff aspects of CAORE activities.

The original member of CAORE was Major F.G.B. Maskell who had served in OR overseas during WWII. By May 1950 the staff was enlarged to 5 members including G.D. Kaye and Major H. Goodfellow. In May 1951 Dr A.C. Lauriston joined the staff but Major Goodfellow left to set up 1 Canadian Army Operational Research Team in Korea.

In 1951 the practice of employing students in CAORG during the summer was initiated and continued each year thereafter. Incidentally, a similar procedure was in vogue in all OR units of the DRB/ORG, and has continued ever since.

The Work Program

The original program consisted of some 60 projects submitted by AHQ Directorates. This large set of proposals was soon reduced to 17 projects of which only 9 were actually undertaken. These included a study of bridging requirements, the investigation of variable time fuzes in warheads, estimating Army manpower requirements, and lethality studies of mortar bombs in snow. Other early work included a comparison of certain British and US weapons, work on anti-tank weapons, and an investigation of northern land warfare.

In 1954 provision was made for the move of CAORE from Kingston to Ottawa, the relocation to be completed by 1 December 1954. This move eliminated some liaison problems between CAORE and AHQ. CAORE was then reorganized under a Senior Research Officer reporting to the Deputy Chief General Staff. Its program was made subject to review by an Operational Research Committee chaired by the Deputy Chief General Staff.

Canadian Army Operational Research Establishment at National Defence Headquarters

CAORE continued as an active and growing establishment at NDHQ from December 1954 until its organization was altered in February 1965 as a result of the integration of the Canadian Armed Forces. During this period its complement increased from six to seven in 1954 to 50 in 1964/65 and it had six different directors including Dr D.B.W. Robinson who held the appointment as Senior Research Officer (SRO). On

1 April 1957 the title "Senior Research Officer CAORE" was re-designated "Director, CAORE" (D/CAORE). The names and periods of service of these directors were as follows:

| | |
|--------------|---------------------------|
| 1954-1956 | D.B.W. Robinson (SRO) |
| 1956-1957 | P.B. Wilson (D/CAORE) |
| 1957-1959 | R.J. Sutherland (D/CAORE) |
| 1959-1963 | H.H. Watson (D/CAORE) |
| 1963-Sep-Nov | R.W. Rae (D/CAORE) |
| 1963-1965 | J.W. Mayne (D/CAORE). |

Among other developments, the size and scope of the establishment warranted the appointment of the position of Deputy Director in 1957. The incumbents of this appointment and their terms of office were:

| | |
|-----------|-----------------|
| 1956-1957 | R.J. Sutherland |
| 1957-1958 | J.S. Vigder |
| 1958-1963 | R.W. Rae |
| 1964-1965 | L.J. Byrne |

Under the leadership of Dr Robinson CAORE grew in size and influence. There were many problems to be resolved and day-to-day working relations with AHQ Directorates had to be encouraged and put on a mutually satisfactory basis. The help and advice of the SA/CGS, Dr N.W. Morton, were particularly useful during the early days of CAORE at NDHQ.

Among projects undertaken and completed at this time were the standardization of vehicles and engineering equipment of the North West Highway System, studies of Army reinforcements,

the effectiveness of artillery fire, and the determination of proper butt lengths for army rifles.

In this period arrangements were completed for the exchange of OR scientists with the UK War Office AORG. The first exchange scientists were Dr W.L. Archer from CAORE and R.W. Brittain from AORG. This practice continued until the early 1960's. Also two DRB scientists joined CAORE in this period to work on training problems and human factors.

The Period 1956-1957

In this period under P.B. Wilson several new advances in the CAORE program of work were started. These included the organizing and staffing of war game facilities, the provision of direct scientific assistance to the Army in the design, conduct, and analysis of field trials and experiments (on Army equipment, clothing, and general stores), and the study of the use and effects of nuclear weapons.

The CAORE staff increased and Army officers were seconded to CAORE to conduct war games. Organizing war gaming for the Army within CAORE was done mainly by Major J.W. Stafford and Mr C.E. Law.

The Period 1957-1959

The Director during this period was Dr R.J. Sutherland, an experienced OR analyst and ex-army officer, who later became Director General of the OR Division which was

established after the integration of the Armed Forces. During his term of office CAORE increased in size and influence, at home and abroad.

Projects that were successfully undertaken included air defence and national survival problems, automatic data processing systems for the Canadian Army, ATk defence, improvement of Centurion tanks, and studies of clothing and protective equipment. CAORE continued and expanded its contribution to tripartite and other international conferences on OR. War gaming activities also increased in scope and importance.

The Period 1959-1963

In 1959 Mr H.H. Watson became D/CAORE and remained in this post until he was appointed Scientific Advisor to the Chief of the General Staff. He was succeeded by Mr R.W. Rae who had been Deputy Director CAORE for several years. He resigned in November 1963 having been Director less than four months.

An internal reorganization during this period resulted in CAORE having two wings, one dealing with systems studies and the other with tactical studies. War gaming was conducted in the latter wing. The work program was extended to include more participation in Army summer exercise concentrations in the field, work on battlefield surveillance and combat intelligence, studies of anti-tank warfare and of operations on a nuclear battlefield. A very interesting innovation was the use of three distinct techniques jointly for attacking some Army problems - war

gaming, analysis, and field experimentation. Another development that added to the relevance and timeliness of CAORE studies at this time was an arrangement whereby an annual work program was prepared in consultation with AHQ Directorates and an approved program with priorities assigned to projects was authorized by The Army Research and Development Committee after being reviewed by the Army Combat Development and Tactical Doctrine Committee.

The Period 1963-1965.

The next and final Director of CAORE was Mr J.W. Mayne, an ex-Army officer and experienced OR analyst who had done considerable Army OR work while with the Northern Operational Research Section. During his tenure CAORE reached its maximum strength, a total of 50 personnel which included 15 military staff on war gaming.

The work program continued as under previous Directors but new projects were started in the areas of field mobility and logistics and improvements were made in CAORE's method of developing and approving its research program. The new programs provided for some 15% of the available effort to be devoted to internally generated projects. A further change was an increased emphasis on presenting formal and informal briefings to project sponsors and senior military staff on progress and results of OR studies.

At the time of integration of the Armed Forces (1964) CAORE was the largest, and probably the most productive, operational research unit in Canada. It had grown progressively over the years after WWII and established the value of the operational research approach in military studies and provided trained personnel for other military and some civilian OR groups. It had earned the full confidence of senior Army staff to the extent that virtually no decisions regarding introducing new equipment or operational tactics were made without CAORE being consulted and appropriate OR analyses conducted.

OPERATIONAL RESEARCH AT MILITARY FIELD COMMANDS IN CANADA

Operational Research at RCAF Commands

The first OR unit in a RCAF Command after WWII was the one-man staff at the Maritime Air Groups Station at Greenwood, N.S., already mentioned. There were six other RCAF Commands/Regions which had OR teams or sections and there was one at the Joint Maritime Warfare School, Halifax, N.S., called the Anti-Submarine Warfare Operational Research Team (ASW/ORT).

An OR unit was set up in 1957 at Maritime Air Command HQ, Halifax under R.P. Hypher who was followed as SORO by A.G. Staflund and D.A. Grant. Most of the OR work was concerned with ASW operations.

In August 1951 the first OR scientist reported for duty at HQ Air Defence Command. He was W.J. Franks. He was succeeded by H. Larnder, one of the founding fathers of

operational research, in January 1952. Mr Larnder became the first SORO of the Command and scientific advisor to the Air Officer Commanding. This unit which became the Operational Research Branch (ORB) in 1953 was particularly effective and productive under the leadership of Harold Larnder, Dr G.R. Lindsey, and R.L. Baglow. It conducted many successful studies on air defence operations. The maximum complement of the Branch was 7 scientists in 1958.

The OR Branch at Air Defence Command (ADC/ORB) was a very active and successful unit. Details of its history, personnel, and achievements are given in Ref 8 but some brief mention of its activities are certainly warranted. Projects undertaken by the ADC/ORB were many and varied. During the period 1952-53 under Harold Larnder such investigations as AA artillery studies, analyses of air defence exercises, studies of the optimum tactical location of the Mid-Canada Line of radars, analyses of expected radar coverage, and interception capabilities of the air defence system were conducted.

During the period 1954-1959 under Dr G.R. Lindsey the ORB grew in size and influence. Among the many projects undertaken were studies and investigations concerning electronic data processing for the aircraft control and warning system, radar performance, tactical use of the Mid-Canada Line, ECM, air defence capabilities, capacity required by a ground control interception system for manned fighters, ambient lighting in operation rooms, air defence concepts and procedures, counter-ECM activities, and analysis of electronic warfare trials.

Work of the type just mentioned was continued under the next Director R.L. Baglow (1960-1964). In addition a major study of the maintenance of the CF-101 aircraft was undertaken and an elaborate model for the purpose was constructed, applied, and found very useful. A further study of importance involved the development of an assignment algorithm to generate personnel posting plans in order to optimize selected career criteria such as total cost, average cost, etc.

The Air Defence Command ORB continued at St. Hubert, Quebec until after the integration of the Armed Services at what became HQ Mobile Command. Its last SORO was Dr J.J. Conn who remained SORO at the new Command HQ.

During the period 1952-1956 there was an OR team at the Joint Service HQ in Edmonton which worked for Tactical Air Command and Western Army Command. It was known as the Joint Services Operational Research Team (JSORT). Its first leader was W.E. Stevens who was followed by J.W. Mayne in 1953 and he was succeeded by J.A. Easterbrook in 1955. The work of the team was concerned with both air and army operations in the North. It worked closely with an OR section at the Defence Research Northern Laboratory at Fort Churchill, Manitoba. Members of this Section were M.F. Coffey, E.C. Law, W.W. Mair, J.A. Easterbrook, and D.I. Ross. The two latter scientists became qualified parachutists in order to study problems associated with parachuting in the North.

In the summer of 1961 a one-man OR unit was set up at HQ Air Transport Command, Trenton, Ontario. This OR scientist was R.P. Hypher who remained there until 1970. This OR unit is still in being. The work, of course, is concerned with air transport problems.

Shortly after the Northern North American Air Defence Region HQ moved to North Bay, Ontario in 1963, an OR unit was organized to work for the Region. The first OR analyst there was John Laskoski who was joined in August 1963 by S.H. Woodend on his return from HQ 1 Air Division in Europe. This unit is still in existence and has continued work on air defence problems so well done earlier by the ORB at Air Defence Command.

Two other OR units that were involved with both air and naval problems are the teams at Maritime Command Atlantic and Maritime Command Pacific. Some remarks on these two units are given in the following section.

The names and heads of the several OR units serving the RCAF Commands and the Air element of the Armed Forces along with appropriate dates are shown in the following table. Further details on the activities and personnel of these units may be found in Ref 7 and 8.

TABLE III
OPERATIONAL RESEARCH UNITS AT RCAF
COMMANDS AND THEIR DIRECTORS
(1950-1968)

| <u>NAME OF O.R.</u> <u>UNIT</u> | <u>RELEVANT RCAF</u> <u>HQ</u> | <u>HEAD, CHIEF</u> <u>OR DIRECTOR</u> | <u>DATES</u> |
|------------------------------------|--|--|--------------|
| Maritime Air Command/ORB | Maritime Air Group (Greenwood, N.S.) | J.F. Ruddell | 1950-1952 |
| | Maritime Air Command (Halifax, N.S.) | R.P. Hypher | 1957-1961 |
| | | A.G. Staflund | 1961-1962 |
| | | D.A. Grant | 1962-1966 |
| Air Defence Command/ORB | Air Defence Command | W.J. Franks | 1951-1952 |
| | | H. Larnder | 1952-1954 |
| | | G.R. Lindsey | 1954-1959 |
| | | R.L. Baglow | 1959-1964 |
| | | J.J. Conn | 1964-1966 |
| JSORT | Joint HQ Tactical Air Command and Western Army Command | W.E. Stevens | 1952-1953 |
| | | J.W. Mayne | 1953-1955 |
| | | J.A. Easterbrook | 1955-1956 |
| Air Transport Command/ORS | Air Transport Command | R.P. Hypher | 1961-1970 |
| Directorate of OR/NNR | Northern NORAD Region | J. Laskoski | 1963-1963 |
| | | S.H. Woodend | 1963-1966 |
| ASW/ORT | Joint Maritime Warfare School (Maritime Command Atlantic) | W.J. Jones | 1952-1954 |
| | | J.E.D. McCord | 1954-1957 |
| | | R.L. Baglow | 1957-1957 |
| | | Dr N.J. Hopkins | 1957-1961 |
| | | M.F. Coffey | 1961-1966 |
| MARPAC/ORT | Maritime Command Pacific | K.R. Kavanagh | 1964-1968 |

Operational Research at Naval Commands

Brief mention has been made above about the OR units at HQ Naval Commands. The first of these in the post-WWII period was at Joint Maritime Warfare School in June 1952. The team was named ASW/ORT and its first two members were W.J. Jones and J.F. Ruddell. They were officially members of the DOR(N) staff. The work of the team was concerned mainly with ASW problems such as exercise analysis, procedures and methods for selecting sonar operators, and with submarine detection devices and procedures.

In April 1966 the name of ASW/ORT was changed to the Maritime Command Operational Research Branch and the SORO was re-designated Director. The Directors have been M.F. Coffey (1966-1968), D.A. Grant (1968-1973), D.M. Murray (1973-1977), and P.R. Anderson (1977 - present time).

For a short time there was one OR scientist at the Operational Evaluation Group in organization of the RCN in Halifax. The first OR analyst there was K.R. Kavanagh who reported for duty on 1 August 1955. This organization ceased to exist shortly after the integration of the Canadian Armed Forces (July 1964). The main function of the organization was to coordinate and supervise all operational evaluations carried out in RCN ships or establishments, in which work they were well served by the OR scientists in analysing evaluation findings.

In August 1964, one OR scientist, Mr K.R. Kavanagh was posted to HQ Maritime Command Pacific in Esquimalt, B.C. This unit, never more than 2 in number is still functioning there. The work of this OR team has been devoted to studies and scientific advice on ASW operations, exercise analysis, evaluating programs, and assisting in tactical trials and operational planning of the Command.

Operational Research at Army Commands

Unlike the RCAF and the RCN the Canadian Army concentrated its OR resources in CAORE and, following integration in its successors, i.e. the Directorate of Land Air Warfare Operational Research and the Directorate of Land Operational Research. However, as occasion required teams were set up temporarily outside NDHQ. Two of these were outside Canada and are noted in the next Section.

As already mentioned an OR team operated at HQ Western Command in Edmonton, Alberta for 4 years (1952-1956). It was the only OR field unit that worked with the Army in Canada until integration when OR services were provided at HQ Mobile Command, St. Hubert, Quebec. The first two SORO's there were Dr J.J. Conn and Mr F.J. Cripwell who followed him in September 1968. Further details on Army OR field units are given in Ref 6.

CANADIAN MILITARY OPERATIONAL RESEARCH
OUTSIDE CANADA

Operational research scientists of DRB have served at a number of posts abroad, some with the Armed Forces and some on other postings. Several of these were with the RCAF, two with the Canadian Army, at others with NATO, US, or UK OR units. Details of these postings are given in Refs 6, 7, and 8 and in the interests of brevity only brief mention is made herein.

In late 1953 five Canadian OR personnel and a secretary reported to Washington, D.C. under H. Larnder to provide the Canadian component of the Canada-US Scientific Advisory Team (CUSSAT). The purpose of the team was to analyse North American air defence problems for a Joint Military Study Group in putting forward recommendations for improving continental air defence. The work of CUSSAT came to an end in 1957 but D.A. Grant continued related work at the Pentagon until 1961.

In June 1954 Dr C.W. Leggatt joined the staff at DRB/ORG and was posted to HQ 1 Air Division at Metz, France. He was succeeded in 1957 by J.F. Ruddell and one or two OR scientists were at HQ 1 Air Division until integration of the Canadian Armed Forces. Since then 2 OR scientists have been maintained at the HQ Canadian Forces Europe in West Germany.

In mid-1957 E.L. Leese reported to the newly formed North American Air Defence (NORAD) HQ for OR work where he was soon joined by J.E.D. McCord. Canadian participation in OR analysis there is still in effect.

From 1 Sept 1954 until May 1958 one OR analyst was at HQ Allied Forces Central Europe. In 1955 Canada began providing one OR scientist to the Supreme Headquarters Allied Powers Europe (SHAPE) Air Defence Technical Centre (now SHAPE Technical Centre) and this contribution is still in effect. The second of these (J.W. Mayne) was re-posted from the Centre to start the first OR team at SHAPE itself in February 1959.

After the formation of DRB and the ORG two OR scientists served briefly with the OR staff at UK Admiralty in London. The first of these was Dr J.W. Abrams (1950-1952) and the second J.E.D. McCord (1952-1954).

In 1954 it was decided to introduce an exchange of OR scientists between CAORE and AORG in the UK. As already noted the first Canadian scientist to go to AORG on exchange was Dr W.L. Archer (1954-1956) and the first UK exchange scientist to be posted to CAORE was Mr R.W. Brittain (1954). The exchange arrangement continued until the early 1960's.

In the summer of 1951 Major Goodfellow of CAORE went to Korea to set up 1 Canadian Army Operational Research Team with Dr W.L. Archer a DRB scientist who had been in Korea as an OR analyst since December 1950 accredited to the Operations Research Office of the US Army. The Canadian OR Team continued work in Korea with 25 Canadian Infantry Brigade until it was disbanded in March 1954. Other OR scientists with the Team were G.D. Kaye, Dr A.C. Lauriston, Major F.G.B. Maskell, and Dr R.J. Sutherland. Only two

of them served at the same time. The team worked on user trials, counter bombardment techniques, wastage rates, artillery fire, and other problems.

In May 1955 another field team designated 2 Canadian Army Operational Research Team was established as an increment of 1 Canadian Infantry Brigade in West Germany. Mr R.W. Rae and Major F.J. Sergi formed the team and in June they were joined by Master Gunner Williams. They worked on problems concerning tank warfare and related subjects. The unit was closed down in May 1957. Among other investigations 2 CAORT studied requirements for field defence stores, vehicle accidents, and field exercises.

In 1961 Dr G.R. Lindsey was posted from SAG to head the OR Branch at the SACLANT ASW Research Centre in La Spezia, Italy, a position he filled with distinction until he was succeeded as Canadian OR representative at La Spezia by Mr J. Langis in 1964. Other Canadian OR scientists there have been Mr R.P. Hypher (1970-1973), Dr J.A. Scrimger (1973-1976), and Mr N.O. Fothergill (1977-1980).

In the 1970-1971 period when the Malaysian Government was planning on establishing a Defence Research Centre in Kuala Lumpur, Dr G.R. Lindsey, then Chief of the Defence Research Analysis Establishment (DRAE), was invited to visit Malaysia and comment on possible OR services at the Centre. He recommended that a small OR unit be included and on accepting this advice the Malaysian Government requested aid in the form of experienced OR analysts to help getting military OR started. Canada's response was to post OR scientists to the Malaysian Defence Research Centre for temporary duty.

The first two were Mr K.R. Kavanagh and Mr H. Marr (1971-1973), then Mr W. Ditto and M.F. Coffey (1974-1976), and finally Mr S.A. Brightwell who returned to Canada in 1977. Regrettably Mace Coffey died suddenly in Kuala Lumpur shortly after joining the OR staff there.

Some details of these OR units outside of Canada are summarized in Table IV.

MILITARY OPERATIONAL RESEARCH IN CANADA AFTER
INTEGRATION OF CANADIAN ARMED FORCES

Changes and Reorganizations

In early 1965 the organization of the OR services within the Department of National Defence was changed to adjust to the needs and new structure of the integrated Armed Forces. The new OR organization was adopted with effect from 1 February 1965. It consisted of an establishment of DRB scientists called the Operational Research Establishment (ORE) headed by a Chief Superintendent (CS/ORE) and an Operational Research Division (ORD) under a Director General responsive to the Chief of Defence Staff and manned by Canadian Forces and DRB personnel. The DRB personnel of both organizations were the same persons, and they differed only in that the ORD had a number of military personnel in addition to the DRB civilians. The interim organization of the ORD in which the title of the head of establishment was called Chief of Operational Research is shown in Chart I. The organization of the ORD shortly thereafter is shown in Chart II which includes the names of the several directors and heads of OR field units.

TABLE IV
OPERATIONAL RESEARCH UNITS OUTSIDE
CANADA - POST-WORLD WAR II

| Name of OR Unit | Relevant Headquarters | Canadian OR Head or Personnel | Dates |
|--|--|---|---|
| Directorate of OR, Admiralty | UK Admiralty | J.W. Abrams J.E.D. McCord | 1950-1952 1952-1954 |
| 1 CAORT | 25 Cdn Infantry Brigade (Korea) | W.L. Archer G.D. Kaye H. Goodfellow | 1950-1951 1951-1952 1951-1952 |
| CUSSAT | Military Study Group The Pentagon | H. Larnder I.H. Cole | 1953-1955 1955-1957 |
| AORG 1 Air Division/OAS | UK War Office HQ 1 Air Div. RCAF | W.L. Archer C.W. Leggatt J.R. Ruddell S.H. Woodend S.A. Brown | 1954-1956 1954-1957 1957-1960 1960-1963 1963-1965 |
| AAFCE/ORS | Allied Air Forces Central Europe | C. Barnes J.H. Morgan | 1954-1956 1956-1958 |
| Operational Division SADTC ¹ | SHAPE Air Defence Technical Centre | S. Hellyer J.W. Mayne N.J. Hopkins M.D.F. Boulton | 1955-1958 1958-1961 1961-1964 1964-1968 |
| 2 CAORT | Canadian Infantry Brigade (Europe) ² | R.W. Rae F.J. Sergi | 1955-1957 1955-1957 |
| Operations Analysis Directorate | NORAD | E.L. Leese J.E.D. McCord J.J. Conn J.P. Ruddell | 1957-1960 1960-1961 1961-1964 1964-1967 |
| Air Defence Division OR Branch | SHAPE | J.W. Mayne | 1958-1960 |
| SACLANT OR Division | SACLANT ASW Research Centre | G.R. Lindsey J. Langis R.P. Hypher | 1961-1964 1964-1967 1967-1970 |

¹ Later SHAPE Technical Centre, The Hague, Netherlands.

² The OR unit worked closely with the British OR unit with the British Army of The Rhine.

CHART I

INTERIM ORGANIZATION -
OPERATIONAL RESEARCH DIVISION

1 Feb 1965

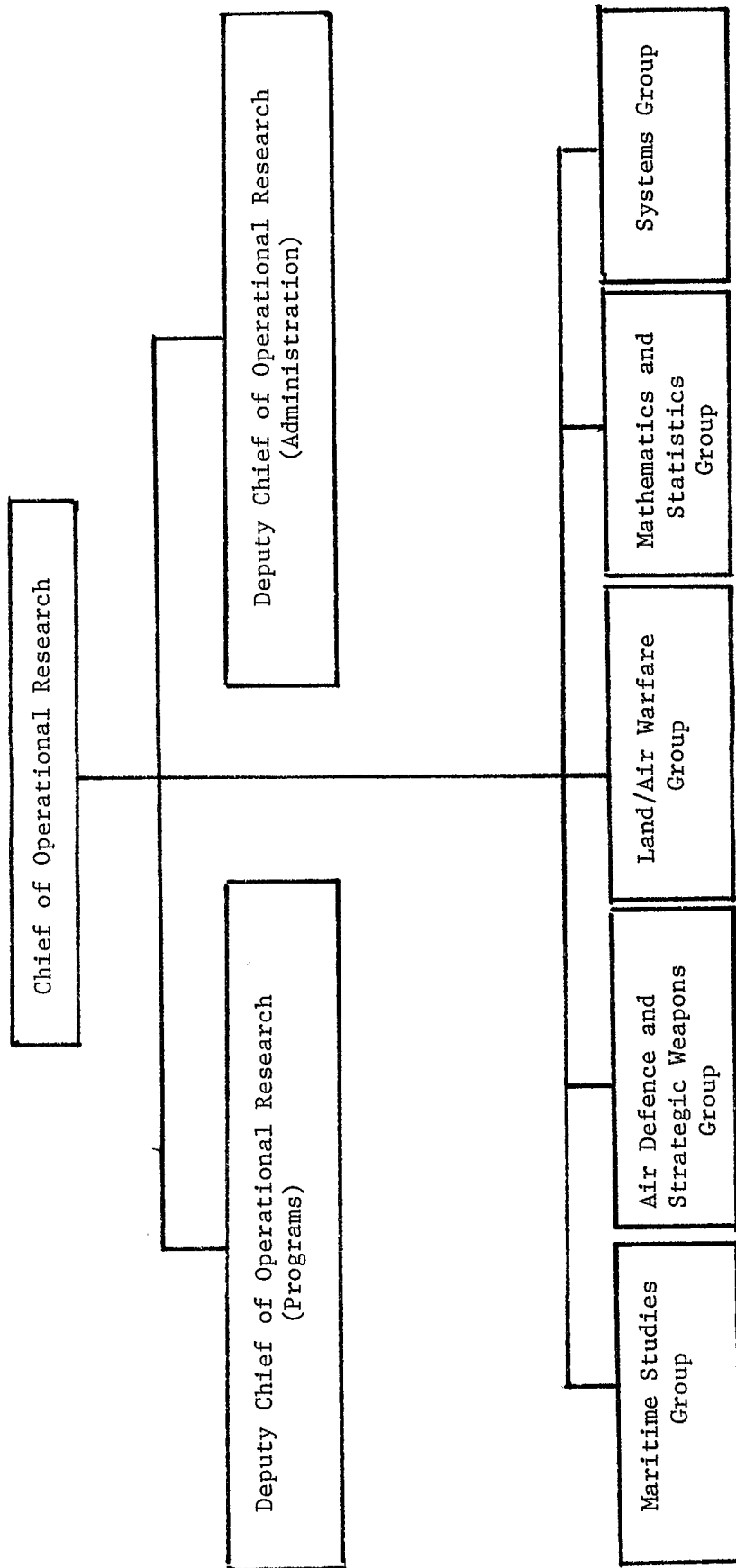
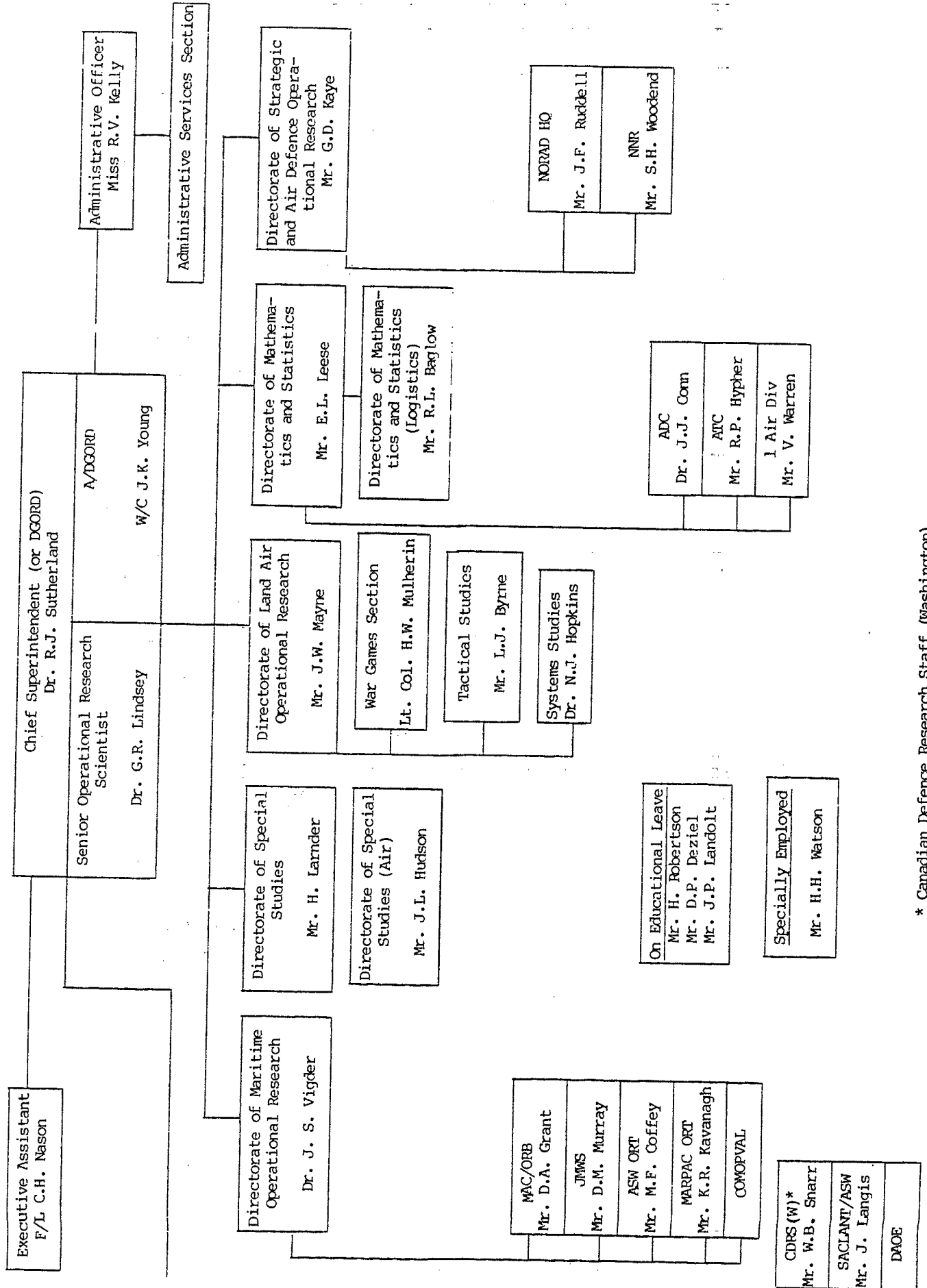


CHART II
ORGANIZATION OF THE OPERATIONAL RESEARCH ESTABLISHMENT



* Canadian Defence Research Staff (Washington)

The new ORE/ORD organization replaced the former OR elements (DOR(N)), CAORE, DORS(Air), DSA, and SAG), and the Chief of Operational Research, DRB. This position became in effect two, Chief Superintendent (CS/ORE) and Director General Operational Research Division (DG/ORD). These appointments were filled by one person. The first of these was Dr R.J. Sutherland who had been Chief of Operational Research DRB under the former organization. He held these posts until his untimely death in the spring of 1967. He was succeeded by Dr G.R. Lindsey, who has held these positions, or their equivalent with other names, until the present.

On 1 January 1966 there was another change in organization. The original one had two Deputy Chiefs, one for programs and one for administration and five Groups (Maritime Studies, Air Defence and Strategic Weapons, Land/Air Warfare, Mathematics and Statistics, and Systems). The revised one had a Senior Operational Research Officer and an Assistant DG/ORD. The Groups were renamed Directorates, and the Systems Group was replaced by a Directorate of Special Studies. Later in December 1967 the Directorate of Land Air Operational Research became the Directorate of Land Operational Research (DLOR), and Directorate of Air Operational Research (DAOR) was set up, and a Directorate of Strategic Operational Research was established with no responsibility for air defence matters which were assumed by the Air, Land, or Maritime OR Directorates as appropriate.

There were still other changes including the introduction of the name Defence Research and Analysis Establishment (DRAE) which became the Operational Research and Analysis Establishment (ORAE) effective 1 April 1974. These two Establishments consisted of two Divisions, the Operational Research Division and the General Analysis Division. The former had three Directorates (DAOR, DLOR, and Directorate of Maritime Operational Research (DMOR)) and was tasked directly by, and responsive to, the Deputy Chief of Defence Staff (DCDS). The General Analysis Division had five Directorates, the Directorates of Strategic Analysis, Manpower Analysis, Mathematics and Statistics, Social and Economic Analysis, and Logistics Analysis. Work on logistic analysis was started by R.L. Baglow in 1965 after some preliminary study of the need for OR in this area. He became the first Director of Logistics Analysis which was originally a sub-directorate of the Directorate of Mathematics and Statistics under E.L. Leese, which in turn was the successor to the former Statistical Analysis Section. In December 1973 the new Directorate called the Directorate of Social and Economic Analysis (DSEA) was set up to undertake analyses of social and economic issues of interest to the Department of National Defence. Its first Director was Mr S.H. Woodend who was succeeded in 1980 by Dr J.J. Conn.

There were also OR units in the field with Service Commands at Maritime Command, Maritime Command Pacific, Mobile Command, Canadian Forces Europe, Air Defence/Northern NORAD Region, Air Transport Command as before. Later an OR unit was set up at HQ Training Command, Winnipeg, Manitoba. Also the OR postings abroad have been maintained at NORAD HQ, STC, SACLANTCEN, and HQ Canadian Forces Europe.

The first Director General Operational Research Division was J.W. Mayne who held the post from 1968 till the end of 1974 when he retired to take up the NATO appointment of Chief Operations Research Division at the SHAPE Technical Centre, The Hague. He was succeeded by J.L. Hudson. Dr G.R. Lindsey served as both Chief of the Establishment (DRAE and later ORAE) and Director General Analysis Division. The ORAE comprised all Directorates of the former DRAE and the new DSEA. This revised organization is the one in effect today. In 1980 Mr S.H. Woodend was appointed Director General General Analysis Division and the position of Senior Operational Scientist, held for several years by G.D. Kaye, was deleted from the establishment on his retirement.

The first post-integration organization, the ORD, was made responsible to the Vice-Chief of the General Staff for tasking and reporting. But when the DRAE was established it was made responsible to the Assistant Deputy Minister for Policy at NDHQ. However, the Director General Operational Research and his Division were tasked by the DCDS and his senior officers. These arrangements are still in effect.

Personnel and Organizations

It should be noted that the OR resources in the Department of National Defence were never very large. The largest OR unit was CAORE which had an establishment of 22 scientists in 1960 but never more than 18 were on strength. The DOR(N), and DORS(Air) never had more than 6 or 7 scientists, and DSE and DSAG had at most 7 or 8.

The field units other than the ADC/ORB and ASW/ORT normally had one or two scientists, and the strength of those two larger teams never had more than 6 or 7 scientists. In March 1960, the complement of DRB scientists for OR was raised from 58 to 78 to meet the increases requested by the Services. However, it was not until many years later that the strength approached the 78 figure. At present (1980), the authorized establishment of ORAE is 146 of which 26 are military staff and 80 are scientists. Current strength varies from time to time but is about 75 scientists, 26 military officers and other ranks, and 20 civilian support staff. Organizational charts for DRAE as of August 1968 and of ORAE as at present are shown in Charts III and IV following.

The only OR units within the Department of National Defence have been those mentioned above. While DRB establishments other than the ORG or ORAE conducted work similar in some respects to OR, particularly systems analysis work at the Defence Research Establishment Valcartier (formerly the Canadian Armament Research and Development Establishment), none had or have OR units or branches under that name.

Since this report is concerned with the origins and early development of OR in Canada, further details of military OR after 1965 are not included herein. Indeed, an account of the last fifteen years (1965-1980) of OR in the Department of National Defence remains to be written although very brief accounts up to 1970 will be found in Refs. 6, 7, and 8. However, before ending this Chapter on military OR in Canada since WW II, mention must be made of the contribution to OR elsewhere in Canada and abroad and to the impact on planning and decision making within the Department of National Defence. An attempt to describe those contributions is made in the following section.

ORGANIZATION AND FUNCTIONAL CHART
DEFENCE RESEARCH ANALYSIS ESTABLISHMENT

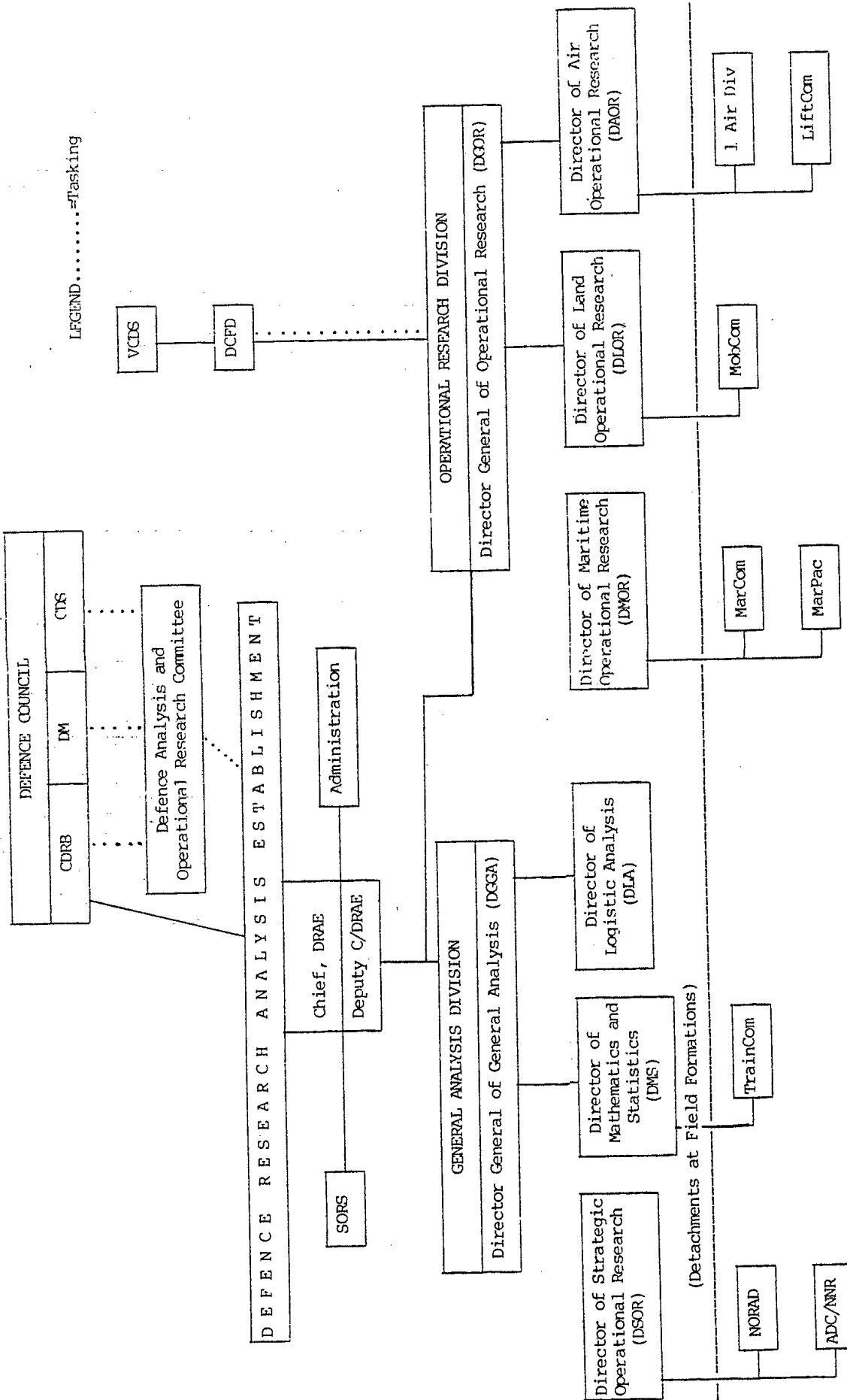
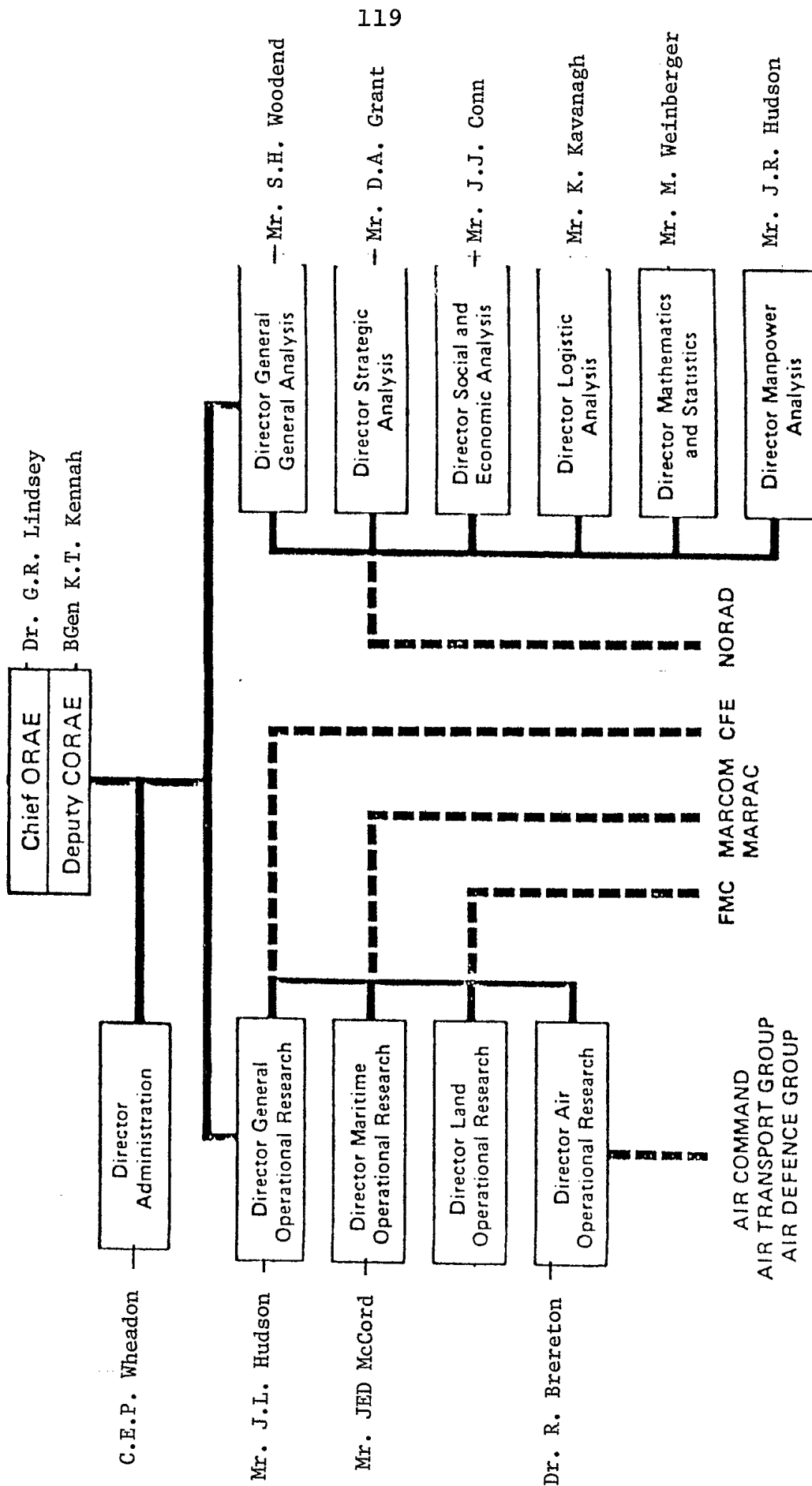


CHART IV

OPERATIONAL RESEARCH
AND
ANALYSIS ESTABLISHMENT



CONTRIBUTIONS OF CANADIAN
MILITARY OPERATIONAL RESEARCH

General Contributions

Some comments on the usefulness of OR in WW II are given above in the Research Section of Chapter II. Somewhat similar observations have been submitted by senior military officers of the Canadian Armed Forces. The continuing growth of the ORAE in itself attests to the invaluable contributions of military OR to operations, planning, procurement, and force composition in the Department of National Defence since WW II. ORAE has expanded and diversified its activities into the fields of logistics, arms limitation, strategy, and manpower, social, and economic analysis. Also, in response to the growing requirement for quantitative assessments in these and other areas ORAE has pioneered in the quantification of military capabilities in output terms. This flexibility and adaptability has helped enhance its credibility and usefulness.

In personal interviews and discussions with senior military officers of all three Armed Forces elements (Land, Sea and Air) regarding OR contributions since WW II, comments and opinions expressed included the following:

- (i) OR was, and is, very valuable and held in high regard;
- (ii) there is no question of its importance;
- (iii) OR has been used extensively by the RCN and has had tremendous impact in many areas such as the specifications of characteristics of new vessels, the performance capabilities of sonars, weapon systems, and other equipment, anti-submarine tactics, etc.;

- (iv) Since WW II, the relationship between OR and the military has strengthened to a point where joint military/scientific teamwork is accepted as essential to sound decision-making;
- (v) Virtually all major decisions incorporate OR analyses.

In a foreword to Ref.8, Air Marshal C.R. Dunlop, former Chief of the Air Staff, made the following statements:

It has been my privilege to have known and worked with many of the research scientists mentioned in this history. I can state categorically that their contribution to the Royal Canadian Air Force was invaluable. It is my firm belief that the partnership which has developed between the operational research scientist and the military must not only continue but must grow in strength. I sincerely hope that this historical sketch will contribute to this end.

Although many examples of the influence of OR findings on important decisions taken by senior management in the Department of National Defence could be mentioned, it is not always obvious just what part an OR study may have played in the final decision. For example, staff of ORAE made many important quantitative inputs to the extensive work leading up to a decision on the new fighter aircraft, particularly in respect of comparative cost-effectiveness analyses. But factors other than cost-effectiveness had to be taken into account, for example industrial benefits of the procurement program, where 'Canadian Content' should be provided, etc. Some of these factors had a political implication which the OR staff did not attempt to assess. Accordingly, the preceding general remarks are presented, without further detail, to indicate the high regard in which OR is held within the Department of National Defence and give some idea of the extent to which it is used and appreciated.

The OR organization, through the mechanism of DRB awards and NATO fellowships, provided on-the-job training in OR for NATO defence scientists from several countries including Belgium, France, Turkey, and Norway. Some details are presented in Ref.8.

As already noted, Canadian OR scientists served in several capacities with organizations and research centres outside of Canada, e.g. U.K. Admiralty, AORG, CUSSAT, NORAD, STC, SHAPE, SACLANTCEN, and the Ministry of Defence, Malaysia, as well as with the Canadian Forces abroad. They have also been active in maintaining liaison with OR units and personnel with UK, USA, France and Australia. They have contributed heavily to a variety of NATO, Tripartite, Quadripartite, and Commonwealth Committees and study groups.

Mention is made later in the report of the contributions of military OR personnel to the founding and on-going activities of the Canadian Operational Research Society (CORS) and the CORS Journal and its successor INFOR, the Canadian Journal of Operational Research and Information Processing. Eight of the early presidents of CORS were originally OR scientists of DRB (Drs. O.M. Solandt, G.R. Lindsey, J.W. Abrams, N.J. Hopkins, and Messrs K.J. Radford, H. Larnder, C.E. Law, and J.L. Hudson).

It perhaps should be observed that the staff of OR organizations of the DRB contributed a great deal to the development of OR in other government departments, both federal and provincial, and in industrial agencies, and universities. An important means of doing so was by training young scientists in OR methodology and techniques and their applications. These then left to accept, invariably, better paying positions in OR elsewhere. Other means were by publications in the open

literature, participation in conferences and meetings, as officers of the CORS, and as lecturers in courses and seminars on operational research at local universities (Carleton and Ottawa) and elsewhere. It should be noted that the interaction with OR personnel in industry, government and universities has been recognized and appreciated (Ref. 18) and that it is not a one way street. Some further comments on the contribution of military OR to the development of non-military OR in Canada are given in the next Chapter.

Personal Contributions

Much of the credit for establishing a viable OR organization within DRB after WW II must be attributed to the first Director General, later Chairman, DRB, Dr. O.M. Solandt who had been Head of the AORG in the UK during WW II. In his advocacy for, and support of, OR as an integral part of the DRB, he was aided and assisted by the first Vice Chairman (E.L.L. Davies), Dr. Otto Maass, Dean C.J. MacKenzie of the National Research Council, and by such senior military officers as Vice Admirals H.E. Reid and H.T.W. Grant, Gen. C. Foulks, Air Marshals R. Leckie and W.A. Curtis, AVM E.W. Stedman, Col. W.W. Goforth and L/Col A.M. Fordyce. Without the active encouragement and support of Dr. Solandt and those supporting him it is unlikely that OR in the Department of National Defence would have developed as quickly and effectively as it did, despite the need for it.

Among others who contributed much to the development of military OR in Canada in the post-WW II period should be mentioned Dr. N.W. Morton, the first Director of OR in the Department of National Defence, Dr. J.W. Abrams, his successor and in turn, after him, Dr. Wm. Petrie, Dr. R.J. Sutherland,

and Dr. G.R. Lindsey who also headed the military OR organizations. All of these scientists made extensive and valuable contributions as organizers and leaders and the latter two, particularly, as OR analysts also. All five of them were instrumental in enhancing the credibility of OR in the Armed Services, and, as heads of the military OR organization, provided foresight, efficient management, and attractive career opportunities and working arrangements for the OR staff. In particular, they all made careful and satisfactory selection of staff for the several OR appointments at home and abroad. Doing so was critically important in the early post WW II formative days of the ORG. In the careful recruitment and selection of OR staff, credit must also be given to the DRB Directors of Personnel and their personnel staff.

Finally, mention must be made in a general way, at least, of the many other contributors to the early growth and on-going development and application of OR in and for the Canadian Armed Forces. They include directors general, directors, section heads, project leaders, OR analysts, and support staff. Regrettably, a comprehensive list of these would be too lengthy to include in this report. Their names and the units in which they served are given in Refs. 6, 7 and 8 and some are named in Chart IV. Their dedication, enthusiasm, capability, and persistence as project leaders and analysts were vital to the success of military OR in Canada and to them much of the credit for the credibility and achievements of the OR units is due. Without their efforts and contributions, and those of the military and support staff who worked with them, little of real value could have been accomplished.

Comprehensive lists of publications by military OR analysts in the first WW II period up to 1965 are given in Annexes to Refs. 6,7 and 8. These lists of titles are quite extensive and are not reproduced here. Most of the publications are classified and not available as open literature.

CHAPTER IV

ORIGINS OF NON-MILITARY OPERATIONAL

RESEARCH IN CANADA

INTRODUCTION

In trying to determine the origins of OR in any area of application, the twin difficulties of the definition of OR, and the use of what is generally said to be OR methodology by scientists, engineers, economists, and others who are not organized into OR units confuse attempts to establish 'origins'. There can be little doubt that OR methodology came to be applied in many Canadian businesses, industries, and levels of government shortly after its first use by the Canadian Armed Forces, usually without OR units being set up under that name or the practitioners calling their type of work OR. Accordingly, any treatment of the subject must necessarily be approximate only.

Records show that outside the Department of National Defence, the earliest activity in OR in Canada occurred in certain businesses and industries in Ontario in the early 1950's, then courses in OR were started in universities in the mid-fifties, and in other federal government departments and agencies in the early to mid-sixties. Among provincial governments, the earliest reported use of OR, by departments, was in the early 1950's, while the first OR unit organized under that name was in 1965. Earlier, in 1952, OR methodology was introduced into the study of the operations of the Energy Resources Conservation Board of Alberta and by the Petroleum and Natural Gas Conservation Board of Alberta in 1956. It was not until the early seventies that municipal and regional governments in Canada started to set up OR units or employ OR personnel on a full-time basis.

The first Canadian university to offer a course in OR was the University of Toronto which began an evening extension course in the subject in the mid-fifties. The first OR courses in degree programmes were also given at the University of Toronto in 1958. Other Canadian universities and colleges soon followed suit and by 1970 OR courses and programmes were given by at least 21 institutions. By 1978, the number had risen to at least thirty (Ref.19), and by 1980 to thirty-five.

RELEVANT FACTORS

Although the success of military OR in WWII had much to do with the early development and growth of OR in non-military areas, there were other causes as well. A number of prominent Canadian practitioners and users of OR in all areas of application were queried on how they first learned about OR and what factors they thought were most influential in the development and growth of OR in Canada. A summary of their responses is given in the following paragraphs.

There was a wide variety of ways in which OR workers and users first became acquainted with the subject. These included discussions with other people, reading research papers and technical literature (including the Canadian Operational Research Journal, the UK Operational Research Quarterly, and the US Journal of Operational Research and Systems Analysis), by being confronted by complicated problems at work, and by doing OR-type work without knowing that it was what they later learned was known as OR. Another important source of learning about OR was universities in Canada, UK, and the USA. Several responses were to the effect that on-the-job challenges required new approaches and the need to apply computers

to complex problems and that these in turn prompted the investigators to learn about and apply OR methodology.* Others were employed by agencies and government departments where OR was being practised, for example in the Federal Department of National Defence. Again, some first learned of OR by attending conferences, meetings, and seminars where papers using OR were presented and discussed. Others learned about OR in the UK before coming to Canada. Some worked in OR and came to Canada to practise. One reply noted that first acquaintance with OR came from applying computers to the planning and scheduling of problems of a large oil company in the mid-1950's. Thus, many different means have been responsible for learning about OR in Canada. Fortunately, many of these led to learning more about OR methodology and employing it successfully in a wide range of applications.

There was considerable agreement on the factors considered to be most influential in the development and growth of OR in Canada, although the replies covered a range of factors. One of the main factors cited was the influence of the effective use of OR by the Defence Research Board and Department of National Defence, i.e. of military OR. Specific mention was made of the beneficial influence of the interest and dedication of a few experienced veterans of military OR in WWII. Similarly, some thought that a major factor was the successful use of OR by governments, business, and industry, and particularly by large industrial and business organizations such as Air Canada, Canadian National Railways, Ontario Hydro, and oil and paper companies. Other replies noted that the influx of OR scientists from Europe, particularly the UK, and the development on growth of OR in the USA were important factors. Several mentioned the importance of university courses in OR and related subjects

* In some cases by taking courses in OR, for example, one of the OR pioneers Dr. J.G. Debanné, while with the Texaco Exploration Company in Calgary, learned about OR by taking a course in the subject given by Dr. Jack Sherman of Texaco's Beacon Laboratories, New York in 1955.

and the formal adoption of OR in the curricula of engineering and business schools as strong contributing factors. One respondent considered that the propagation of OR through formal educational programs and research at the university level has been extremely important and that without the university effort OR "would have withered many years ago!"

Several other factors that contributed a major influence in the development of OR in Canada were the growing awareness of the need to maintain productivity in the face of competition, the increasing complexity of decision making, the search for more efficient business practices, dealing effectively with increasing technical complexity, the nature of production processes, and dissatisfaction with the way affairs had previously been conducted (without OR). Still others were the development of computer methodology, the advent of a group of qualified practitioners, the use of OR by consultant agencies, the Canadian Operational Research Journal, and the advancement to managerial levels of persons with an OR point of view. One response stated that OR techniques and methodology developed in military OR during WWII, and after, have been adopted by non-military organizations, many of which could not compete successfully without the OR approach to problem solving.

Mention was also made of restraint in government spending, inducing incentives for efficiency and rational resource allocation as a factor in the development of OR in Canada. Also, the increasing credibility of OR was cited as an important factor, as were changes in problems, urgency of solutions, training and experience of personnel, and in organizations. Mention was made of the fact that the Economic Council of Canada and the Science Council of Canada have undertaken and encouraged studies based on OR thereby helping to introduce OR in some areas of application.

Related to these several factors, and major factors in themselves, have been the foresight, encouragement, and support of managers, decision-makers, and the chairmen of university faculties and their willingness and readiness to innovate. Without such sagacity, espousal, and succor, OR in Canada could not have grown to the extent that it has, nor attained, the level of recognition and acceptance that it now enjoys.

CHAPTER V

OPERATIONAL RESEARCH IN CANADIAN FEDERAL GOVERNMENT DEPARTMENTS AND AGENCIES

INTRODUCTION

In considering the origins and development of OR in Canadian governments, the twin difficulties already mentioned arise and an added complication results from the rather frequent change in the composition of departments. Both federal and provincial governments alter the duties, responsibilities, structure, and names of departments and agencies from time to time making it onerous, if not almost impossible, to get data and records on such elements or service centres as OR units.

The chief means of obtaining relevant information on OR in federal and provincial governments and agencies* were questionnaires and interviews. A copy of the questionnaire used and the covering letter is shown in Appendix A. As convenient, or deemed necessary, further information was obtained through personal interviews and reviews of literature.

In general, response to the questionnaires was satisfactory. However, in many cases, follow-up action was required in the form of second or third letters, interviews, and phone calls. Questionnaires were originally sent to all federal and

*including crown corporations.

provincial government departments known or considered likely to have OR units or use OR methodology. In cases of doubt questionnaires were forwarded to avoid inadvertent omissions. As a result coverage is judged to be quite complete. In the following treatment the answers to questionnaires have been grouped and summarized so that all details are not necessarily reflected in the text. The groupings are somewhat arbitrary and not necessarily mutually exclusive.

CENTRAL OPERATIONAL RESEARCH UNITS IN FEDERAL GOVERNMENT DEPARTMENTS AND AGENCIES

Information on the use of OR was obtained from over forty federal government departments, agencies, and crown corporations, other than the Department of National Defence. Some returns were very complete, others much less so. Since the main concern in this report is with units or branches set up specifically to do OR as a full-time occupation, attention is given first to those cases wherein at some time OR units were organized as a central team to serve several elements of the department or agency. Consideration is then given to the remainder.

Some relevant data on non-military departments and agencies of the federal government which reported having central OR units serving more than one client or patron are given in Table V. However, OR in Air Canada and the Canadian National Railway (CNR) is discussed in a later chapter on OR in Business and Industry.

TABLE V

INFORMATION ON FEDERAL GOVERNMENT DEPARTMENTS AND

AGENCIES THAT HAVE USED OPERATIONAL RESEARCH AS A CENTRAL SERVICE

| Department or Agency | Date of Introduction of OR | Persons First Introducing OR Practicing OR ¹ | Number of OR Personnel: Originally | 1980 |
|--|----------------------------|---|------------------------------------|-----------------|
| Revenue Canada | 1962 | H. Milburn T. Charsky | 3 | 22 |
| Canadian Broad-casting Corpn | Sept. 1963 ² | W.N. Danagher L. Waitman | 3 | 9 |
| Defence Production | Dec. 1963 | A.R. Bailey, T. Foran P.J. Reynolds | 7 | --- |
| National Energy Board | 1964 | I.N. MacKinnon, J.G. Debanné J.G. Debanné, P.F. Taylor | 2 | --- |
| Supply & Services | Dec. 1965 | A.R. Demirdache A.R. Demirdache, Brant Howell | 5 | 18 |
| Canada Post | June 1966 | C.F. Hobbs Fred Johns | 5 | 12 |
| Manpower & Immigration - Manpower | 1966 ⁴ | D.R. Campbell P.B. Fay | 5 | --- |
| Indian & Northern Affairs ⁵ | 1969 | A.B. MacArthur A. Netherton | 1 | --- |
| Canadian Transport Commission | 1969 | R.R. Cope, R.M. Soberman R.M. Soberman, E.K. Cully | 4 | 10 ⁶ |
| Transport Canada | 1970 | N. Subramini A. Malecki | 8 | 6 |

INFORMATION ON FEDERAL GOVERNMENT DEPARTMENTS AND
AGENCIES THAT HAVE USED OPERATIONAL RESEARCH AS A CENTRAL SERVICE

| Department or Agency | Date of Introduction of OR | Persons First Introducing OR Practicing OR ¹ | Number of OR Personnel | |
|---|----------------------------|---|------------------------|-----------------|
| | | | Originally | 1980 |
| Manpower & Immigration/ Immigration ³ | Sept. 1970 | J. Vanderloo C. Boyle | 5 | 1 |
| Agriculture Canada | Oct. 1972 | T.C. Kerr T.C. Kerr | 20 | 10 ⁷ |
| Health & Welfare Health Production Br. | 1973 | D. Bray G. Richard | 2 | 0 |
| Canada Mortgage & Housing Corp. ⁸ | 1975 | A. Stubel W. Mulvihill | 2 | 1 |
| Fisheries & Oceans | Apr. 1979 | T.E. Ford D.L. Simmermon | 3 | 2 |

¹Name(s) on first line are those of persons instrumental in getting OR work started;

name(s) on second line are those of first OR team leader; other names are those of early OR staff.

²OR was first practiced as a recognized activity by individuals on a part-time basis in January 1959.

³Now Employment and Immigration Canada.

⁴Quantitative Methods Division of the Strategic Planning & Evaluation Group.

⁵Now Indian Affairs and Northern Development and has no centrally organized OR unit at present.

⁶Six of these in Computer Applications Group and four principally in econometrics. Only 4 mainly in OR. Others get involved in cost-benefit and cost-effectiveness analyses, statistical analyses, etc.

⁷Most of those work on OR part-time

⁸In the Canada Mortgage and Housing Corporation OR was first introduced in 1954 with individuals working on a part-time basis. In 1975 a central OR service was established.

It will be noted from this Table that between 1962 and 1979, fifteen federal departments or agencies (other than National Defence) set up central OR units. However, some OR work was done in a few of them prior to forming the central team.

In the case of the National Energy Board (NEB) OR was first practiced as a recognized activity in 1965 in constructing environmental models, investigating computer systems and procedures, and doing mathematical analyses. The OR work was organized by Dr. J.G. Debanné with the support and encouragement of NEB Chairman, Mr. Ian N. McKinnon, who had been the founder and first Chairman of the Petroleum and Natural Gas Conservation Board of Alberta and first Chairman of the NEB.

Neither the NEB, the Department of Indian Affairs and Northern Development (DIAND), or the Canadian Broadcasting Corporation (CBC) now have central OR units. But work similar to OR is still being conducted in all three. The CBC has 3 OR staff in materials management and 6 in telecommunications. In other cases, e.g. Agriculture Canada, the OR staff are not all engaged in OR work full-time. OR was first used in the Department of National Revenue (Revenue Canada) in 1960 before the first team was organized.

In Revenue Canada the OR activity has been and continues to be conducted at a high level. The present OR manager (J.G. Williams) reports that three projects have been outstanding with regard to meeting departmental objectives from a basic cost-benefit point of view. These are called Compliance Measurement System, Fair-Isaac method of selecting files with profitable audit potential, and the DIF technique.

of scoring-schemes for selecting files with profitable audit potential. Projects are carried as Projects for Audit, Projects for Verification and Collection, and Operations Research Projects. Since 1974 these categories have had 13, 5, and 12 active projects. The latter category includes correlation analysis, devising and testing a multi-project computer package with resource allocating capabilities, developing a linear programming package with sensitivity analysis to meet current and future needs, building a mathematical model to allow managers to assign resources having the greatest impact on ensuring compliance with the law, estimating the amount of unreported taxes, and a cost-benefit analysis of three alternatives for data centre implementation.

The Department of Defence Production (DDP) ceased operations as a separate department in the mid-sixties when the Department of Supply and Services was organized. At one time (1966-67) DDP had an OR staff of 6 professionals under P.J. Reynolds. Prior to its disbandment in 1974 the OR section in NEB had over 30 members. OR type work is still done in NEB particularly in the Energy Models Division, e.g. on surplus energy determination procedures. The data for the Fisheries and Oceans Department are all post-April 1979, when the new department was formed. Earlier in what became the Department of Fisheries and Environment OR was introduced on a small scale in 1965.

The difficulty in tracing origins and current OR work in Federal Government Departments is exemplified by the history of the Bureau of Management Consulting (BMC). This unit had its origin in the Management Analysis Division of

the Civil Service Commission in 1946 with 2 analysts working in the general area of management methods. In the early 1960's a separate OR group was set up in this Division as a result of consultations with Mr. Harold Larnder in 1963/64. An OR group was organized in December 1965 under Dr. A.R. Demirdache. In 1967 the unit was reorganized as BMC Services and in 1969 became an element of the recently formed Department of Supply and Services (DSS). It is now a sub-unit of the Management Science and Economics Division of DSS. The second director of OR was Brant Howell (1968-1972), the third was Dr. David Deziel (1972-1975), and the present one is Dr. Gavin N. Currie. Somewhat similar evolvments have occurred in other departments, details of which are not presented herein for reasons of brevity.

The three federal departments and/or agencies which no longer have OR units as such use many OR techniques in the course of their operations. The CBC has used correlation analysis and model construction, inventory and replacement models and probability theory, while DIAND uses scheduling techniques, linear and integer programming, transportation, replacement and mining cash flow models, and forecasting and predictive resource allocation modelling. The OR unit at NEB was disbanded in 1973 but OR devices such as model construction (inventory and replacement models), linear programming and probability theory are being used.

It is worthy of note that in 1968 Mr. Baldwin the Deputy Minister of the Department of Transport (DOT), now called Transport Canada, commissioned an optimal investment study by the OR Branch of NEB of ship requirements for Coast Guard operations. At the time DOT did not have an OR capability

but the success of this study, conducted by Dr. Debanné, influenced DOT in introducing OR units shortly thereafter (Table V).

Operational research was first practiced as a clearly identifiable activity in the Post Office in June, 1966. It was introduced by C.F. Hobbs who constructed docking simulation models and two methods of doing plant layout by simulation. Due to the success of these methods the Department decided to create an OR Branch in 1967 with Mr. Hobbs as its first Director. The major achievement during the period 1966-1969 was the success of the use of OR techniques in studying the Toronto and Montreal postal regions, and in forecasting mail volumes to 1985, and then by means of simulation recommending the number, size, and location of postal processing plants in these cities.

In the Department of Agriculture OR work has been done in the Research Division of the Economics Branch since October 1972 and in the Evaluation Unit of that Branch since 1976. Systems analysis (Engineering) has been conducted at a low level of manpower commitment in the Research Branch since 1971. While the Management Consulting Services staff have not been involved in OR per se they have been doing some organization analyses, and some systems analyses since the early 1960's and some project management analysis since 1976. The situation just described is somewhat typical in that some federal departments have a few analysts working on OR or OR-related projects in more than one branch or division but do not have a centrally organized OR unit.

The number of OR staff members presently working in these departments and agencies varies from 2 to 18. The numbers in the original OR units were of course fewer than those shown in the table for 1980. It may also be noted that these numbers are small in relation to the 75 OR staff presently employed in the ORAE of DND. Further relevant information is given in the next table.

This table indicates the wide variety of types of problems undertaken by OR teams and the change in types of work over the years. It also shows that most of the departments and agencies concerned have used outside consultants or management firms to do OR type studies. The number of these varied from 1 to 25 over the past five years.

It has always been considered important that OR staff have direct access to management at a high level. As is seen from the Table the OR units mentioned report to a range of management levels from Assistant Director to Assistant Deputy Minister.

As far as conveniently possible names of early OR staff members in federal government departments have been collected. These are listed by department and agency in Appendix D.

TABLE VI
FURTHER INFORMATION ON FEDERAL GOVERNMENT DEPARTMENTS AND AGENCIES
WHICH WERE OR ARE USERS OF OPERATIONAL RESEARCH AS A CENTRAL SERVICE

| Department or Agency | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Types of OR Services by Outside Consultants or Management Firms |
|-----------------------------------|--------------------------------|--|---|---|
| Revenue Canada | Director | Measurement of audit results; developing criteria for sampling income tax files to be audited; determining homogenous groupings of income tax returns. | Identifying problems of non-compliance; model development to reflect effects of changes in the Income Tax legislation; statistical analyses. | |
| Canadian Broadcasting Corporation | Assistant Director | Inventory control; transportation; communications rationalization. | Queuing theory procedures. | Workload problems; correlations; financial models. |
| National Energy Board | Chairman | Industrial model conservation (pipelines, hydro-electric) | - | None in past 5 years. |
| Defence Production | | Supply model; truck scheduling; manpower planning; advertising. | - | |
| Supply & Services | Director | Fleet management; air corridor safety; airport planning. | Decision, economics, operations and policy analysis; program evaluation; zero base budgetary. | Similar to those in previous column. |
| Canada Post | Assistant Deputy Minister | Revenue and expenses apportionment; mail volume and workload forecasting; plant locations. | Simulation and modelling of clientele traffic and effects of closing some stations; training personnel to process mail on mechanized equipment; cost benefit analyses of mechanization. | Facilities location; pricing policies; organization of staff functions. |
| Manpower & Immigration - Manpower | | Surveys of manpower services usage. | | |

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TABLE VI CONT'D
 FURTHER INFORMATION ON FEDERAL GOVERNMENT DEPARTMENTS AND AGENCIES
 WHICH WERE OR ARE USERS OF OPERATIONAL RESEARCH AS A CENTRAL SERVICE

| Department or Agency | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Types of OR Services by Outside Consultants or Management Firms |
|---|--------------------------------|--|---|---|
| Indian Affairs & Northern Development - Development | Director | Model construction; education research (northern peoples); statistical support; population models. | Air line & railway analyses (national international); models of consumer behaviour for market research; measurement models simulations and optimizations. | Model for network analysis. |
| Canadian Transport Commission | Vice-President Research | Short haul inter-city transportation; grain transportation; air & ferry services. | Design options; traffic control techniques. | Similar to those in previous column. |
| Transport Canada | Director | Simulating air terminal buildings; design options traffic control; techniques. | Policy analysis and commodity markets forecasting. | Development of forecasting model for Canadian agriculture. |
| Agriculture Canada | Director | Evaluating feed grain policies and their impact on livestock. | - | - |
| Health & Welfare Health Protection Directorate | Director | Strategies for field sampling. | - | - |
| Fisheries & Oceans | Director General | Management information systems studies and development. | Management information. | Communications systems. |

TABLE VI CONT'D
 FURTHER INFORMATION ON FEDERAL GOVERNMENT DEPARTMENTS AND AGENCIES
 WHICH WERE OR ARE USERS OF OPERATIONAL RESEARCH AS A CENTRAL SERVICE

| Department or Agency | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units | | Types of OR Services by Outside Consultants or Management Firms |
|---------------------------------------|--|---|---|---|
| | | Originally | Currently | |
| Employment & Immigration | Director Operations Planning & Development | Delivery systems development; modelling. | Systems analysis and development; impact analysis. | Statistical analysis of program delivery process. |
| Canada Mortgage & Housing Corporation | Director | Developing financial feasibility and simulation models. | Decision, simulation, and complex computational models. | |

OPERATIONAL RESEARCH IN FEDERAL GOVERNMENT DEPARTMENTS
OR AGENCIES NOT HAVING CENTRAL OPERATIONAL RESEARCH UNITS

Most federal government departments and agencies using OR do not, and did not, have centrally organized OR teams or units. In some, OR and OR-type analyses are done by individuals on a part-time basis or by small OR units working full-time or part-time for, and within, branches, directorates, or other sub-units of the department concerned. In some of these and in others OR studies are sometimes conducted by outside consultants or management firms.

As far as has been possible relevant data on aspects of OR in these departments and agencies have been summarized in the following tables. The first of these, Table VII, gives data on times and personnel and the second, Table VIII, gives further information, particularly on the kinds of problems and projects undertaken.

The first of these Departments to use OR as a recognized activity was in 1954 as indicated in the Table. However, over the 10 year period 12 departments or agencies introduced OR in small teams or by individuals doing OR part-time. The numbers of persons devoting most of their time to OR and OR type work are small varying from 4 to 7.

It is worthy of note that beginning in the early 1970's the Treasury Board encouraged and emphasized the use of quantitative methods including OR techniques in the preparation and submission of departmental programs. This emphasis played a part in the increasing use of OR type analysis (cost-effectiveness, cost-benefit, quantitatively supported submissions, in many federal departments.

TABLE VII

INFORMATION ON FEDERAL GOVERNMENT DEPARTMENTS AND AGENCIES
THAT HAVE USED OPERATIONAL RESEARCH AS A NON-CENTRAL SERVICE

| Department or Agency | Date of Introduction of OR ¹ | Persons First Introducing OR Practicing OR ² | Number of OR Personnel: | |
|---|---|---|-------------------------|------------------|
| | | | Originally | 1980 |
| Canada Mortgage & Housing Corporation | 1954 | A. Stukel W. Mulvihill | 3 | 1 |
| Environment Canada | Late 1960's | J. Beaman ³ B. Holling, D. Brown | 3 | 4 ⁴ |
| Unemployment Insurance Commission | 1967 | D. Cousineau D.J. Steele | 3 ⁵ | - |
| Consumer and Corporate Affairs | 1968 | - | 5 ⁶ | - |
| Public Works Canada | 1969 | T.J. Jones | 2 | 9 ⁷ |
| Treasury Board | Early 1970's | D.G. Hartle | N/A | N/A ⁸ |
| Regional Economic Expansion | Early 1970's | R. Marshall, J. Howe D. Tate | 3 | N/A |
| National Harbours Board | Early 1970's | Yvan Gagnon Hervé Tharoval | 2 | 3 |
| Health & Welfare Policy Planning & Information Branch | 1973 | T.R. Robinson F. Sully, J.A. Schriell | 3 | 2 |
| Ministry of State Science & Technology | March 1974 | D.M. Francis | 1 | 0 |
| The Seaway/Transport Canada Operations | April 1974 | W.F. Blair J.B. McLeod, A.A. Landry W.A. Davidson | 3 | 4 ⁹ |

TABLE VII (cont'd)

| Department of Agency | Date of Introduction of OR | Persons First Introducing OR Practicing OR ¹ | Number of OR Personnel: | |
|--|----------------------------|---|-------------------------|------|
| | | | Originally | 1980 |
| Health & Welfare Income Securities Programs Branch | 1975 | A.K. Liljefors | 4 | 5 |
| Secretary of State | March 1979 | Paul Larose M. Boivin, R.S. Mayne | 3 | 7 |

¹Dates are approximate in some cases because OR units were not established as such.

²Names on first line are those of persons instrumental in getting OR started, names on second and third lines are those of first OR team leader and OR staff.

³For Parks Canada; also first head of OR in department and reported to G. Yeates, Director Program Management Branch. Dr. B. Holling is with the Canadian Forestry Service and Dr. D. Brown with the Computing and Applied Selected Directorate.

⁴Four statisticians and 165 computer scientists in the Department.

⁵Originally OR work was done by two consultants and three in-house staff. The latter were basically sociologists applying OR techniques.

⁶OR was performed in a Departmental Consulting Branch. It was headed by a Director and staffed by 5 to 10 members with masters of business administration degrees. The unit was disbanded in 1976.

⁷OR work is done by contract or by personnel from the Applied Science Division of the Department's Directorate of Management Information Systems. The figure shown for the number of original OR workers is nominal only.

⁸Some in Program & Personnel Policy Branch doing OR related work.

⁹This Agency plans on expanding its OR services.

TABLE VIII
 FURTHER INFORMATION ON FEDERAL GOVERNMENT DEPARTMENTS AND AGENCIES
 THAT HAVE USED OPERATIONAL RESEARCH AS A NON-CENTRAL SERVICE

| Department or Agency | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units | Types of OR Services by Outside Consultants or Management Firms |
|-----------------------------------|--------------------------------|---|--|
| | | Originally | Currently |
| Environment Canada | Director | Control of forest pest infestations; studies of park visitor populations; outdoor recreation demands. | Cost benefit analysis of a hydrometric survey; expenditure standards for interpretation and visitor services (to parks). |
| Unemployment Insurance Commission | Chairman | Multiple regression analysis; studies of abuses of unemployment insurance fund. | - |
| Public Works | Director | Construction design and engineering. | Real estate investment model; resource production building inventory base model. |
| Treasury Board | | Systems analysis; cost-benefit analysis. | - |
| Regional Economic Expansion | Director & Director General | Evaluation of the regional development incentives program; other program evaluations. | Problems relating to the economic impact of development projects in Canada. |

TABLE VIII CONT'D
 FURTHER INFORMATION ON FEDERAL GOVERNMENT DEPARTMENTS AND AGENCIES
 THAT HAVE USED OPERATIONAL RESEARCH AS A NON-CENTRAL SERVICE

| Department or Agency | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Types of OR Services by Outside Consultants or Management Firms |
|--|---------------------------------|--|---|--|
| National Harbours Board | Vice-Chairman | Queuing theory problems at wharves; tank farm inventory problems; ship turnaround times & berth occupancy. Cost benefit analyses. | | |
| Ministry of State for Science and Technology | Director | Identification of significant factors for monitoring vessel lock times; Welland Canal simulation model; canal capacity and shunter evaluation. | System benefits of widening a section of Welland Canal; capacity increase studies monitoring capacity factors; forecasting capacity year. | |
| The Seaway Transport Canada | Manager of Operational Planning | Evaluating customer satisfaction and quality of product; evaluating technical developments. | Continuation of those in adjoining column and work on employee satisfaction; development of standards. | Evaluation of computers, administrative services, and organizational structures; citizenship participation in Program. |
| Secretary of State | Assistant Deputy Minister | Simulation; mathematical model building; survey research; welfare research using linear programming; regression analyses. | As originally plus information systems development; analysis relating to the public assistance system, welfare, pensions, etc. | |

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TABLE VIII CONT'D
 FURTHER INFORMATION ON FEDERAL GOVERNMENT DEPARTMENTS AND AGENCIES
 THAT HAVE USED OPERATIONAL RESEARCH AS A NON-CENTRAL SERVICE

| Department or Agency | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units | | Types of OR Services by Outside Consultants or Management Firms |
|--------------------------------------|--------------------------------|--|---|---|
| | | Originally | Currently | |
| - Income Securities Programme Branch | Assistant Deputy | Analysis of impact of security agreements on programs of Branch; program forecasting study of extending eligibility for spouses's allowance program. | Program forecast and data analysis; quantification of policy operations affecting programs. | |

Again these departments exhibit a wide range in the level at which they report to management and in the types of problems undertaken. Also extensive use has been made of outside consultants or management firms by some departments. The number of these over the past years has been small, in no case were more than 5 studies by outside consultants reported over the past 5 years.

In the Department of Health and Welfare eight branches and the Office of the Special Adviser, Policy Development were canvassed using the questionnaire. Only three of these have or had teams or individuals doing OR. One of these, the Health Protection Branch had an OR unit from 1973-1979 when it was disbanded. It was set up as a Central unit by David Bray, Director, Planning and Evaluation and the first team leader was George Richard. The team of 2 persons worked on strategies for field sampling. In 1973 also, a team was organized in the Analytic Services Division of the Policy, Planning, and Information Branch to do what was called quantitative analysis. In 1975, the Programs, Planning and Evaluation Directorate of the Income Securities Program Branch set up a team of three analysts who used OR techniques in quantitative work such as cost and beneficiary caseload impact analysis of various policy proposals; the term 'quantitative economic research' is preferred to OR in describing this work, which is done on a regular basis. It is the two latter units that are included in Tables VII and VIII. From the responses, it appears that a total of 9 persons were employed, at least part time on OR type work by the Department in the original teams and now there are 7 plus 3 computer systems staff members and 2 junior assistants, the latter in the Analytic Services Division of the Policy, Planning and Information Branch.

FEDERAL GOVERNMENT DEPARTMENTS AND AGENCIES THAT
DO RESEARCH RELATED TO OPERATIONAL RESEARCH

While several Federal government departments and agencies do not conduct operational research under that name many of them do research work related to OR and use some of the methodology and techniques usually considered by many as OR. Some by virtue of their role do not conduct applied scientific research as such.

On reviewing information provided by these federal departments and agencies it is convenient to summarize the information by department or agency. Such summaries are given below in alphabetical order.

Canadian International Development Agency (CIDA)

There is no OR unit as such in CIDA and as a discipline is not structured or referred to by name. However there has been some OR type work undertaken by individuals on a part-time and project basis.

Department of Communications

Although the Department is involved in projects covering all aspects of communications research, there never was a separate unit engaged in OR.

Consumer and Corporate Affairs Canada

A departmental management consulting branch of from 5 to 10 staff members that performed OR established in 1968 was disbanded in January 1976 as part of an economy drive. Directors of this branch were N. Van Duyvendyck, J. Swayne and John Baker. The OR and related functions are now divided

between a number of organizations. There are wide varieties of types of projects and degrees of professionalism in the general OR area. Quantitative methods are used in some research projects and generally relate to cost-benefit and cost effectiveness techniques. Management consultants are sometimes employed. Three types of program evaluation are carried out and are done in-house or on contract depending on the situation.

Economic Council of Canada

Does not engage in OR but uses linear programming in research activities.

Energy, Mines and Resources

Some OR techniques such as cost-benefit analysis, linear programming, sick-benefit analysis, regression analysis, and other statistical estimating and modelling procedures are used on an on-going basis particularly in policy and program analysis. The Department does not have, nor has it had, any units specifically mandated to work in OR.

Department of Finance

OR techniques are not easily identified as a research concept in the department's highly statistical-mathematical models dealing with the economy.

Industry, Trade and Commerce

Response from this Department stated that "enquiries had been made across the Department and we have to advise that no use has been made of operational research under that name."

International Development Research Centre

This Centre replied that it is not involved in operational research and did not answer the questionnaire

Labour Canada

OR as defined in the letter of request (Appendix A) is not being undertaken. The Economic Analysis Branch is engaged in research and analysis and uses a variety of quantitative methods with some emphasis on econometrics.

Loto Canada

Did not conduct OR as such but some market survey work was done using OR related techniques.

National Capital Commission

The Systems Development Division and the Planning, Research and Services Branch make periodic use of quantitative research measures and maintain an in-house economic research model (CAPSIM).

National Research Council Canada

Does not have a formally organized OR unit but OR techniques have been and continue to be used in the analysis of problems, particularly in the program planning function. The valuable contributions of the NRC to military OR during WW II have been mentioned earlier.

Public Service Commission

A number of the techniques of OR have been used in some projects, including systems analysis and cost-benefit analyses.

Science Council of Canada

OR is not a recognized activity of the Science Council but from time-to-time work that may be marginally classified as OR is done.

The Seaway Transport Canada

Reports that over the period 1967-1978 the development of applied OR occurred through evolvement. There never was a distinct decision to build an OR capability but rather the approval to proceed to the next step was always associated with the need to accomplish a given project, and, in this sense there is virtually no routine operating budget for OR; all the money for such work is identified with projects.

Solicitor General

No OR done internally in Correction Services but some OR type work has been done by outside consultants (model constructed to predict number of inmates in penitentiaries). Some game theory has been used in the Security Branch.

Solicitor General - Royal Canadian Mounted Police

Considerable R&D¹ is conducted by, or under the auspices of, the Royal Canadian Mounted Police (RCMP). This work is being coordinated by the Office of the R&D Coordinator, Science and Technology Advisory Group, "L" Directorate. The R&D is divided into two main groupings, Human Sciences and Natural

¹Research and Development

Sciences. Some of the work is done in-house and some is contracted out to external agencies.

Although the RCMP does not have a central unit doing operational research (OR) under that name, much of the research work can be called OR in the sense used in this report. It is R&D undertaken to meet specified operational needs. In recent years, the RCMP has developed a program through which human and natural science research requirements are raised on an annual basis.

With the natural sciences, once all of the submissions are received the R&D Coordinating Centre prepares a comprehensive brief and package for review by the R&D Liaison Committee. This Committee begins the difficult tasks of determining priorities, and which projects will be deleted, done internally, externally (through the Lead Agency Role) or jointly by the Force and an expert agency. These recommendations are forwarded to the Director's Policy Coordinating Committee for further refinement and the Senior Executive Committee gives the final stamp of approval for that year's RCMP Research programme. Those projects designated as external are now routed through an outside process where the RCMP has been designated as the Lead Agency. The Operational Research Committee (ORC) of the Canadian Association of Chiefs of Police reviews submissions for research from all police departments across Canada including the RCMP's 'external' project requirements. The ORC (which is comprised of representatives from Provincial and Municipal Police Departments, the RCMP and the National Research Council) assigns priority and turns the final list of requirements over to the Lead Agency for total management. Unsolicited proposals

(which can originate from any outside source, e.g. a business, university etc) are also channelled through the R&D Coordinating Centre for processing.

A very similar process exists for the human sciences program. The same steps are followed except those projects designated as external are forwarded to the Research Division of the Ministry of the Solicitor General via the RCMP representative to the Research and Statistics Strategy Committee. There is a three-tiered committee system now involved with the furtherance of our external Human Sciences research. Agencies served by the Ministry (and this includes the RCMP, Correctional Services, National Parole Board) have representation at three different levels. The first level is the Research and Statistics Projects Committee. The R&D Coordinator is a voting member on this committee.

The Research and Statistics Strategy Committee sets the priority and directs which research is to be done by the Research Division. The Deputy Commissioner, Canadian Police Services, represents the Force at this level. He ensures RCMP projects are incorporated into the overall program and is also a member of the Police and Statistics Research Committee. The top level committee, Senior Policy Advisory Committee, has Force representation through the Commissioner. This Committee gives final approval to the annual research plan.

Research capability within the RCMP is not centralized in any single unit but is spread widely through the Force. In doing internal OR type work, use is made of many techniques including modeling, e.g., constructing models and prototypes of telecommunications equipment. Much of the R&D work is

performed externally by management and consulting firms, universities, and the NRC. Some examples of externally and jointly performed research are; investigations concerning bomb suits, tear gas, police helmets, women and policing, child abuse, traffic law enforcement, and the environmental design of buildings from the point of view of crime prevention. Examples of human sciences research conducted internally are; studies on training, personnel development and management, recruitment procedures, and police/community relations. Examples of internal work in the natural sciences area have been the specification of design, and the testing and evaluation of soft body armour prototypes. Most of this work is concerned with equipment needs.

Statistics Canada

While financial and other quantitative inputs are used, wherever appropriate, in managerial decision making in Statistics Canada, there is no significant use of OR or related techniques in support of policy research or decision making since the department's role is to supply information for decision making rather than making policy and program decisions. The bureau does not have a formal organization engaged in OR work for preparing quantitative studies for departmental decision making. Econometric modelling and other OR techniques are used in the development and analysis of statistical data and are offered, in some cases, as a service to policy departments for their use. However, this use is not related to the decision-making process of the bureau.

Veterans Affairs

OR has not been used in any organized manner in the Department. Within the Management Consulting Division established in 1971, and its predecessor the Management Services Division established during the 1950's, consultants with OR skills from time to time have been hired. However, with the exception of studies in the late 1950's and early 1960's, related to hospital operations, no use of OR techniques identified in Question 12 of the questionnaire (Appendix A) has been made.

In addition to the preceding information and data it may be noted that the following federal departments and agencies that do not have an OR unit or fulltime OR staff make some use of OR methodology and techniques such as model construction, inventory models, linear programming, queuing theory, replacement models, or game theory: Consumer and Corporate Affairs Canada, Department of Indian Affairs and Northern Development, Energy, Mines and Resources, Environment Canada, Labour Canada, Ministry of State for Science and Technology, National Energy Board, and Public Works Canada.

REMARKS AND OBSERVATIONS

While not exhaustive the preceding treatment does present a fairly comprehensive picture of the origin and development of OR within the federal public service. Four* of the departments and agencies (Consumer and Corporate Affairs, DIAND, the CBC, and NEB) have discontinued OR units as such but have continued using OR techniques. These changes and other developments suggest that there has been some diffusion of OR from teams or

* Also, the Health Protection Branch of the Department of Health and Welfare had an OR unit from 1973-1979.

units operating centrally, or as small units within different branches, to individuals doing OR part-time or incidentally as required by project work or day-to-day activities. On the other hand, operational research and analysis within the Department of National Defence remains as a central establishment (ORAE) and is the largest, and perhaps the most successful, OR service in the country.

An appreciation of the rate of development of OR in federal departments and agencies can be had from the following Table which is based on the preceding tables.

TABLE IX
DEVELOPMENT OF OPERATIONAL RESEARCH
IN FEDERAL GOVERNMENT DEPARTMENTS AND AGENCIES

| PERIOD | Number of Departments and Agencies: | | TOTAL |
|---------------|-------------------------------------|---------------------------------|-----------|
| | With Central OR Services | With Non-Central OR Services | |
| 1950-1960 | 1 | 1 | 2 |
| 1961-1965 | 5 | 0 | 5 |
| 1966-1970 | 6 | 7 | 13 |
| 1971-1975 | 3 | 3 | 6 |
| 1976-1980 | 1 | 1 | 2 |
| TOTALS | 16 | 12 | 28 |

N.B.: Years shown under Period are inclusive. The entry in the first column for the first period is for the Department of National Defence. This Table shows that the greatest expansion was during the five year period 1966-70 but the rate of development cannot be considered to be rapid in terms of the number of departments and agencies introducing OR per year or five-year period. On the other hand, in the thirty-year period 1951-1980, the number of OR personnel in the federal service increased from about 10 to over 200 civilian scientists with over 25 military officers in National Defence also working as OR staff. A listing of early OR staff in the federal government is given in Appendix D.

Although the personnel figures shown in Tables V and VII are not complete nor, perhaps, fully accurate, they do indicate that there has been some increase in OR personnel in federal government departments (other than National Defence) over the years since OR was introduced. By considering the figures in these two Tables, it is seen that the total OR personnel, when OR was introduced, was about 110, and in 1980 the number is about 125; the corresponding figures for those departments with central OR services, and for those with non-central OR services being 35 and 75, and 35 and 90 respectively. It may be noted here that at the end of 1950 the number of OR personnel in the Defence Research Board of the Department of National Defence was 10 and now the Operational Research and Analysis Establishment has some 75 civilian OR scientists as well as over 25 military officers and support staff. Thus the totals for all federal government departments covered in this report are approximately 120 at the time of introduction of OR and 200 or more in 1980, apart from the military staff working on OR in National Defence. Accordingly, the increase over the years has been considerable but not very great.

It should be noted that the numbers of federal departments ministries and agencies have increased over the thirty years covered in Table IX. It could therefore be expected that there would be some increase in the number of OR units introduced. On the other hand, there have also been many changes in the names and responsibilities of several departments and some agencies and departments have ceased to exist as such. For example, the Unemployment Insurance Commission is now a part of Employment and Immigration Canada, and there is now a Department of Fisheries and Oceans (the corresponding department has had ten different names all told, and five since OR

was introduced in Canada), and we have both a Minister of Energy, Mines and Resources and a Minister of State for Mines. Indeed, the numbers of departments have increased over the years from 15 in 1940 to 20 in the 1950-1960 period, 23 in 1970, and 32 in 1980, depending on how one counts departments and ministries. Accordingly, it becomes difficult to obtain relevant data on OR services and personnel without extensive search of old records, which was not done in most cases, reliance having been placed on answers to questionnaires and personal interviews.

In a later Chapter in this report, the influence and impact of OR on managers and decision-makers is discussed. Although these factors are difficult to assess with confidence, it seems safe to assert that this account of OR in the federal service indicates that OR has played an important part in providing analyses and inputs for federal government decision making and in increasing the use of quantitative methods in the planning, analysis, and evaluation of federal policies, programs, and operations.

CHAPTER VI

OPERATIONAL RESEARCH IN PROVINCIAL GOVERNMENT

DEPARTMENTS AND AGENCIES

INTRODUCTION

In soliciting information on the origins and development of OR in provincial government departments and agencies, the same questionnaire as was used for the federal government (Appendix A) was employed. In addition, telephone conversations and personal interviews provided supplementary information.

The method of presenting the findings adopted in the federal case will be followed for provincial departments and agencies. And again the difficulties and complications mentioned earlier are encountered, yet many relevant data were obtained and are described below with, regrettably, the proviso that returns, and therefore the data, were not as comprehensive as was the case with federal departments and agencies.

For ease in analysis and presentation, the treatment is given in the following sections by geographical regions - the Atlantic provinces, the Central provinces (Quebec and Ontario), the Prairie provinces, and British Columbia, Yukon and the Northwest Territories. Thereafter, some relevant comments on regional differences are submitted.

THE ATLANTIC PROVINCES

A total of 48 provincial departments and agencies were approached and 35 returns were received, a 73% response rate. Of these 48, 11 were in Newfoundland (Nfld), 12 in Prince Edward Island (P.E.I.), 11 in Nova Scotia (N.S.), and 14 in New Brunswick (N.B.). Of the 35 replies, nine were from Nfld., nine from P.E.I., seven from N.S., and ten from N.B. However,

only 11 of these departments and agencies have OR units or staff engaged in OR as a recognized activity on a part or full-time basis. Some details of OR in these 11 cases are presented in the following Tables X and XI.

From Table X we see that the earliest use of OR in Atlantic governments was by the Nova Scotia Research Foundation Corporation in February 1967, followed by the New Brunswick Department of Health in April 1969, and the P.E.I. Department of Education in 1970. However, the growth of OR units in the Atlantic provincial governments has not been rapid and the number of OR staff remains rather small with the one exception of Social Services in P.E.I.

Further information on OR in these provincial departments and agencies is given in Table XI which shows that the OR units mentioned report in at suitably high levels, managers to deputy ministers. Also, rather a wide variety of problems and projects have been undertaken by the OR staffs and although it is difficult to determine without further investigation, there are indications that the types of problems have become somewhat more complex and comprehensive with time. Further, most of these departments and agencies have made use of outside consultants on a variety of problems, the number of such studies ranging from one to 15 over the past five years. It is interesting to note both the similarities and differences in the types of studies undertaken by in-house and outside personnel.

Several provincial departments or agencies in the Atlantic provinces that do not have OR units or employ OR as a recognized applied research did report on conducting OR-type studies and using outside consultants. Brief accounts of these activities are given by province in the following paragraphs.

TABLE X

OPERATIONAL RESEARCH IN PROVINCIAL DEPARTMENTS
AND AGENCIES OF THE ATLANTIC PROVINCES

| Province | Department or Agency | Date of Introduction of OR | Persons First Introducing or Practicing OR ¹ | No. of OR Personnel 1980 |
|----------------------|---|----------------------------|---|--------------------------|
| Newfoundland | Newfoundland & Labrador Hydro | June 1971 ² | John Fitzgerald | 6 |
| | | | Leo Cole | |
| | | | John Fitzgerald Ross Young F. Wilcox | |
| Newfoundland | Transportation & Communications | Sept. 1978 | A.L. White | 3 |
| | | | W.T. Beckett | |
| | | | A.F. Ryan D.M. Clouston | |
| Newfoundland | Forest Resources ² and Lands Fisheries ³ | 1980 | R. Nazit | - |
| | | | G.C. Slade | |
| | | | Carl Sullivan | |
| Prince Edward Island | Education | 1970 | L.R. Moase | 1 |
| | | | D. Russell | |
| | | | G. Hughes | |
| Prince Edward Island | Social Services | Sept. 1973 | J.E. Green | 20 |
| | | | F. Schwartz | |
| | | | C. MacLean | |

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TABLE X (Cont'd)

OPERATIONAL RESEARCH IN PROVINCIAL DEPARTMENTS
AND AGENCIES OF THE ATLANTIC PROVINCES

| Province | Department or Agency | Date of Introduction of OR | Persons First Introducing or Practicing OR ¹ | No. of OR Personnel 1980 |
|---------------|---------------------------------------|----------------------------------|---|--------------------------------|
| Nova Scotia | Nova Scotia Research Foundation | Feb. 1967 | T.B. Nickerson | 3 |
| | | | T.B. Nickerson | |
| | | | T.G. O'Flaherty | |
| | Energy, Mines and Resources | 1975 ⁴ | J. French | 4 |
| | | | J. French | |
| New Brunswick | Health | April 1969 ⁵ | J.G. Clarkson | 8 |
| | | | D.J. Junk | |
| | | | R.E. Hanusiak | |
| | Natural Resources | 1975 | | 2 |
| | N.B. Electric Power Commission | Aug. 1976 | P. Whalen P. Whalen W. Davies, L.K. Lee | Variable (part-time) |

¹Name(s) on first line are those of person(s) instrumental in getting OR started; those on second and third lines are names of first OR leaders. In this Table and similar ones to follow, the person to whom the original OR leader reported is sometimes shown on the first line.

²No organized OR unit or full-time workers.

³OR staff not designated at time of questionnaire.

⁴Organized as a central OR service in 1978.

⁵Organized as a central OR service in 1976.

TABLE XI
 FURTHER INFORMATION ON PROVINCIAL GOVERNMENT DEPARTMENTS AND AGENCIES OF THE
 ATLANTIC PROVINCES WHICH HAVE OPERATIONAL RESEARCH UNITS OR USE OPERATIONAL RESEARCH

| Provincial Department or Agency | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Types of OR Services by Outside Consultants or Management Firms |
|---------------------------------|---|---|--|--|
| Newfoundland & Communications | Assistant Deputy Minister | Pavement markings; use of studded tires and seat belts. | As originally plus evaluation of time studies and analysis of benefit cost variables | Transportation of wood |
| Forestry Resources & Lands | Director of Forest Management & later Assistant Deputy Minister | Benefit cost-analyses; design of flow information for benefit/cost analysis. | - | Identification of need for information collection and retrieval with associated applications |
| Fisheries | Deputy Minister | None as yet. | - | As for in-house. |
| Newfoundland & Labrador Hydro | Chief Engineer Deputy Minister | Present worth analysis of generation and transmission additions to meet projected load growths. | As in previous column | Feasibility study and cost analysis of establishing a provincial public kindergarten system. |
| Prince Edward Island Education | Deputy Minister | Reorganization of provincial school structure into larger administrative units. | Investigation of declining enrolments, teacher surplus, and drop-outs. | |

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TABLE XI CONT'D
 FURTHER INFORMATION ON PROVINCIAL GOVERNMENT DEPARTMENTS AND AGENCIES OF THE
 ATLANTIC PROVINCES WHICH HAVE OPERATIONAL RESEARCH UNITS OR USE OPERATIONAL RESEARCH

| Department of Agency | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of OR Services by Outside Consultants or Management Firms |
|---|--|---|---|
| Prince Edward Island - Social Services | Originally Deputy Minister now Director | Design of a managerial information system; study of intake system for coordinated service delivery. | Implementation of industrial-commercial model in sheltered workshops; evaluation of a home for mentally retarded children. |
| Nova Scotia - NS Research Foundation Corporation | Originally President, now Manager, Industrial & Information Services | Fishing vessel simulation models; fishing information systems simulation; water supply planning. | Microprocessor systems for data handling; forest inventory models; computer programming; projection support of data acquisition; and analysis; linear programming for determining optimum feed mix. |
| - Energy, Mines and Resources | Deputy Minister | Economic evaluation of energy matters. | Similar to internal, usually project oriented. |
| New Brunswick - Health | Deputy Minister | Medicare implementation; nursing personnel requirements; hospital planning; morbidity/mortality analysis; bursary program review; library services. | Labour services administration medicare computer; systems development; hospital cost analysis; mental health services review. |
| - Natural Resources | Coordinator Policy & Planning | Forest productivity modelling. | Problems related to spruce budworm damage. |

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TABLE XI CONT'D
 FURTHER INFORMATION ON PROVINCIAL GOVERNMENT DEPARTMENTS AND AGENCIES OF THE
 ATLANTIC PROVINCES WHICH HAVE OPERATIONAL RESEARCH UNITS OR USE OPERATIONAL RESEARCH

| Department of Agency | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units | | Types of OR Services by Outside Consultants or Management Firms |
|--------------------------------|--|--|--|---|
| | | Originally | Currently | |
| - NB Electric Power Commission | Originally Manager of Plan Operations, now Director R&D | Practicality of coal oil mixing fuel as a cost effective substitute for residual fuel oil. | Alternative coal combustion technologies; alternative energy generation schemes. | Technical design and cost estimate for equipment modification. |

In Newfoundland, the Department of Health undertakes some cost benefit assessments as part of on-going operations and planning. And the Board of Commissioners of Public Utilities from time to time engages outside consultants to do studies relating to utility rate increases. The Department of Fisheries are implementing a program of computerization of services as the result of a study done by a crown corporation which will assist in the work which is expected to take about three years. The Newfoundland and Labrador Hydro Commission has had five studies done by outside consultants in the past five years.

In Prince Edward Island, the Department of Fisheries carries out research "of an applied or developmental nature" but does not refer to it as OR. The Department of Health carries out some limited evaluation of program activities but this is not construed as OR. The Department of Industry and Commerce reports that OR is "Not being practiced yet" but that in the past five years 25 OR studies have been conducted by outside consultants. These were related to manufacturing and processing activities in industry throughout the province. The Department of Public Works has no separate OR unit but cost effectiveness and cost benefit analyses are conducted.

In Nova Scotia, the Department of Development undertakes some studies of the OR type. These include work on simulation models of the provincial economy and its substructure and analysing certain large projects and suggesting the nature and degree of government participation in them. On occasion, this Department uses outside consultants to assist with OR-type questions usually in conjunction with internal staff. They use model construction and linear programming and are increasingly involved in simulations of several types as guides for economic policy. The Department of Transportation has used some linear programming on an experimental basis but not on a

continuing basis. The Nova Scotia Power Corporation states that it does have some employees who have taken OR courses but that the application of any OR techniques is very limited at present (Feb 1980).

In New Brunswick, the Department of Agriculture and Rural Development reports that it has no OR team specifically organized to provide OR expertise but does use some of the OR techniques in the development and implementation of programs. The Department of Social Services reports that it does not have an OR unit or activity and does not currently use the OR devices mentioned in Question 12 of the questionnaire (Appendix A). The Department of Transportation states that it has not adopted OR as a recognized activity but does devote attention to the cost-effectiveness of its activities. The Fisheries Department reports that OR is not included 'as a function of this department' although its 'operation is mainly concerned with applied research'. The Department of Labour and Manpower has never had an OR unit or team and does not utilize the OR devices cited in the questionnaire (Question 12, Appendix A), nor has the Department made use of outside resources to conduct OR studies. The New Brunswick Public Utilities Board has no in-house OR capability but occasionally, since 1965, has used an outside consultant firm to examine and sort out applications by telephone companies for rate increases.

THE CENTRAL PROVINCES

In the Central Region, 16 Quebec provincial government departments and agencies were canvassed and 17 Ontario ones. Despite follow-up action, only seven replies were received from Quebec but 17 from Ontario for a 70% response from the Region. In the case of Quebec, only two of the seven replies showed

that an OR unit had been organized and one other that the department concerned uses OR techniques sometimes. In Ontario, eight departments either have organized OR units or individuals working in OR on a part-time basis and also three departments mention that OR techniques are used occasionally.

Some information regarding these OR units and relevant available details are presented in the following Tables (XII & XIII). These follow the format used previously and are given on separate pages.

From Table XII it is seen that the earliest use of OR as an organized and recognized activity in provincial government ministries in Quebec and Ontario was in the Ontario Ministry of the Environment in 1965 and that such use of OR was a recent development in the Quebec government. The number of OR staff presently in these ministries varies from one to 20. However, OR was used as early as 1951 in the Ontario Hydro Commission (e.g. Dr. P.J. Sandiford), and on a formal basis by 1955.

It is noted from Table XIII that the level at which OR units report in these provincial ministries varies from director to assistant deputy minister. Only three of Ontario ministries have used outside consultants or management firms to conduct OR-type studies and the numbers of these in the past five years varied from one to 10. The types of OR studies undertaken by the ministries concerned are indicated in the Table. They show some growth in both number and scope.

In Quebec, the Services de Protection de l'Environnement reports that they do not use OR as described in the request received, and the Ministère des Travaux Publics et de l'Approvisionnement states that, although they do not have an organized OR service, various professionals in the ministry use OR techniques

TABLE XII

OPERATIONAL RESEARCH IN PROVINCIAL GOVERNMENT DEPARTMENTS
AND AGENCIES IN THE CENTRAL PROVINCES

| Province | Department, Ministry or Agency | Date of Introduction of OR | Persons First Introducing or Practicing OR ¹ | No. of OR Personnel 1980 |
|----------|---|----------------------------------|---|--------------------------------|
| Quebec | Energie et des Ressources | 1975 | - | - |
| | Richesses Naturelles | Jan. 1977 | Jean A. Guérin P. Filion, M.H. Cao, J.R. Caron | 4 |
| | Hydro-Québec | 1970 | - | - |
| Ontario | Ontario Hydro | Sept. 1955 | G.B. Tebo W. Shelton, B. Bernholtz P. Sandiford | 8 |
| | Environment | 1965 | K. Symons, D. Jeffs D. Jeffs | 20 |
| | Transportation & Communications | Mar. 1967 | E.J. Orr, J.M. Childs J.M. Childs, A.P. Cunliffe | 9 |
| | Management Board Cabinet Secretariat | 1968 | - | - |
| | Government Services ² | Oct. 1973 | O.M. Berg | - |
| | Energy ³ | March 1974 | J. Thacker J. Newton, G. Dominy | 5 |

TABLE XII (Cont'd)

OPERATIONAL RESEARCH IN PROVINCIAL GOVERNMENT DEPARTMENTS
AND AGENCIES IN THE CENTRAL PROVINCES

| Province | Department, Ministry or Agency | Date of Introduction of OR | Persons First Introducing or Practicing OR ¹ | No. of OR Personnel 1980 |
|------------------|--|----------------------------------|---|--------------------------------|
| Ontario (cont'd) | Revenue | June 1976 | L.P. Leonard L.P. Leonard | 5 |
| | Community and Social Services | | | |
| | Management Science Branch | Dec. 1968 | C. Brannan O.M. Berg | - ⁴ |
| | System Management & Coordination Branch | Sept. 1979 | O.M. Berg T. Moon | 1 ⁵ |
| | Liquor Control Board | - | - | 2 ⁶ |
| | Industry & Tourism ⁷ | - | M. Karasek | 1 |

¹Names on first line are those of persons instrumental in getting OR started, those on second line are names of first OR leaders.

²Formerly Public Works. Neither of these departments has had an OR unit as such but OR work was done in the Management Science Branch dissolved in March 1977.

³The Ministry does not identify OR as a separate activity but uses various quantitative methods and techniques.
⁴One full-time and several part-time.

⁵This Branch was originally in the Treasury Board. It was disbanded in Sept. 1975. Its functions were transferred to Government Services in April 1975.

⁶One economic and one distribution analyst.

⁷Industry and Trade Analysis Branch - prefer to call the work 'Quantitative Methods'.

TABLE XIII
 FURTHER INFORMATION ON PROVINCIAL GOVERNMENT DEPARTMENTS AND AGENCIES OF THE CENTRAL PROVINCES WHICH HAVE OPERATIONAL RESEARCH UNITS OR USE OPERATIONAL RESEARCH

| Provincial Department or Agency | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Types of OR Services by Outside Consultants or Management Firms |
|-------------------------------------|--------------------------------|---|---|---|
| Quebec Riçhesse Naturelle | Directeur | Statistical analysis of energy demands; forecasts of energy demands. | Modelling power system demands and supply based on economic and social systems. | - |
| Energie et des Ressources | - | Simulation to improve wood production; optimal location of forests and processing plants. | Evaluating economic impact of development programs. | - |
| Hydro-Québec | - | Computing problems ¹ | - | - |
| Ontario Environment ² | Director | Hydrologic studies of new basins. | Stream assimilation, efficient waste disposal systems, air pollution problems, long range transport of air pollutants. | Modelling of water quality/quantity, water supply options and waste disposal options. |
| Transportation & Communications | Director | Setting service levels, developing planning criteria & values. | Developing resource requirements, productivity studies. | - |
| Energy | Executive Coordinator | Energy demand & supply modelling. | Assessment of future energy supply options, conservation and renewable energy investments, analysis of energy demand-price futures. | Development of computer models, assessment of oil and gas drilling data, financial analysis of energy transportation tariff structures. |

¹Four or five analysts originally concerned mainly with computer problems.

²There are 3 OR units: water quality modelling, started in 1965; air quality monitoring, started in 1968; and quantity modelling, started in 1969.

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TABLE XIII CONT'D
 FURTHER INFORMATION ON PROVINCIAL GOVERNMENT DEPARTMENTS AND AGENCIES OF THE CENTRAL
 PROVINCES WHICH HAVE OPERATIONAL RESEARCH UNITS OR USE OPERATIONAL RESEARCH

| Provincial Department or Agency | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Types of OR Services by Outside Consultants or Management Firms |
|---------------------------------|--|---|--|--|
| Liquor Control Board | 3 | — | Development of consumption models; traffic network analysis; warehouse system modelling. | (yes) |
| Revenue ⁴ | Director | Process design. | Process design. | — |
| Community & Social Services | Director | Initial assessment of needs and projects still underway. | Inventory and 'what-if' models. | — |
| Natural Resources ⁵ | Assistant Deputy Minister ⁵ | Evaluating program effectiveness. | Evaluating program effectiveness and investigating how to develop more efficient operations. | — |
| Industry and Tourism | — | Applied regression analysis; models of the Ontario tourism environment. | Econometric modelling of various industries; optimization of trade policies; medium and long term forecasting based on models. | Quantitative analyses of Ontario trade and industrial environments and/or their particular segments. |
| Ontario Hydro | Director of Research | Vehicle replacement policy; stores inventory control. | Simulation of nuclear reaction design; interim storage of irradiated fuel; social costs of air pollution, optimum inventory of nuclear fuel; load management studies, and statistical studies. | |

³ No OR unit but intend to expand OR services.

⁴ There are now 2 OR units and 1 formed in 1977 concerned with impact analysis and project design; one other in 1978 engaged in tactical support.

⁵ The Department does not have an OR unit as an organization entity. In many cases OR techniques are employed in the types of problems listed. The Program Analysis Office reports to the Assistant Deputy Minister, Administration, and is responsible for coordinating the ministry's program evaluation program.

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TABLE XIII CONT'D
 FURTHER INFORMATION ON PROVINCIAL GOVERNMENT DEPARTMENTS AND AGENCIES OF THE CENTRAL
 PROVINCES WHICH HAVE OPERATIONAL RESEARCH UNITS OR USE OPERATIONAL RESEARCH

| Provincial Department or Agency | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units | | Types of OR Services by Outside Consultants or Management Firms |
|---|--|--|-----------|---|
| | | Originally | Currently | |
| Community & Social Services -- Management Science Branch | Executive Director, Advisory Services Division | Planning study of evaluation modelling for reproduction activi- ties; planning the money system; estimating real property market values; simulation of LCB ware- house. | -- | -- |
| -- Systems Management and Coordination Branch | Branch Director | Initial assessment of needs and projects still underway. | -- | -- |

as required in their work. Hydro-Québec states that they had an OR division from 1970 to 1975 but it was dissolved in favour of having OR done in each of the operating units in which several OR techniques, particularly modelling, are used.

The Ontario Ministry of the Environment mentions three OR teams: one of these works on water quantity modelling, set up in 1965, is doing hydrologic studies; one on air quality modelling (air pollution concentrations from point sources), set up in 1968; and one on water quality modelling set up in 1969 and doing waste assimilation modelling. The first OR team was set up in 1965 by provincial/federal agreement. The Ministry of Transportation and Communications has a Management Improvements Branch first established with a staff of two in the mid-sixties which conducts systems analysis reviews covering such aspects as appropriateness of products and services through to organization development. This work is in addition to that mentioned in Table XIII.

The Ontario Ministry of Government Services notes that in 1968 an organized approach to OR in the Ontario government began with the establishment of the Management Science Branch in the Management Board of Cabinet Secretariat in 1968. Prior to that, some ministries had done some OR using their own staff or consultants. Neither this ministry nor its predecessor, the Department of Public Works, had an OR unit as such. The Management Science Branch was organizationally part of the Ministry from October 1973 until March 1977 when the Branch was dissolved along with its parent organization, the Management Consulting Services Division.

The Ministry of Energy reports that it does not identify OR as a separate activity but that the application of quantitative methods and techniques is fairly common and generally

encompasses the work of the Strategic Planning and Analysis Group. The Ministry of Revenue states that in 1977 an OR unit was formed to work on impact analysis and project design, and one in 1978 which was called Tactical Support.

The Ministry of Community and Social Services states that O.M. Berg, Assistant Deputy Minister, Finance and Administration, was instrumental in getting OR started in the Ministry in September 1979 with the unit reporting to the Director, Systems Management and Coordination Branch. No specific problems have been carried out yet (Nov 1979) although some possibilities have been identified. Use is made of inventory models, 'what-if' models to assess the impact of program changes, and of models of patient care requirements as a basis for staffing standards. Also, work is being done on the development of social indicators to measure relationships between community resources and social needs.

The Ontario Ministry of Consumer and Commercial Relations has no unit with OR as its principal, explicitly stated responsibility, but considerable work is being done in systems analysis and development, financial and operation analysis, program analysis and evaluation, etc. Also, some OR is done when necessary but it is very sporadic. Among OR techniques, model construction is sometimes employed.

In the Ministry of Health cost-effectiveness studies and systems analyses have been used since the 1960's. These and related techniques have been used where relevant in many studies, but have not been classified as OR. 'Quantitative inputs to decision makers' include hospital and manpower statistics and studies on a large scale, involving several divisions of the Ministry.

In the Ontario Ministry of Labour, OR is not undertaken on any regular basis by a specialized team or unit. It is occasionally carried out on a project basis but is dependent on the mix of skills of either internally or externally assigned personnel.

The Ministry of Natural Resources does not have an organized OR unit as such. Each main office division is responsible for developing more efficient operations and in doing so, in many cases, OR techniques are employed. The Program Analysis Office, which reports to the Assistant Deputy Minister, Administration, is responsible for coordinating the Ministry's evaluation program.

The case of the Ministry of Industry and Tourism deserves comment. The term OR is eschewed and 'quantitative methods' is preferred and used. Elements of statistical regression analysis and multivariate methods are employed, as well as econometric and systems modelling, and optimization techniques (not necessarily only linear programming). Such analytical tools are employed by Meric Karasek, an economist in the Industry and Trade Analysis Branch.

A reply was received from the Ontario Ministry of Agriculture and Food which does not recognize OR as an organized activity in the Ministry. Research for the Ministry has been conducted since 1874 when it started at the School of Agriculture and Experimental Station at Guelph. This Section is now part of the University of Guelph and research has been continuous since 1874.

The Ontario Ministry of Treasury and Economics does not do, and has not done, OR as such. Use is made of econometrics and a model of the Ontario economy has been constructed and the Ministry makes use of University of Toronto facilities in some of its computer oriented and model building work.

The Ontario Research Council Foundation has never had a formal unit involved in OR. On occasion, projects have been undertaken which have an OR component.

Special mention should be made of the pioneer work in OR done by the Ontario Hydro Commission. OR was first used, formally, in 1955 and the project was the development of a vehicle fleet replacement study. Other studies in the first few years concerned inventory, short term forecast of river flow variations, economic scheduling of hydraulic and thermal generating plants, spare parts policy evaluation, and short-term forecasting of electric demand. These studies were carried out by Dr. P.J. Sandiford, Dr. W. Shelton, Dr. B. Bernholtz, Mr. D. MacLachlan, and Dr. J.C. Templeton. An account* of three early studies on lake-level forecasting, forecasting daily peak loads, and vehicle replacement analysis is given in Ref. 20. However, as early as 1951, Dr. Sandiford was using OR techniques as an employee of the Commission. It is also interesting to note that the Ontario Hydro Commission is one of several organizations (including the Liquor Control Board) that plans on expanding its OR activities.

THE PRAIRIE PROVINCES

In the Prairie provinces, seven government departments and agencies in Manitoba, 14 in Saskatchewan, and 12 in Alberta, were asked to complete questionnaires. Replies were received from 7, 12, and 12 respectively for a response of 31 out of 33 requests, a 94% return. However, only three of the Manitoba replies, four of the Saskatchewan ones, and eight of those

*This account was one of the earliest OR publications by Canadians in the Journal of the Operational Society of America. Earlier publications in that Journal were by Dr. O.M. Solandt, J.W. Mayne, Dr. N.W. Morton, and Dr. N.J. Hopkins. See section on Publications below.

from Alberta reported having organized OR units, and one of those from Alberta covered systems analysis rather than OR. Of the replies, one from Manitoba, and three each from Saskatchewan and Alberta, stated that they do not conduct OR as defined in the letter forwarded with the questionnaire (Appendix A). The remaining nine either use OR occasionally as required on a part-time basis, or use OR techniques in the course of other research.

Summarized information on these OR activities is presented in the following Tables XIV and XV. Thereafter, some further relevant comments are submitted.

From Table XIV we see that OR was started in provincial government agencies in the Prairie provinces earlier than in government departments. As early as 1952, OR-type work was being done for the Energy Resources and Conservation Board of Alberta by E.R.Q. Stoian and in 1956 the Petroleum and Natural Gas Conservation Board of Alberta sponsored OR studies by Dr. J.G. Debanné. He, with the encouragement and support of the Board Chairman, I.N. McKinnon, was instrumental in introducing OR methodology and the use of computers in the study of oil production, formation and conservation. Three resulting applications¹ are described in Ref.21 and represent one of the earliest uses of OR in Canada other than military applications.

In 1962, the Saskatchewan Wheat Pool began using OR by individuals on a part-time basis. The first department to introduce OR in the Prairie provinces was Alberta Transportation in 1963. Several other departments in these provinces began using OR in the 1970's. There is quite a variation in the numbers of OR workers presently involved in the several departments and agencies concerned.

¹Earlier, Dr. Debanné pioneered the use of computers (IBM 604 Electronics Punch) in the Texaco Exploration Co., Calgary, for data processing and engineering purposes.

TABLE XIV

OPERATIONAL RESEARCH IN PROVINCIAL GOVERNMENT DEPARTMENTS
AND AGENCIES OF THE PRAIRIE PROVINCES

| Province | Department or Agency | Date of Introduction of OR | Persons First Introducing or Using OR ¹ | No. of OR Personnel 1980 |
|--------------|--------------------------------------|----------------------------|---|--------------------------|
| Manitoba | Health & Community Services | May 1972 ⁴ | K. Gray R.R. Kuropatwa, K. Gray | 12 |
| | Labour & Manpower | May 1975 | J.E. Nykoluk, B.J. Warrack B.J. Warrack, A.F. Kobie, K. Hawkins | 1 |
| | Agriculture | 1979/80 | S. Spivak, K. Sandy K. Sandy | 6 |
| Saskatchewan | Saskatchewan Wheat Pool | 1962 | R.H.D. Phillips R.H.D. Phillips, A.D. McLeod | 7 ³ |
| | Saskatchewan Continuing Education | Nov. 1972 | R.F.E. Harvey A.J.V. Guy, A.M. Belsey D.J. Phillipon, D. Drever | 9 |
| | Saskatchewan Telecom- munications | 1975 | R.G. Allen W.H. Wendell J.G. McGregor | 250 ⁴ |
| | Government Services | 1980 | D.R. Archer D.R. Archer | 5 |
| | Mineral Resources | - | - | 4 ⁶ |

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TABLE XIV (Cont'd)

OPERATIONAL RESEARCH IN PROVINCIAL GOVERNMENT DEPARTMENTS
AND AGENCIES OF THE PRAIRIE PROVINCES

| Province | Department or Agency | Date of Introduction of OR | Persons First Introducing or Using OR ¹ | No. of OR Personnel 1980 | |
|----------|--|----------------------------|--|--------------------------|--|
| Alberta | Energy Resources Conservation Board | May 1952 ⁷ | E.R.Q. Stoian G.W. Govier E.R.Q. Stoian | 4 ⁸ | |
| | Petroleum & Natural Gas Conservation Board | 1956 | I.N. MacKinnon J.G. Debanné | - | |
| | Alberta Transportation | Sept. 1963 | (no single person) | - | |
| | Housing & Public Works | Early 70's | - | 3 | |
| | Education | April 1974 | E.K. Hawkesworth W.R. Duke, W.P. Eddy C.A. Lomas | 8 | |
| | Alberta Research Council | Feb. 1975 | J.E. Feick, E. Wiggins J.E. Feick DJ. McConaghy | 3 | |
| | Government Services | 1976 | J.T. Kyle, C. Hill A. Boys, J. Esplen | 12 ⁹ | |
| | Energy & Natural Resources | 1976 | M. Kanick M. Kanick, R.H. Cook | 3 ¹⁰ | |
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TABLE XIV (Cont'd)

OPERATIONAL RESEARCH IN PROVINCIAL GOVERNMENT DEPARTMENTS
AND AGENCIES OF THE PRAIRIE PROVINCES

LEGEND:

¹Names on first line are those of persons instrumental in getting OR started, those on second line are names of first OR leaders.

²OR was set up as a central unit in September 1975.

³Includes support staff.

⁴Part-time

⁵At present OR is being done by individuals on a part-time basis.

⁶One research officer, Policy, Planning and Research Branch; three engineers, Petroleum and Natural Gas Branch.

⁷No formal OR unit established in 1952; Systems Analysis Division formed circa 1969 under E.R. Bushett.

⁸Two doing systems analysis, two in cost-benefit analysis work.

⁹Mostly engineers and doing OR occasionally.

¹⁰Part-time on OR but not called OR.

TABLE XV
 FURTHER INFORMATION ON PROVINCIAL GOVERNMENT DEPARTMENTS AND AGENCIES OF THE
 PRAIRIE PROVINCES WHICH HAVE OPERATIONAL RESEARCH UNITS OR USE OPERATIONAL RESEARCH

| Provincial Department or Agency | Level at which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Types of OR Services by Outside Consultants or Management Firms |
|--------------------------------------|--|---|--|---|
| Manitoba Health & Community Services | Originally Executive Director, now Deputy Minister | Paper plan problems; caseload/workload problems. | Special studies; program analysis and review. | --- |
| Labour & Manpower | Director | Development of post-secondary enrolment forecast models & manpower stocks & flow model. | Development of collective agreements analysis system; evaluation of fire inspection reporting system; cost-benefit analysis of programs. | --- |
| Agriculture | Originally Minister, now Director | Supply policies review; restructuring of supply program and its components; implementing field purchasing system. | Operational review; program reviews & evaluation. | --- |
| Saskatchewan Continuing Education | Originally Deputy Minister, now Director | Policy and program planning; enrolment flow studies; graduate follow-up and feasibility studies. | As in adjoining column; program & policy evaluation. | Systems analysis, cost-benefit analyses & various evaluations. |
| Government Services | --- | --- | --- | Accounting; central records warehousing. |
| Mineral Resources | Director | Oil revenue modelling; oil economic forecasting using model. | Energy demand forecasting & uranium revenue model development & application. | --- |

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TABLE XV (CONT'D)
 FURTHER INFORMATION ON PROVINCIAL GOVERNMENT DEPARTMENTS AND AGENCIES OF THE
 PRAIRIE PROVINCES WHICH HAVE OPERATIONAL RESEARCH UNITS OR USE OPERATIONAL RESEARCH

| Provincial Department or Agency | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Types of OR Services by Outside Consultants or Management Firms |
|---------------------------------|--|---|--|---|
| Saskatchewan Wheat Pool | Corporate Secretary | Railway branch line rationalization; industrial utilization of grains & oil seeds. | Railway branch line rationalization; transportation. | — |
| Saskatchewan Telecommunications | Vice President Operations Development | Mathematical & statistical applications. | Economic evaluation models; best cost routing for networks. | — |
| Alberta Transportation | — | Systems planning applied to road systems; cost-benefit analyses of mutually exclusive highway alternatives. | (No OR unit at present) | — |
| Housing & Public Works | Assistant Deputy Minister | — | Studies concerning capital construction; cost analyses & office space renovations & leasing. | Planning for systems development. |
| Education | Originally Deputy Minister, now Director | Investigation in finance; curriculum studies in french, social studies, reading etc.; studies of superintendency, school building, discipline, etc. | Studies of exceptional children (problem learners, gifted children, etc.); pupil instruction, learning & growth; pupil progress & school evaluation. | Curriculum, special education; administrative, etc. |
| Government Services | Originally Assistant Deputy Minister, now Branch Heads | Measurement of efficiency & effectiveness of government services; cost-benefit analyses. | Systems design and value analysis related to the central purchasing function; short & long term planning related to cross government EDP system. | Systems design & analysis; cost-benefit studies. |

† A systems analysis group is in charge of all the computer and manual systems in the Department - some OR related activities only.

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TABLE XV CONT'D
 FURTHER INFORMATION ON PROVINCIAL GOVERNMENT DEPARTMENTS AND AGENCIES OF THE
 PRAIRIE PROVINCES WHICH HAVE OPERATIONAL RESEARCH UNITS OR USE OPERATIONAL RESEARCH

| Provincial Department or Agency | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Types of OR Services by Outside Consultants or Management Firms |
|------------------------------------|---------------------------------------|---|--|---|
| Alberta Research Council | Originally Director, now Branch Chief | Energy resources allocation (using linear & dynamic programming & mixed integer techniques). Optimizing technical & statistical data processing. | Energy resource allocation | --- |
| Energy Resource Conservation Board | Chairman | Benefit-cost analysis; energy resource allocation; optimal harvesting of timber. | Systems and cost-benefit analyses. Benefit-cost analysis; demand & supply forecasting for energy resources. | --- |
| Energy & Natural Resources | Executive Director | | | Benefit-cost analysis development of linear programming allocation model. |

It is noteworthy that, in several of the Prairie government departments, the minister, deputy ministers, or assistant deputy ministers were instrumental in getting OR started in departments. Such was the case with Manitoba Agriculture (the Minister), and Health and Community Services, Saskatchewan Continuing Education, and with the Departments of Education, Housing and Public Works, and Government Services in Alberta. Thus, in six cases, the OR units reported originally or later to an assistant deputy minister, and in one case, originally to the minister (Table XV). Again an apparent increase in the complexity and scope of the type of projects undertaken is noted. The use of outside consultants over the past five years varied from one to 12 cases, with one very high number of 100 (Department of Education, Alberta). Three of these departments reported having more than one OR unit. These were Manitoba Health and Community Services, Manitoba Agriculture, and Alberta Government Services.

Several of these departments that do not have organized OR units report that they make use of various techniques and devices generally considered to be those involved in OR. Examples are model construction, linear programming, queuing theory, and game theory.

Certain departments that do not have OR units or individuals doing OR work on a part-time basis report using quantitative analysis such as OR does. Among these are the Departments of Consumer, Corporate and Internal Services, Energy and Mines, and Natural Resources and Environment in Manitoba. In the latter, the Systems Section (Administrative Service Division), the Program Evaluation Unit, and line branches, such as Water Resources, use various forms of quantitative analysis in the course of their work.

In the Department of Mineral Resources of Saskatchewan, OR activities are restricted to some modelling (production, economic, tax system) in resource areas as well as systems and cost-benefit analyses and consideration is being given to implementing an energy demand model. Most of such OR work is done by engineers in the Petroleum and Natural Gas Branch. In Saskatchewan health, while no OR work is being done by a specific unit in any concentrated area as of yet, if OR is defined as the provision of quantitative inputs to decision makers, then it has been used by the Department of Health ever since a research branch was first instituted in 1943.

In Saskatchewan Consumer Affairs there is no formal OR activity, but OR work is conducted by consultants or the small staff of three analysts of the Planning and Policy Analysis Branch. Types of studies undertaken include methods of automating licensing procedures, cost-benefit analyses, and estimating future levels of consumer complaints or requests. In the case of the Saskatchewan Power Corporation, one individual, J.B. Street (P.Eng.) has post-graduate training in OR but to date only classical statistical methods have been used in attacking problems.

In the Alberta Department of Environment, cost-benefit analyses are occasionally employed. The Department of Consumer and Corporate Affairs does limited applied research but does not engage in OR as such. The Department of Education reports that prior to 1974 an OR Branch was in operation but most of its work was concerned with examinations and resulting research. In Government Services, three branches, Management Services, Supply Analysis, and Planning and Policy, utilize OR part-time. The OR activity began when those branches were formed in 1976, 1977 and 1978 respectively.

Although Manitoba Hydro does not have an established OR group, any internal group requiring OR work generally provides its own talent on a part-time basis. Such groups and the types of studies are as follows:

a. System Operations (electric production) Group

Some optimization studies are done to maximize the use of water power for generating electricity to eliminate excess water going over the dam as well as minimizing coal and gas usage for thermal purposes.

b. System Planning Group

Simulation studies are done to assist in determining the optional sequence of generation developments. A similar technique is used in minimizing the cost of transmission line design and construction.

c. Load Forecasting Group

Models of customer response to price and income as well as total sales responses to population changes are used to forecast sales and revenues.

d. Various engineering studies also use substantial mathematical analysis for optimizing design to minimize costs.

In the Bureau of Management Improvement of the Saskatchewan Finance Department of Cooperation, which is a central service agency committed to supporting program managers within government, OR is not regarded as a single and unique discipline but as a set of skills "available to support a part of the process of defining solutions to a broader range for management problems."

The support is provided through three units, Administrative Policy, Program Based Management Information System, and Operational Review. As in OR generally, the service is oriented towards the 'total' system. The Administrative Policy Unit provides a policy framework for program operation; the Management Information System supports program managers in specifying goals and objectives and providing output indicators for quantifying and reporting on program performance; the Operational Review Unit evaluates compliance with established policies, efficiencies and effectiveness in meeting program objectives and identifies opportunities for improving system performance within established criteria for, or through, alternatives to the existing program.

The underlying theme of the total system approach and the optimizing of program efficiencies and effectiveness provides commonality with OR. This commonality is strengthened by extensive use of scientific methods, techniques and tools in identifying problem solutions.

BRITISH COLUMBIA, YUKON
AND NORTHWEST TERRITORIES

The only reply to the letter and questionnaire to the Government of the Yukon was from the Department of Consumer and Corporate Affairs which has no specific group engaged in OR. However, cost-benefit analyses are performed by the Department staff on day-to-day procedures.

The Government of the Northwest Territories reported that OR as defined and used in the letter and questionnaire is not related in any way to the type of work being done.

The response from British Columbia was much more satisfactory. Returns were received from 11 departments, branches, and agencies. Eight of these have OR units or recognize OR as a formal on-going procedure, at least as a part-time activity. Information and data concerning these OR activities are given in the following Tables XVI and XVII.

Table XVI indicates that as early as 1950, OR was recognized and practiced in the British Columbia Ministry of Agriculture and that there has been a gradual growth in the number of ministries and agencies using OR and setting up OR units. In 1980, some 45 research analysts were working part or full-time in OR in seven of these ministries.

As shown in Table XVII, OR and related research work is conducted on a very wide range of issues in British Columbia ministries and agencies. And, as before, the OR units report in to several executive levels from directors or the equivalent to a vice-president and deputy minister. Seven of these make use of outside consultants on a variety of OR or OR-type studies. The number of such studies commissioned in the past five years varies from two to many (hundreds of small investigations in the case of the Division of Policy Development of the Ministry of Education).

The first OR consulting group in British Columbia (BC) was initiated by Mr. Donald S. Smith at B.C. Research. He brought Mr. Frank L. Sawyer, one of the original WW II analysts, from the UK on a one-year contract to start an OR group. Mr. Sawyer returned to the UK in 1958 and he was succeeded by Dr. J. Charles Clapham who had been with the National Coal Board in the UK. He was at B.C. Research until 1968 during which time he built up a successful OR consulting group. Other members of this group were Harry Dunn, Philip Daykin, and Tom Lambe. The present

TABLE XVI

OPERATIONAL RESEARCH IN PROVINCIAL DEPARTMENTS
AND AGENCIES OF BRITISH COLUMBIA

| Department, Ministry or Agency | Date of Introduction of OR | Persons First Introducing or Using OR ¹ | Number of OR Personnel 1980 |
|--|----------------------------------|--|-----------------------------------|
| Agriculture | April 1950 | - ² | 0 ² |
| Forests-Engineering Br. | March 1953 | K.W. Rieche, R.G. White K.W. Rieche, Menzing | 6 |
| B.C. Research | April 1957 | D.S. Smith F.L. Sawyer, J.C. Clapham | 10 |
| B.C. Railway | 1967 | N. Martin, J. Broadbent N. Martin, J. Johnson, R.N. Young | 6 |
| Education - (Division of Policy Development) | Sept. 1974 | - | 12 ³ |
| Consumer & Corporate Affairs | 1974 ⁴ | W. Nielson, K. Murdoch W. Wai | 6 |
| Forests - Silviculture Branch | 1976 | M.H. Wyeth, R.C. Jones M.H. Wyeth | 2 |
| Mines & Petroleum Resources | Dec. 1976 | J. Rohwedder | 3 ⁵ |

¹As for earlier tables.

²Individuals on part-time basis only; none in organized OR units.

³Originally a central team of 12 was set up, but later it was reduced to a few members and particular expertise is now purchased for particular tasks.

⁴A Research Division of the then Department of Consumer Services had some broadly defined OR responsibilities.

⁵Not specifically OR staff but use OR techniques as required.

TABLE XVII
 FURTHER INFORMATION ON OPERATIONAL RESEARCH IN PROVINCIAL
 MINISTRIES AND AGENCIES OF THE GOVERNMENT OF BRITISH COLUMBIA

| Ministry or Agency | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Types of OR Services by Outside Consultants or Management Firms |
|---------------------------|---|---|---|--|
| Agriculture | -- | Various trials, pesticide, etc.; applications of new management technology. | -- | Examination of waste products and their potential use as live-stock feed; strategy for development of the swine industry in B.C. |
| Forest-Engineering Branch | Originally Construction Engineer, now Manager, Resource Development | Land clearing, equipment & work method development; terrain classification; road construction studies. | Log haul studies; equipment development & assessment, simulation & quantitative analyses. | Work studies, computer programming assistance. |
| B.C. Research | Head of Division | Comparative costs of serving certain domestic loads with either gas or electricity; manpower requirements in a sawmill lumber sorting chain; scheduling a newspaper press room. | Forecasting provincial population and school enrolments; modelling (shiploading, electrical distribution systems, etc.); strategic planning processes; approaches to quality of working life. | Strategic planning processes; approaches to quality of working life. |
| B.C. Railway | Vice President & General Manager | Economic research; return on investment analysis; cost analysis; time and motion studies; establishment of EDP systems. | Economic analysis; traffic analysis profitability & planning; short & long term forecasting; development of marketing information systems; specific operational problems. | -- |

TABLE XVII CONT'D
 FURTHER INFORMATION ON OPERATIONAL RESEARCH IN PROVINCIAL
 MINISTRIES AND AGENCIES OF THE GOVERNMENT OF BRITISH COLUMBIA

| Ministry or Agency | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Types of OR Services by Outside Consultants or Management Firms |
|--------------------------------|--------------------------------|--|---|--|
| Education | Deputy Minister | Facilities planning; attendance; declining enrolment; effects of various factors on achievement; counselling services. | Fifty projects underway ranging across the entire ministry operation. | Wide variety of studies. |
| Consumer & Corporate Affairs | Director | Consumer related program effectiveness issues; price monitoring program. | Cost-benefit legislative proposals; systems analysis and development; regulatory impact studies. | Revision of securities regulation; system analysis; consumer store front evaluation. |
| Forestry - Silviculture Branch | (R.C. Jones) | Systems analysis; work scheduling. | Information processing; decision processes. | Simulation and linear programming work. |
| Mines & Petroleum Resources | Director | Cost-benefit analysis; investment decision-making; analysis of regional/provincial projects. | Cost-benefit analyses; computer based analyses of mining projects including risk & sensitivity analyses; production scheduling modelling. | Risk analysis, cost-benefit analysis. |

head of OR activities at B.C. Research is Alex Tunner who reports to John E. Roberts, Head Management Services Division. The 'quality of working life' approaches noted in Table XVII are concerned with labour management questions, organization and job design, and productivity. Depending on the definition of OR, it is planned by B.C. Research that OR work will be expanded.

The B.C. Ministry of Transportation reports that the Ministry has no OR units as such but that some OR techniques are used, for example, in the Highways Division in transportation system and traffic demand modelling and project cost comparisons. The Ministry of Labour states that the Ministry has no staff doing OR on a full-time basis but that they do undertake a zero-base budgeting exercise that has some OR overtones.

The Ministry of Economic Development has a staff of about 40 people engaged in statistical studies and using quantitative methods but the work has never been specifically designated as OR. Other related work, including econometric forecasting discounted cash flow simulation modelling is done in the Central Statistics Bureau. Also, some staff in the Economic Analysis and Research Bureau undertake work that could be broadly identified as OR, but 'it does not carry that label'.

It is interesting to note the first Deputy Minister of Consumer Services (William Nielson) identified the need for research capability as described herein. That need has since been confirmed and expanded upon by subsequent Deputy Ministers (Tex Enewark, Peter Bazowski). The separate research capacities of the live programs were combined in January 1979.

SUMMARY OBSERVATIONS

Reviewing across the regions, it is noted that the first use of OR in the Atlantic provinces was at the Nova Scotia Research Foundation in February 1967, and that some two years later OR began in government departments, first in the Department of Health in New Brunswick. In the Central provinces, OR was being used in the Ontario Hydro Commission in the early 1950's and in Ontario government departments by 1965 (Environment). Based on the questionnaire returns, OR came late to Quebec and is still not widely practiced or recognized in Quebec government ministries and agencies. In the Prairie provinces, OR was being used by provincial agencies of Alberta in the early 1950's but not in provincial departments until 1963. On the other hand, OR was introduced into government departments and agencies of British Columbia in the 1950's. The preceding findings also show that in Ontario and British Columbia provincial government departments and agencies adopted OR earlier, and OR is used more widely, than is the case in the other provinces.

There is considerable commonality in the provincial departments and ministries having OR units or staff and using OR services. We note that Nova Scotia, New Brunswick, Quebec, Ontario, Saskatchewan, Alberta and British Columbia use OR in departments or ministries responsible for energy, mines and natural or other resources, that Prince Edward Island, Nova Scotia,¹ Ontario and Manitoba use OR in the field of social services, that Prince Edward Island, Saskatchewan, Alberta and British Columbia do in Education, and that Newfoundland, Ontario, and Alberta do in Transportation and Communications. Also, Ontario, Saskatchewan and Alberta have introduced OR in ministries of Government Services, New Brunswick and Manitoba

¹Information obtained by personal contacts.

have done so in Health, Newfoundland and British Columbia in Forestry (particularly British Columbia in Silviculture), and that Manitoba and British Columbia use OR in their department or ministry of Agriculture. Only one province reports using OR in Fisheries (Newfoundland), Environment (Ontario), Revenue (Ontario), Industry and Tourism (Ontario), Labour and Manpower (Manitoba), and Housing and Public Works (Alberta).

CHAPTER VII
OPERATIONAL RESEARCH IN CANADIAN CIVIC
AND MUNICIPAL GOVERNMENTS

INTRODUCTION

In order to get information on the use of OR in civic and municipal governments, the questionnaire for federal and provincial governments (Appendix A) was forwarded to cities and municipalities in the several provinces. Again, the choice of addresses was subjective rather than random. Questionnaires were sent to all capital cities, regional municipalities, and major cities. The list included 36 of these population centres and 20 replies were received of which 14 reported positively. The reports are summarized and described below.

Summaries of the data obtained by the questionnaire are given in the four tables below. Because of the very complete return from the City of Edmonton, the information is summarized separately in Tables XX and XXI. Still other relevant information is given in the text of succeeding paragraphs.

FINDINGS

From Tables XVIII and XX we see that the earliest major Canadian city to use OR as a recognized activity was Vancouver in 1962 and that the first organized OR unit as a central service in local governments was set up in the Finance Department in Edmonton in 1965 followed by Vancouver in 1966. The unit in Brandon established in 1974 was an early OR service in civic administration originally set up as a team or unit. The number of OR workers in 1980 varies from one on a part-time basis (City of Toronto) to 12 in Calgary full-time and 10 full-time plus three part-time in Vancouver and 25 part-time in the Real Estate and Housing Department of the City of Edmonton where the total, including part-time OR workers, is over 80 (Table XX).

TABLE XVIII

OPERATIONAL RESEARCH IN CIVIC AND MUNICIPAL GOVERNMENTS

| City or Municipality | Date of Initial Use of OR | Type of Original Unit | Date of First Organized OR Unit as Central Service | Persons first Introducing or Practicing OR ¹ | Number of OR Personnel 1980 |
|--|---------------------------|------------------------------------|--|--|-----------------------------|
| Vancouver ² Engineering Dept. | 1962 | Individuals part-time | 1966 | Wm. Curtis K.F. Dobell, B. Davies V. Sawadsky | 10 ³ |
| Toronto Services Dept. Toronto Transit Comm. | July 1965 Early 1960's | Individuals part-time O.R. Unit | -- -- | B. Cramer B. Cramer, C. Gregory J.H. Bookbinder ⁴ | 1 |
| Oshawa | 1968 | Individuals part-time | Sept. 1970 | O. Vyskocil O. Vyskocil | 4 |
| Calgary | Oct. 1972 | Individuals part-time | Oct. 1972 | R.G. Conway D.E. Richmond | 5 12 ⁵ |
| Windsor | July 1973 | Individuals part-time | Jan. 1979 | H.G. Payne W. Coulter R. McConnell | 2 |
| Brandon | June 1974 | O.R. Unit | June 1974 | R.J. Boyd | 5 |
| Municipality of Metro Toronto | 1976 | Individuals part-time | -- | G. Humble D. Richmond D. Richmond | 3 |

¹Names on first line are those of person(s) introducing OR; those on second line were early practitioners of OR.

²City Engineering Department.

³Plus 3 part-time.

⁴Dr. Bookbinder is the present (1980) head of the OR section, not the original one. The unit has been concerned with bus scheduling, the optimization of transport services, and other related investigations.

⁵Originally 5.

It is also interesting to note that, while most of the governments concerned introduced OR on the basis of individuals part-time, several of them have since organized OR units as a central service.

It is perhaps not surprising that the OR units or practitioners report in at a variety of levels as shown in Table XIX and XXI. These Tables also indicate a wide range of problems and projects undertaken by OR workers in civic and municipal or regional governments and that, in most cases, the type of such studies has undergone changes towards greater complexity. The nature of the studies, of course, depends heavily on the management official or tasking authority concerned.

The very complete return from the City of Edmonton warrants special comment. Thanks to the cooperation of Mr. Chris H. Heffring, Manager, Management Studies Branch, and of the early OR practitioners in the Edmonton municipal government, all City departments provided answers. Of these, the non-users of OR are: Executive Services, Utilities Services, Public Relations, Corporate Policy Planning Office, City Assessment, Auditor-General Office, City Clerk's Department, Library, Administration Branch, Business Development, Law, Health, and Parks and Recreation. However, in the Auditor-General's Office, the application of models and their cost-benefit effects in improving departmental performance is of concern and under continuing review. Pertinent details on other departments of which almost twenty use OR or have OR units, are given in Tables XX and XXI.

Information and details on the use of OR in the Edmonton Telephones Department as provided by S.W. Shpiel, acting Organization Development and Financial Results Manager are given below. OR has been used in five branches (Financial Control and Results beginning in 1972, in Corporate Studies in January 1974, in

TABLE XIX
 FURTHER INFORMATION ON CITIES AND MUNICIPALITIES THAT HAVE
 OPERATIONAL RESEARCH UNITS OR USE OPERATIONAL RESEARCH

| City or Municipality | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Types of OR Services by Outside Consultants or Management Firms |
|----------------------|-----------------------------------|--|--|--|
| Vancouver | City Engineer | Optimal replacement period for trucks and cars; optimal mix of hiring or owning city vehicles; simulation of sanitation operation; analysis of parks operations; scheduling shift workers. | Fleet management (trucks and cars); survey sampling; systems designs; environmental monitoring; selection of computer mapping system; management information systems design. | Electronic systems design for mobile radio data system; impact of a consolidated trucking system; programming; analysis & review of city departments; study of electrical plant. |
| Toronto | Director | Heat demand model; municipal financial simulation. | Vehicle scheduling; parking lot usage and planning model. | --- |
| Oshawa | Committee | Organizational realignment; improvement of operational practice; streaming budgetary processes and refinement and procedures. | Resource deployment; management & support of daily operations; development of computer systems & work processing. | Fire station location. |
| Calgary | Manager, Urban Information and OR | Land use & transportation modeling; tax policy analysis; project managing & scheduling; economic & demographic forecasting. | Performance measures; maintenance scheduling; applied economic analysis; staff scheduling & assignment; policy analysis. | (Yes, quite extensively by various City departments). |

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TABLE XIX CONT'D
 FURTHER INFORMATION ON CITIES AND MUNICIPALITIES THAT HAVE
 OPERATIONAL RESEARCH UNITS OR USE OPERATIONAL RESEARCH

| City or Municipality | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units | Types of OR Services by Outside Consultants or Management Firms |
|-------------------------------|--------------------------------|--|--|
| | | Originally | Currently |
| Windsor | Director of Operations | Estimating costs of road maintenance & refuse collection. | Devising cost control system for estimating costs (relative & absolute) of road maintenance, etc. (Similar) |
| Brandon | Executive Director | Designing cost-benefit systems; analysing validity of estimates. | Advice & assistance in establishing OR unit. Cost analysis of unused sick leave benefits. |
| Municipality of Metro Toronto | Chief, Administrative Officer | Financial simulations; models of revenue & expenditures of Metro Toronto | Budget work; financial simulation; housing modelling; Toronto transit subsidy modelling. |

TABLE XX
OPERATIONAL RESEARCH BY GOVERNMENT DEPARTMENTS OF THE CITY OF EDMONTON

| Department | Date of Initial Use of OR | Type of Original OR Unit | Date of First Organized OR Unit | Persons First Introducing or Practicing OR ¹ | Number of OR Personnel 1980 |
|--|---------------------------|---------------------------|---------------------------------|---|-----------------------------|
| Water & Sanitation | Early 1960's | Individuals part-time | — | Various engineers | 202 |
| Finance | 1965 | OR unit | 1965 | John Paproski, E.K. Barry, T.J. Peach, Van Deelen | 03 |
| Planning - Communications Branch | 1970 | Individuals part-time | — | W. Walchuk, P. Elwood D. O'Neil, Bill Thomson | — |
| General Research Services Community Planning Branch | Indefinite | — | — | M. Barrow | 24 |
| Social Service | 1973 | — | — | M. Sorochan | 05 |
| Business Development | — | No formal OR organization | — | — | 06 |
| Central Supply and Services | April 1974 | Individuals part-time | — | George Knowles, H. Mayhew George Knowles, Fred Keane | 7 |
| Fire | Dec. 1975 | Team | — | L.C. Day, Chief E.C. Gilchrist | 27 |
| Engineering, Roadways | 1975 | Individuals part-time | — | — | — |
| Real Estate & Housing | 1975 | Individuals part-time | July 1978 | B.C. Flatten | 258 |

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¹ Names on first line are those of person(s) introducing OR; those on second line were early practitioners of OR.
² About 20 use OR occasionally.
³ Function transferred to another department in 1970.
⁴ None explicitly; two explicitly.
⁵ None, but several social planning staff members use OR techniques as required.
⁶ None formally, but OR techniques are used to obtain effectiveness & efficiency; each manager is responsible for implementing OR in program activities.
⁷ Two, part-time, in 1980.
⁸ OR is carried out largely by a centralized Policy, Planning & Control Branch of 25 members. The number doing OR varies.

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TABLE XX CONT'D
 OPERATIONAL RESEARCH BY GOVERNMENT DEPARTMENTS OF THE CITY OF EDMONTON

| Department | Date of Initial Use of OR | Type of Original OR Unit | Date of First Organized OR Unit | Persons First Introducing or Practicing OR ¹ | Number of OR Personnel 1980 |
|--|---------------------------|--------------------------|---------------------------------|---|-----------------------------|
| Transit | 1975 | Individuals part-time | 1976 | L. Lawrence, R. Bird R.J. Charles, H.K. von Gaza A.R. Crawford | 10 |
| - Transit Research & Systems Engineering | 1976 | — | — | — | — |
| - Services Development | 1977 | — | 1976 | W.J. Brown, R.F. Lunney | — |
| Police | Jan. 1976 | Team | — | W.J. Brown, D.R. Butler | 2 |
| Management Studies | 1977 | Team | 1977 | Commissioner Adams, S.W. Sadler C.H. Heffring, J. Keefe, B. Butler | 2 |
| Computer Systems Development Services | | | | | |
| - Computer Information Services Branch | — | Individuals part-time | — | Director, Research Planning | — |
| - Computer Systems Development and Services Department | Jan. 1978 | Team | 1978 | S.W. Sadler C. Heffring | 8 ⁹ |
| Personnel | | | | | |
| -Manpower Planning Br. | Jan. 1978 | Individuals part-time | — | General Manager Branch Director | —10 |
| -Staff Development Br. | June 1978 | Team | — | General Manager Branch Director | 4 |

⁹ Eight on OR related work.
 10 No specific OR unit as such.

TABLE XXI
 FURTHER INFORMATION ON OPERATIONAL RESEARCH IN THE GOVERNMENT
 OF THE CITY OF EDMONTON

| Department | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Types of OR Services by Outside Consultants or Management Firms |
|--------------------------------------|------------------------------------|--|---|--|
| Water & Sanitation | N/A | Linear programming; research analysis; location & critical path analysis. | As originally plus simulation dynamic programming; production scheduling; time & motion studies. | — |
| Finance | General Manager of Finance | Improving functions related directly to servicing of public issue of permits, licences, etc. | Nil - functions transferred elsewhere in 1970. | — |
| Edmonton Power | General Manager | Network analysis; transportation models; economic analysis; development & use of forecasting models. | — | — |
| Planning - Communication Branch | — | Population projection; data base analysis; strategic choice model construction & use. | OR used in the engineering production, distribution, and administration decisions and in the system planning section. | — |
| Social Service | Acting Director | Program planning & scheduling for Edmonton Home Care Program. | Task/time analysis and scheduling for research studies & program evaluations. | — |
| Planning - Coordination Branch | — | Population projection for the region and city. | — | — |
| Planning - General Research Services | Director General Research Services | — | Modelling; data analysis forecasting. | Parking requirements; population models; studies of policies & procedures. |

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TABLE XXI CONT'D
 FURTHER INFORMATION ON OPERATIONAL RESEARCH IN THE GOVERNMENT
 OF THE CITY OF EDMONTON

| Department | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Types of OR Services by Outside Consultants or Management Firms |
|---------------------------|--|---|--|--|
| Business Development | --- | Revision & upgrading of departmental reports; market presentations & formats & economic & market research activities. | As originally. | --- |
| Central Supply & Services | Originally Superintendent, now Director Research Policy | Maintenance cost evaluation & evaluation of maintenance facility location. | Information systems & operational analysis. | --- |
| Fire | Originally Chief, now Director of Planning & Research | Manpower department; studies of training function and information flow. | Station location analysis; fire ground strategy; computer aided dispatch. | --- |
| Engineering Roadways | Director, Support Services | Queuing theory & dynamic programming to determine number of trucks to accompany snowblowers. | Replacement models to determine re-placements for heavy equipment; linear programming to minimize work force requirements. | --- |
| Real Estate & Housing | --- | Life cycle costing; investment analysis. | Work for the Policy, Planning & Control Branch. | --- |
| Transit | Manager of Administration & Director Systems Engineering | Simulation, critical path analysis; location/allocation analysis; searching & sorting problems. | Scheduling, routing & queuing problems; fleet sizing; production scheduling; life cycle costing; service evaluation. | Life cycle costing; staffing & production scheduling; critical path analyses; operator shift design; routing & scheduling. |

1 Transit Research & Systems Engineering Branch does life cycle costing, operator shift design, investment analysis, and is available to all areas of departments as required; Services Development Branch do studies concerned with the design and development of public transit routes & services with special emphasis on existing service evaluation.

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TABLE XXI CONT'D
FURTHER INFORMATION ON OPERATIONAL RESEARCH IN THE GOVERNMENT
OF THE CITY OF EDMONTON

| Department | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Types of OR Services by Outside Consultants or Management Firms |
|--|--|--|---|---|
| Police | Chief | Simulation of priority dispatch procedures; development of computerized shift shift schedules. | Development of shift schedules; developing police patrol simulation to determine resource requirements. | --- |
| Management Studies | Manager, Management Studies prices & services. | Fire station location; parking | Yard & facility locations; airport use; resource deployment; fiscal impact. | --- |
| Computer Systems -Development & Services | Director, now General Manager | Computer performance projections. | --- | --- |
| Computer Systems Development & Services Department | --- | Emergency services; fire station locations; City Hall operating impact. | Systems development studies; planning; implementation consulting. | --- |
| Personnel -Staff Development Branch | Branch Director | Executive management training; statistical analyses of in-house training to schedule & forecast types of future programming. | Problem identification in relation to training and designing training programs. | Competency analysis profile on senior management positions. |

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TABLE XXI CONT'D
 FURTHER INFORMATION ON OPERATIONAL RESEARCH IN THE GOVERNMENT
 OF THE CITY OF EDMONTON

| Department | Level at which OR Unit Reports | Types of Problems Undertaken by OR Units | | Types of OR Services by Outside Consultants or Management Firms |
|----------------------------------|--------------------------------|--|---|---|
| | | Originally | Currently | |
| Manpower Planning Branch | Branch Director | Organization design & audit; studies of manpower system demand, supply, & policy analysis framework. | Manpower demand & supply forecasting; policy analysis & evaluation; organization development problems in departments. | -- |
| Edmonton Telephones ² | -- | -- | -- | -- |

² See main text for information and details.

Rates and Economic Studies in January 1974, in Commercial Methods in November 1974, and in Commercial Forecasting in January 1975). But all have used OR by individuals part-time. Further details are listed as follows:

Originators of OR:

| <u>Section:</u> | <u>Name:</u> | <u>Appointment:</u> |
|-------------------------------|---------------|---------------------|
| Commercial Methods | F.W. Windwick | Commercial Manager |
| Commercial Forecasting | F.W. Windwick | Commercial Manager |
| Rates & Economic Studies | A.S. Baptie | O.D. & F.R. Manager |
| Corporate Studies | A.S. Baptie | O.D. & F.R. Manager |
| Financial Control and Results | A.S. Baptie | O.D. & F.R. Manager |

| <u>Assistant Heads & Leaders:</u> | <u>To Whom They Reported:</u> |
|---------------------------------------|-----------------------------------|
| A.H. Johnson | F.W. Windwick, Commercial Manager |
| R.B. Bird | A.S. Baptie, O.D. & F.R. Manager |
| S.W. Shpiel | A.S. Baptie, O.D. & F.R. Manager |

First OR workers were: D.H. Rose, J. Secord, M. Hovestad, N. Louis, Y.A. Van Schaik, K. Edugyan, I. Fraser, A. Crowley, D. McRae, T. Burn.

Current activities are described below:

CURRENT ACTIVITIES:

| Section: | Reporting to: | No. of OR Workers | Types of Problems: |
|-----------------------------|---|-------------------|--|
| Commercial Methods | V. Niblock Director of Commercial Methods | 17 | Policies practices & procedure affecting mechanized & manual operations & budget preparation & tracking. |
| Commercial Forecasting | A. Crawford Director of Forecasting | 13 | Forecasting, Project Planning. |
| Rates & Economic Studies | J. MacPherson Rates & Economic Studies Supervisor | 4 ¹ | Economic studies, investment analysis (modelling), life cycle costing. |

¹These 4 analysts perform OR types of work although they are not considered to be OR staff.

The Telephone Department has used outside OR consultants on four occasions in the last five years to conduct operations reviews and mechanization studies. OR techniques used by Edmonton Telephones staff include simulation, critical path analysis, inventory analysis, queuing theory as well as scheduling, routing and location analysis, and theory of graphs. Individuals using these methods are not necessarily aware of OR activity involvements by them during their analyses.

Although OR is practised in about 20 departments of the municipal government of Edmonton, only five of these have OR units as such (Table XX). Also, several departments not having OR units or recognizing OR as an activity mentioned that use was made occasionally of such OR techniques as model construction and use, queuing theory, inventory analysis, game theory, dynamic and linear programming, simulation, critical path analysis, and investment decision modelling.

The Regional Municipality of Ottawa-Carleton report that it has no specific unit or team of persons whose sole purpose is to carry out OR as a recognized activity. There is, however, a Management Services Section which administers and coordinates Regional programs and activities concerned with organization, systems, methods, and procedures. Some of the work is of a quantitative nature, in some cases regression analysis and other statistical tools are used. Some modelling is also done, e.g. modelling transport networks by the Systems Planning Branch of the Transportation Department. The City of Ottawa does not have any units specifically charged with doing OR as such. However, simplified OR related activities including systems analysis, cost-effectiveness, and cost-benefit analysis techniques, are used in various aspects of the City's operations. It has not used outside OR consultants nor any of the OR techniques mentioned in Question 12 of the questionnaire (Appendix A).

The City of St. Catharines has not considered that the City organization was large enough to identify OR as a separate activity within the municipal administration. The questionnaire was, accordingly, not completed. Such was also the case with the Greater Vancouver Regional District and Ville de Montréal.

The Regional Municipality of Waterloo does not use OR under that name in its operations nor has it used outside OR consultants. It does employ some OR techniques, particularly linear programming.

The City of Charlottetown does not have an OR unit but in some cases uses OR techniques as appropriate. The City has used consultants to undertake traffic analyses and recommend an actuarial pension scheme for employees. The Regional Planning Board does financial planning and scheduling for 13 municipalities and were responsible for a transportation study with OR implications in 1979.

The City of Saint John, New Brunswick, does not have an OR unit nor does it conduct research under that name. However, the City does make considerable use of both management and engineering consultants and in the past year 1979/80 has contracted for 14 management consulting studies which involve the use of various OR techniques.

The City of Winnipeg does not have a unit specifically set up to do OR under that name. There have been studies made on various aspects of the City's operation such as garbage pick-up, farming out of workers, etc. but these as well as cost-effective and cost-benefit analyses have been carried out mostly by respective departmental staff using appropriate techniques. A study is presently (June 1980) being made on police operations by consultants hired by the City.

REMARKS

Perhaps the only general comment regarding OR in civic, municipal, and regional governments in Canada is that although these governments were not among the early users of OR in Canada, during the 1970's many departments of many cities and municipalities either set up OR units or encouraged the use of OR techniques. In view of the sampling method used, it can only be surmised that quite a few other cities also made use of OR services and techniques.

CHAPTER VIII

OPERATIONAL RESEARCH IN CANADIAN BUSINESS, COMMERCE AND INDUSTRY

INTRODUCTION

In order to get comprehensive coverage of business, commercial and industrial firms in Canada, questionnaires and covering letters (Appendix A), were sent to a large number of establishments and companies in Canada. In doing so, all the companies that were canvassed in earlier investigations by the School of Business Administration of the University of Western Ontario (Ref.22) and by the author personally in preparing earlier papers (Refs.19 & 23), those companies mentioned in Ref.18, those known to have OR staff as available from Ref.24, and those obtained from a list of OR employers prepared by the Canadian Operational Research Society (CORS)¹ were included in the distribution list. In addition, many companies were selected from Ref.25 on an eclectic basis which was by no means random. The selection was determined by two considerations: the type of company (e.g. manufacturing, consulting, etc.) thought to be likely to use OR, and gross annual sales, in the belief that those with the larger sales would more probably have OR teams or have staff using OR on a part-time basis. Finally, other firms encountered in literature search in OR and other journals and newspapers were also included in the list of addresses and sent questionnaires.

¹Courtesy of R.N. Burns, Faculty of Mathematics, University of Waterloo.

The Canadian Key Business Directory 1979 lists over 16,000 business companies and some 280 of these not already canvassed were invited to respond to the questionnaire. Of these, about 190 were in Quebec and Ontario, 30 in the Atlantic Provinces, 35 in the Prairie Provinces, and 20 in British Columbia, Yukon, and the Northwest Territories. As a result, over 365 companies were approached. Replies were received from approximately 175, giving a response rate of almost 50%, somewhat less than was anticipated. It is not known, of course, whether companies without OR staff tended to fail to reply. Follow-up action on well over half of the original non-responders was taken with some success. Of the total replies, about 40% were negative in that the companies concerned did not have OR staff or did not use OR in their operations. Accordingly, only about 100 positive replies were received from business, commercial, and industrial companies. And, as already noted, this sample of 100 from a population of over 16,000 was by no means a random one, so that statistical estimation on the basis of it is not possible and will not be attempted.

At the first international conference on OR in Oxford, England in 1957, Patrick J. Robinson of Imperial Oil Limited, Toronto, presented a paper on operational research in Canada (Ref.18). In this paper, reference is made to a mail survey conducted by the School of Business Administration of the University of Western Ontario in February 1956. In the survey, 67 organizations thought to be using OR or to be interested in the subject were sent questionnaires. The returns indicated, at that time, that some 11 organizations were definite users of OR and that one company had been engaged in OR activity since 1950, one since 1951, one since 1952, three since 1953, one since 1954, and two since 1955 (two did not report). Also at that time, only two companies had been using the services of consultants in their OR work, and both planned to continue.

In a survey of industrial OR in Canada by the Canadian Operational Research Society in April 1959, it was found (Ref.26) that 21 companies (of 115 approached, 49 of whom replied) were engaged in operational research activities. All of these were relatively large organizations. The total full-time OR staff for 17 of these companies consisted of 62 professional members and 23 supporting staff. Some 149 research projects were listed by these companies of which the most (26) involved inventory studies, with production (25), transportation (20), planning (18), marketing (14), and research following in order of frequency. Consultants worked in cooperation with internal OR groups for nine companies while eight companies relied on their own staff entirely.

In a subsequent report on a study of OR in Canada prepared in 1963 by the School of Business Administration of the University of Western Ontario (Ref.22), some 20 companies are listed as having recognized OR departments and 15 others as not having recognized OR departments but employing OR workers. The same report lists 10 Canadian consultant firms engaged in OR in 1963.

An article in the Canadian Chartered Accountant in June 1957 (Ref.27) by P.J. Sandiford, states that "in Canada, OR became established in a formal way in the period 1951-54 in two oil companies, a paper company, and a large utility." He was referring to the Imperial Oil Company, the British American Oil Company (now Gulf Canada), the Abitibi Power and Paper Company, and the Ontario Hydro Commission. Among other Canadian companies that made use of OR in the fifties and early sixties are Air Canada, the Consolidated Mining and Smelting Company of Canada Limited (COMINCO), Canadian National Railways (CNR), Eatons, Canada Packers, McMillan-Bloedel, and the Steel Company of Canada. Further data on OR in industrial companies are presented later in this Chapter.

Management and other consultant groups were early Canadian users of OR. Among the first were Stevenson and Kellogg, H.S. Gellman & Co. Ltd.,¹ Adalia Limited and KCS Data Control,² all of Toronto, and Donald Smith's OR consultant group with the British Columbia Research Foundation in Vancouver. Some relevant information about these first users of OR in Canadian business and industry, and later ones, is given in the following paragraphs.

For simplicity in presentation, responses from the business companies and organizations will be discussed below under three headings: banks, insurance and trust companies; management and consultant firms; and industrial companies generally. Federal and provincial companies such as crown corporations, public utilities and other governmental agencies have already been treated. Private foundations and research institutes are given brief treatment later in this Chapter.

OPERATIONAL RESEARCH IN CANADIAN BANKS

Introduction

Under the general heading of Business and Industry, information was solicited by questionnaires from eight chartered banks. The questionnaire used was the same as the one used for business and industry (Appendix A). Replies were received from only five--Commerce, Mercantile, Montreal, Nova Scotia, and Royal. Since it was believed that OR was not widely used in Canadian banks, follow-up action on the non-responses was limited.

¹Now Gellman, Hayward & Partners Ltd.

²Now Josef Kates Associates Inc.

Only one of the banks that replied has an OR unit under that name. Some related research activities were reported by other banks and these are described briefly below. The information was provided by Head Offices of the banks.

The Canadian Imperial Bank of Commerce

This bank has an OR unit in Toronto since December 1969. It was started by Alan Gardner as an OR analyst with Donald Bartlett assisting. The unit is now a Department under Patrick J. Fallon who reports to the Manager, Branch Network Planning. The Department has five OR personnel and outside OR consultants have not been used. Original studies by the OR unit included lease/purchase analysis, analysis of bank float, and cost analysis and projection for proposed customer services. Studies currently (1980) under investigation are a cost-benefit simulation model as an analytical framework for branch closings, and a computerized branch evaluation and decision support system. The Bank has no immediate plans for expanding the OR services. The OR unit is now called Branch Network Research.

The Royal Bank of Canada

The origin of OR in the Royal Bank of Canada dates back many years and OR skills are widely practiced in the Bank. However, only a few persons are involved with building computer based models. There is an OR-type unit in the Royal Bank which is known as "Analytical Systems," the present head of which is L.D. Thomson, for computer based models. He reports to the Manager, Management Control Systems. A total of eight persons work in the Automated Systems Development area. Among early studies undertaken by the staff are economic forecasting, analysis of financial statements, and trend analysis.

The Royal Bank reply, after remarking on the wide scope of OR, notes that there are very few functions in banking to which OR skills are not applied and that such skills are practiced by a large number of persons in both support and line positions in the Royal Bank. In view of these remarks, it may be observed that most other Canadian banks do not recognize this fact or interpret OR more stringently.

The Royal Bank states that the use of OR skills is adjusted regularly depending on need. The Bank has not used outside OR consultants.

The Bank of Montreal

Although the Bank of Montreal does not have an OR unit or branch as such at present, an OR unit was set up in 1969 by the Research Supervisor of the Organization, Research and Systems Division. This OR unit has since been disbanded for the reason that its "activities were more appropriate to line."

The Bank, however, does use such OR devices as those mentioned in the questionnaire (model construction and application, linear programming, queuing theory, etc.) in undertaking projects and studies related to its activities. Also, it has used outside OR consultants.

The Bank of Nova Scotia

The SCOTIA BANK does not have an organized OR team or unit but, in a narrow definition of OR, up to five staff are employed in OR, and about ten in related work. No outside OR consultants (again in a narrow use of the term) have been used, but in some studies related techniques have been employed.

SCOTIA BANK plans on expanding OR services. It also uses such OR techniques as those mentioned in the questionnaire.

The Mercantile Bank

The Mercantile Bank did not complete the questionnaire because the subject matter of the questionnaire (and covering letter) "is inapplicable to this Bank."

OPERATIONAL RESEARCH IN CANADIAN INSURANCE COMPANIES

In order to get some data on the origin and development of OR in Canadian insurance companies, the questionnaire for business and industry (Appendix A) was sent with covering letter to 17 insurance companies. Replies were received (after follow-up action in some cases) from 14 companies but only seven of these had any relevant information. Completely negative replies were received from the following: Canada Life, Confederation Life, Imperial Life, Metropolitan Life, Monarch Life, North American Life, and Wawanesa Mutual Insurance.

None of the other companies that responded have an OR department, division, branch or unit. Crown Life reported that limited OR work is done but only in the context of planning and actuarial research. OR-type work is being done by systems and actuarial analysts. Studies underway include long range planning and marketing models (by in-house staff). The company 'possibly' plans on expanding OR facilities. It has not used outside OR consultants. It does use some of the OR techniques mentioned in the questionnaire. Manufacturer's Life reported that they have no OR units as such, but that OR-type work is done in analysing annual plans and certain new ventures. Some model development in the financial and actuarial areas has been done. They have made some use of OR consultants.

Dominion Life with no OR staff uses OR techniques occasionally. Great West Life currently (1980) have two young university graduates with OR training, who have been working on projects concerned with computer systems development. Actuaries in the Company have been doing OR-type work for some time, particularly in the construction of a financial model, and simulations for investment purposes. Mutual Life report limited use of OR techniques. The National Life uses model construction by actuarial departments in connection with determining future earnings of blocks of business, etc. Sun Life states that a number of simulation and other type models have been constructed for various purposes using a variety of computer languages. Examples are a corporate model developed by the Actuarial Division, and in the Systems Division various models for predicting teleprocessing line loads, computer loads, etc. for capacity planning and configuration testing.

OPERATIONAL RESEARCH IN CANADIAN TRUST COMPANIES

Eight Canadian trust companies were sent questionnaires and replies were received from five of them. Of these, three-- Crown Trust, Equitable Trust, and Guaranty Trust--submitted nil returns, and the Permanent Trust reported that they use OR so little that no useful information could be provided.

Only one of the responding companies, Canada Trust, stated that there is an OR unit in the Company. This unit was set up in June 1976. It was initiated by John Bosak, Manager of Management Information Systems, at the Head Office in Toronto. The first OR staff were Kathy Campeau and Bob Zanani. The present head of the OR section is Eric Daly who reports to the Group Vice-President, Client Services. The section has three members. Originally, work was done on branch productivity, interest rate projection, and cash flow. Current studies

involve product analysis, asset-liability matching, and profit planning, and forecasting. The Company does not plan on expanding the OR services; it has not used outside OR consultants.

OPERATIONAL RESEARCH IN MANAGEMENT
AND CONSULTING FIRMS

Management and consulting companies or firms were early Canadian users of OR. Information on some of these was available from various sources including Refs.22 and 23. Copies of the questionnaire for business and industry (Appendix A) were sent to 26 such agencies and replies were received from 25 of them.

Data obtained from the returned questionnaires and other sources are presented below in two classes: management and consulting firms that have (or had) an OR unit; and those that use OR in some form or other but do not have organized OR units. Table XXII below summarizes information on the first of these classes.

This table shows some interesting points. First, after several management or consulting firms set up OR units in the early and later 1950's, apparently no others were started until the early 1970's. Secondly, most of these companies were operating in Toronto, and, further, at least four of these (Adalia, Gellman, Hayward & Partners, Price Waterhouse Associates, and Josef Kates Associates) no longer have OR units as such. Adalia Ltd. was set up by Robert Watson-Watt, the inventor of radar in the UK in WW II and an early exponent of OR. This company is no longer in business. Josef Kates Associates (formerly KCS Data Control) does not now have an OR unit as such as clients in the main have their own.

TABLE XXII

OPERATIONAL RESEARCH IN CANADIAN MANAGEMENT AND CONSULTING
COMPANIES HAVING¹ OPERATIONAL RESEARCH UNITS

| Company or Agency | Date of Introduction of OR | Persons First Introducing or Using OR ² | OR Staff 1980 |
|---|----------------------------|--|----------------|
| Adalia Ltd (Toronto) | 1954 | Robert Watson-Watt | -- |
| Price Waterhouse (Montreal) | 1954 | P.Wade, R.A. MacDougall P.J. Sandiford | -- |
| (Toronto) | 1956 | J.J. Macdonell G. Cockhill | -- |
| Josef Kates Associates Inc. (Toronto) | 1954 | Josef Kates | -- |
| H.S. Gellman & Co. Ltd. (Toronto) ³ | 1956 | Harvey S. Gellman K. Hastings, V. Weston, L. Kehayes, R. McKee | 0 ³ |
| KCS Data Control (Toronto) | | J. Kates, H.V. Fullerton E.E. Sorenson | -- |
| B.C. Research Council ⁴ (Vancouver) | Apr.1957 | Donald S. Smith F.L. Sawyer | 10 |
| Stevenson & Kellogg ⁵ (Toronto) | 1958 | W. Hossack F.R. Dunham, J. Walter | 4 |
| Quasar Systems Ltd. (Ottawa) | Mar.1972 | M. Potter M. Potter, J. Alexander | 1 |
| DPA Consulting Ltd. ⁶ (Halifax) | 1973 | G. Maffini G. Maffini, A. Robertson | |
| IBI Group Affiliates (Vancouver) | Nov.1974 | J.C. Clapham J.C. Clapham, L. Sims | 4 |
| Hickling-Smith Inc. (Ottawa) ⁷ | 1975 | D.P. Deziel D.P. Deziel, A. Greenwood | 10 |
| TEE Consulting Services Inc. (Ottawa) | June 1977 | L.E. Parker L.E. Parker, S.K. Bhattachayrra | 3 |
| BN-Software Research Inc. (Toronto) | Apr.1978 | C.D. Sadleir A. Steel, W. McCandless | 9 |
| Piché, Charron (Montreal) | Aug.1978 | G. Riquier A. Roy, G. Riquier | -- |
| Ruskin, V.W. & Assoc. (Vancouver) | 1962 | V.W. Ruskin V.W. Ruskin | 6 ⁸ |
| Woods Gordon | 1962 | P.E. Newdick J.A. Cram, G. Shaw | 12 |

TABLE XXII (Cont'd)OPERATIONAL RESEARCH IN CANADIAN MANAGEMENT AND CONSULTING
COMPANIES HAVING¹ OPERATIONAL RESEARCH UNITSLEGEND:

- ¹Or having had
- ²Names on first line refer to those introducing OR; those on second line to practitioners and first OR team leader.
- ³Now Gellman, Hayward & Partners Ltd., Computer Systems Consultants. Their OR people have moved to other work related more to information system than to OR.
- ⁴See also data on B.C. Research under OR in Provincial Governments, Chapter VI.
- ⁵In 1954, Mr. Clive Van Horne of Stevenson & Kellogg directed the implementation of an OR training program for the Steel Co. of Canada Ltd.
- ⁶Development Planning Associates Ltd., Halifax. Do not refer to OR as a specific area.
- ⁷Formerly Systems Approach Consultants Ltd.
- ⁸Four of the six OR staff members are employed in the United States.

The number of OR staff in these companies varies from one to 10. Further information on the work and activities of these companies is given in the next table. Again, one notices from this table the wide variety of problems and problem areas undertaken by the firms concerned and, relative to preceding cases, the high level at which the OR staff report. It is interesting to note that several of these companies plan or hope to expand their OR services.

Information received from companies that do not have OR units or staff is given below, alphabetically, under the name of the company concerned:

Acres Consulting Services Limited (Niagara Falls)

At one time a single OR person was on staff. OR studies form a very small percentage of the work. OR techniques are used but by engineers with some OR experience. OR work is limited and varied and not very sophisticated.

EAC Amy & Sons Limited (Ottawa)

People with qualifications to do OR projects are in the inventory of personnel. Some OR techniques are used and expanded OR services are foreseen.

Bélanger Chabot & Associés (Montreal)

On occasion use is made of external consultants with diplomas in OR.

Bureau of Management Consulting and Computer Communication Services (Halifax)

Outside OR consultants used sometimes, e.g. to develop econometric models which are now maintained internally.

TABLE XXIII
 FURTHER INFORMATION ON MANAGEMENT AND CONSULTING FIRMS
 THAT HAVE OPERATIONAL RESEARCH UNITS OR STAFF

| Name | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Currently | Planning to Expand OR | Use Outside OR Services |
|-----------------------------------|--|--|--|-----------------------|-------------------------|
| Price Waterhouse | Partner-in-Charge Management Consulting | Inventory/purchasing management; production scheduling; facility location. | Financial modelling; inventory management; cost-benefit analysis; leasing analysis; product profitability. | --- | --- |
| Gellman, Hayward & Partners | President | Simulation studies using electronic digital computers. | Nil | No | --- |
| B.C. Research ¹ | Head of Division | --- | --- | --- | --- |
| Stevenson & Kellogg | President | Simulation of satellite rendezvous; linear programming of feed mix; inventory decision rules. | Transportation of wood to mill complex; simulation of vehicle delivery operations; distribution simulation study. | Yes | No |
| Quasar Systems Ltd. | Branch Manager | Management science seminar for grain movement; fire management analysis; simulation of Canadian Forces supply system. | Probabilistic assignment of radio frequencies. | No | No |
| DPA Consulting Ltd. | Vice President | Planning & management consulting. | Large scale policy oriented computer models. | No | No |
| V.W. Ruskin & Assoc. ² | President/Manager | Satellite rendezvous; ASW cost/effectiveness; analysis of air & naval exercises; action information systems for ships. | Financial modelling; forecasting, planning, & budgeting for commercial companies; gas & oil transportation, simulation, & production models. | Yes | --- |

¹See Tables XVI & XVII.

²This Company has changed its investigations from military problems to commercial ones and has expanded geographically providing services in the United States and elsewhere.

TABLE XXIII CONT'D
 FURTHER INFORMATION ON MANAGEMENT AND CONSULTING FIRMS
 THAT HAVE OPERATIONAL RESEARCH UNITS OR STAFF

| Name | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Planning to Expand OR | Use Outside OR Services |
|----------------------------------|--------------------------------|--|---|-----------------------|-------------------------|
| IBI Group Affiliates | Director ² | Traffic management studies; potash distribution; log transportation; container traffic studies. | Grain handling in Western Canada. | No | No |
| Hickling-Smith Inc. ³ | Managing Partner | Air travel forecasting; determination of "real" interest rates; rail relocation cost-benefit study; implementation of Canadian Forces supply system. | Improved sampling design for geochemical surveys; marketing research; cost-effectiveness in safety program simulation; corporate planning; design & present course in management consulting. | Yes | Yes |
| TEE Consulting Services Ltd. | President ³ | River regulation modelling systems. | Several under contract. | Hopefully | No |
| BN-Software Research Ltd. | Vice-President | Development of costing system; planning cable layout. | Decision support systems; manufacturing analysis. | No | No |
| Piché, Charron & Associés | President | Production planning systems; optimization of a transport system. | Optimization of production methods. | — | No |
| Woods Gordon | Executive Partner | Development of economic order quantities; integrated production and inventory planning. | Decision support system for a shipping company; development of wood utilization model; modeling to support project feasibility studies; development of decision processes and analytical methodology. | Yes | No |

²The IBI Group was founded in Nov. 1974 by nine directors of whom one, J.C. Clapham, was experienced in OR. The Group is engaged in architecture, engineering, and planning and practices or as consultants. Three or four of the Group spend two thirds or more of their working time on OR.

³Since 1981, Hickling-Partners.

⁴Head of OR activities is also President.

Canadian Met-Chem Consultants Limited (Montreal)

A subsidiary of USS Engineers and Consultants Inc. - a subsidiary of US Steel Corporation. Research facilities are located in USA.

Currie , Coopers & Lybrand Limited (Montreal)

Quantitative methods employed (e.g. by P.F. Wade) in management consultant work.

ORBITA Consultants Limited (Ottawa)

A recently incorporated firm intends to make heavy use of OR by experienced OR staff.

Principal Consultants Limited (Edmonton)

There is not a formal OR unit within the company, but it is continually making decisions using procedures that "would fall under the OR rubric." A recent decision to change the computing system of Principal Group (of which Principal Consultants is one of fourteen companies comprising the Group) involved OR-type analysis. Also marketing research is done from time to time.

PS Ross & Partners (Ottawa)

The firm does not have a separate OR department or unit. Use is made of various OR techniques depending on the nature of assignments. A similar situation holds for the other offices of the Company.

Peat, Marwick and Partners

The firm does not have separate OR departments as such but does recognize unofficial OR heads in the Montreal, Ottawa and Toronto offices (D. Zalinger, A. Elek, M. Kierans) who report to the managing partner of the individual office. Some OR personnel came in with the KATES merger. OR work is mainly statistically oriented. OR is being done in the area of forecasting (aviation traffic, tourism flows, etc.). Outside OR services are sometimes used, e.g., for computer work.

Price Waterhouse Associates

OR as such started in the Company when Peter Sandiford joined in the early 1950's in Montreal. He was succeeded by R.A. MacDougall who joined around 1956. Peter Wade came to the Montreal Office in the 1960's and Geoff Cockhill joined in Toronto. Other people were added as the years progressed, and an OR group, identified as such that aggregated six or seven persons across the country, existed for a period. In a few years OR became regarded not as a separate and distinct service but rather as representing a way of thinking and a collection of skills that should be applied whenever appropriate in a great variety of business or governmental situations. As a result, the OR group as such was disbanded. The Company reports that: "we no longer even identify OR work as such in our engagement statistics; it is simply an integral part of what we do." The Company has quite a large number of people who have a significant capability to use OR techniques. Some of these are in financially-oriented areas (financial services/ computer financial modelling, advanced capital expenditure analysis, etc.), some are in the computer consulting services group (and are able to build quantitative analytical techniques into systems they design), and some are in the operations management consulting group and use OR skills in production and warehousing distribution, and marketing engagements.

I.P. Sharpe Associates Limited (Vancouver)

The Company is quite involved in client projects using OR techniques and supports a number of software packages that use these techniques on computer service to clients. But the company does not have an OR department and does not, at the branch level at least, use OR techniques in its own business.

Other companies

Fully negative replies were received from Les Consultants SBCS Inc. (Sherbrooke), SOQUEM (Ste.-Foye), and Torchinsky Consulting Limited (Saskatoon).

OPERATIONAL RESEARCH IN COUNCILS,
FOUNDATIONS & RESEARCH INSTITUTES

The business questionnaire (Appendix A) was sent to several councils, boards, foundations, and research institutes. The response was much less than expected and follow-up action did not produce many replies.

Research councils, foundations, or centres known to be sponsored by federal and provincial governments have been treated under earlier sections of this report in Chapters V and VI. Brief summaries of others that replied to questionnaires are given below in alphabetical order of names:

C.D. Howe Institute

It has no OR unit and does not use any of the OR techniques mentioned in the questionnaire, and does not plan on doing so.

Centre de recherche industrielle du Québec

This Centre does not have an OR division or unit nor any studies wherein OR is an obvious requirement.

The Fraser Institute

The Institute does not have an OR unit or program, but does conduct some research which involves the use of computer models.

Ontario Research Foundation

The Foundation has never had a formal unit involved in OR but, on occasion, projects have been undertaken that have an OR component.

Research and Productivity Council (New Brunswick)

In 1965, an OR analyst (Erik Maalo) was recruited in Denmark. He worked on sawmill log selection systems and on the potato growing/selecting/marketing system. He left after a year and has not been replaced as qualified staff were able to master any OR that was required and the Council had no reason to advance its OR techniques.

OPERATIONAL RESEARCH IN CANADIAN INDUSTRIAL COMPANIES

The companies and firms discussed in this section are almost entirely industrial and commercial enterprises. Notable exceptions are Air Canada and the Canadian National Railways and a few other quasi-industrial companies are included partly for ease in making comparisons. In virtually all cases, head offices only were requested to provide information. For simplicity in presentation and later comparisons, results obtained from the industrial survey will be discussed by regions and nature of response. The regions that will be used for this purpose will be the Atlantic Region, the Central Region, and Western Canada.

Industrial OR in the Atlantic Region

Response from industrial enterprises in the Atlantic Region was disappointing. A total of 24 questionnaires was sent to commercial firms in the four Atlantic provinces. Only six replies were received and of these only three reported using OR in any way, and only one of these has a recognized OR unit.

National Sea Products Limited (Halifax)

Has one staff member working on OR. The OR unit was set up in April 1971 at the instigation of the Vice-President (I.H. Langmands) and the first OR analysts were Ian Bruce and Ivan Fische, both P.Eng. The present OR worker is J.D. Baillée who reports to the Vice-President. Work done by OR staff has included the study of fleet operations, product quality improvement, and trucking analysis. At present (1980) an investigation is underway of the optimum utilization of storage space. The Company has not made use of outside OR consultants and may possibly expand its OR staff.

McCain Foods (Florenceville, N.B.)

Has no OR unit as such but uses OR-type techniques in conducting some aspects of its marketing research.

Halifax Industries Ltd

This Company has recently (1978) taken over the Halifax Shipyards complex from Hawker Siddeley Canada Ltd. and has no OR unit as such. When OR-type services are recognized as needed, the Company calls in a consultant from Canadian Pacific (often R.B. Gillis). A few of the present staff have some OR training (including John Landry, Executive Assistant to the President). The Production Engineer uses OR techniques and consultants as required. Up to 10 staff members may be considered on OR-type work but only on a part-time and as required basis. Consultants have been used four times in the two years the Company has been operating the shipyards. Earlier OR techniques were applied in the shipyards on a variety of problems including industrial engineering application in 1963 and thereafter by W.L. Stypulbowski.

Replies received from Harvey & Co. Ltd. (St. John's), Maritime Electric Co. Ltd. (Charlottetown) and C.M. McLean Ltd. (Summerside) showed that they neither had OR staff nor used OR in any way. The Motor Carrier Board (New Brunswick) are not engaged in any OR-type studies. St. John's Transportation Commission reports that OR techniques are rarely used internally and consultants are not involved to any great extent in their operation.

Industrial OR in the Central Region

Most of the responses from industrial concerns were from the provinces of Quebec and Ontario, but the responses rate was not as high as had been hoped. From these replies and other sources, information on some 56 companies has been obtained and is presented below. Only 13 of these are from Quebec and 43 from Ontario. In these provinces, in addition to replies with some information on OR usage, some 38 replies were returned with completely negative answers to all the questions.

In presenting the results obtained, it will be convenient to give them for Quebec companies in two categories: those having (or having had) OR units or staff members; and those making some use of OR or OR techniques in some form or other. Then the Ontario results will be discussed in a similar fashion.

Operational Research in Quebec Commercial & Industrial Companies

The first organized use of OR in Quebec commercial operations was set up in Trans-Canada Airlines in 1956.* It was organized by Dr. Peter J. Sandiford to support corporate

*Renamed Air Canada in 1964.

management functions. Later Alec E. Lee functioned initially on a part-time basis with P.J. Sandiford and P. Jeannot as the first analysts. Then E. Ashton, H. Whelton, R. Peel, R. Linder, and Anne Bodnarchuck worked in OR as the unit expanded. The unit has been one of the most active OR groups in the airline industry. Original OR work was largely technical involving equipment replacement and reliability, aircraft maintenance, forecasting methodology and applications and sales, constructing life expectancy curves and control charts, etc. OR was organized as a central service in 1957/58. Two OR teams have been set up, one concerned with aircraft maintenance in 1956/57 and one in administrative services in 1957/58. Over the years, OR has come to deal with aspects of customer service, technical services, and management planning and administration. According to Ref.28, four OR staff members have risen to Vice President positions in Air Canada and the OR group's activities have covered the whole range of corporate functions, from the daily operating problems of service counter staffing and flight crew scheduling to broad strategic problems of identifying market opportunities and appropriate corporate responses. Further information on OR at Air Canada is given in Refs.29 and 30.

The second OR unit in the province was formed by Peter B. Wilson in the Canadian National Railways in August 1957. Dr. O.M. Solandt had recently become Vice President, Research and Development, in CNR. As an experienced OR analyst, he saw the possibilities for OR in improving CNR operations. His intention had been to form an OR group and run it himself but his new duties as Vice President did not give him time to do so. He then recruited Peter Wilson who was at the time Director Canadian Army Operational Research Establishment. This CNR group was the first OR team in North American railroading and set a pattern for many later developments in the U.S.A. The

OR group was established as one of the major sections in the Research and Development Department and worked very closely with operating groups with problems to solve. It started with Mr. Wilson and a secretary and grew to about 30 OR professionals. As such, it was the largest industrial OR group in Canada and the largest in North American railroading. Several very well known OR analysts worked with the OR unit under Peter Wilson, including Ian H. Cole, D. Pingle, C.E. Law, Jim Davey, John Gratwick, and J.W. Johnston. In a private communication from Peter Wilson (Ref.31) he writes: "We covered the whole gamut of techniques from computer modelling, mathematical modelling, simulations (both computer and manual), statistical analysis, and (very important) experimentation." He notes that they had lots of success with the simple methods (including elementary arithmetic), experimentation, and computer modelling, and less with 'heavy' mathematical modelling, partly because of the difficulty of communicating with practical railroad men who tended to distrust mathematical solutions which they could not understand. However, they would accept computer solutions which they did not understand "because of their faith in anything related to computers." This observation has been noted by others in OR including the author during his work in military OR, and by senior consultants in Management Science.

Other early users of OR in Quebec were the Northern Electric Co. (1958) and Bell Canada (1959) whose research activities were joined in 1971 as a new corporation, Bell Northern Research Ltd. In 1955, a position was established in Bell Canada to provide expertise in the application of mathematical statistics to company problems. The position was the office of the Chief Statistician under the Vice-President Finance. The group leader was R.F. Couch (1955) and early staff members were P.N. Kyte (1956), and R.L. Ellis (1957). Initial problems undertaken

related to sampling, quality control, regression analysis, and forecasting, scheduling, inventory control, and simulations for pricing decisions. In 1959, research activities were expanded to include OR techniques. An early OR project was a study of helicopter operations in maintaining radar stations on the Mid-Canada Line.

The current operational research group consists of 15 analysts with one or more of the following academic disciplines to the Ph.D. level: Operations Research, Statistics, Computer Science, and Industrial Engineering. Their work consists of the application of quantitative methods from straightforward sampling applications to complex simulation problems.

The OR group operates under the umbrella of Management Sciences in the Company headquarters in Montreal. The other principle functions under Management Sciences are: Survey Research, Behavioural Sciences, and Performance Assessment. Many of the operating problems which are dealt with involve the OR group within Management Sciences as well as "field personnel" who will have responsibility for the results produced by any change in operating procedure.

In many cases, the OR group initiates an area of activity and after establishing its viability, transfers the function to the responsible organizational unit. For example, application and training related to forecasting techniques is now part of the Corporate Forecasts organization. In this way, the OR group maintains a reasonable span of control and the expertise is located where the responsibility resides and the work is being carried out.

The Management Sciences Division provides a consulting service related to the application of quantitative methods. It deals with Bell Canada's problems and does not distinguish

between simple and complex problems. It should also be noted that other departments, where the work volume warrants it, have equally competent staff. In many cases, the Management Sciences Division provides the required personnel.

Most of the research facilities of Bell Canada and Northern Electric and Manufacturing Co. are now concentrated under Bell-Northern Research in the Ottawa area. On 1 January 1971, Bell-Northern was officially opened with a staff of 1800. Some comments on work there related to OR are given below in the Ontario section of this report.

Some of the relevant information and similar data for these companies and the others in Quebec which have OR units or staff are summarized in the following Tables XXIV and XXV.

It is interesting to note from these Tables that industrial companies in Quebec introducing and using OR increased at approximately one per year from 1956 to 1973 but there has been no further increase since then. Also, four of the five companies listed have rather large OR units. No doubt OR in one guise or another is practiced in Quebec industrial companies to a greater extent than indicated by these Tables.

As Table XXV shows, OR units in Quebec report in at senior management levels and undertake a wide variety of projects. Again the pattern of getting involved in increasingly complex and important operational problems is observed here. Two of these companies, C.P. Rail and Dominion Engineering, plan on expanding their OR facilities (present strength in each in 1980 is three (Table XXIV)). Four of the eight companies have made use of outside OR services.

TABLE XXIV

OPERATIONAL RESEARCH IN COMMERCIAL AND INDUSTRIAL
COMPANIES IN QUEBEC THAT HAVE OPERATIONAL RESEARCH UNITS

| Company or Agency | Date of Introduction of OR | Persons First Introducing OR or Using OR ¹ | OR Staff 1980 |
|------------------------------------|----------------------------|---|-----------------|
| Air Canada | 1956 | P.J. Sandiford P. Jeannot | 7 |
| CNR | 1957 | O.M. Solandt P.B. Wilson, I.H. Cole | 23 |
| Northern Electric ² | 1958 | -- | -- |
| Bell Canada ² | 1959 | R.F. Couch P.N. Hyte, R.L. Ellis | 15 |
| Canadian Industries Limited | 1962 | M.S. MacGillivray C. de Courval, C.E. Law | 13 |
| Canadair Ltd. ³ | 1963 | S. Geddes J.L. Hudson, R.L. Deans | 8 ⁴ |
| Canadian Pacific Rail | June 1969 | H.M. Romoff, R.B. Gillis J.L.A. Vallée, J.A. Slemish | 3 |
| Dominion Engineering Works Limited | 1970 | V. Chatfield V. Chatfield, J.W. Mosevick | 3 |
| International Paper Co. of Canada | Early 1960 | R.G. Belcher T. Cunia, R. Tischuk E.B. Davies, J. Hough | -- ⁵ |

¹Names on first line are those of person(s) introducing OR; those on second line refer to first practitioners of OR.

²See Text for further information on Bell Canada and Northern Electric.

³See para below describing OR and related work at CANADAIR.

⁴Original group; the OR expertise was absorbed into product-line organizations and there is now no central OR group.

⁵OR unit disbanded in 1971. I.W. Campbell is presently head of OR related activities.

TABLE XXV
 FURTHER INFORMATION ON INDUSTRIAL COMPANIES IN QUEBEC
 THAT HAVE OPERATIONAL RESEARCH UNITS OR STAFF

| Company | Level at Which OR Unit Reports ¹ | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Planning to Expand OR | Use Outside OR Services |
|-----------------------------|---|--|---|-----------------------|--|
| Air Canada | President, General Manager Maintenance, Director, Systems and Operational Research. | Equipment replacement & reliability; aircraft maintenance (see above text). | Productivity improvement; automation analysis (see above text). | — | No |
| CNR | Vice President R&D, System Manager OR & Industrial Engineering | Freight car replacement or repair; freight car allocation; train performance; inventory control. | Hump yard operational improvements & training; main line expansion; line capacity simulation; market forecasting & analysis; modelling intermodal business; CN express manpower planning. | No | Yes - in the early period; infrequently since. |
| Bell Canada | Director Management Sciences | Sampling; quality control; regression analysis & forecasting; scheduling; inventory control. | Applications of quantitative methods from straight forward sampling to complex simulation. | No | No |
| Canadian Industries Limited | Management Services Manager, Systems & Management Information | Rail car information system; fertilizer blending; sales territory planning; distribution of chlorine/caustic soda. | Cost reduction in manufacture & distribution of chlorine/caustic soda; setting corporate objectives; risk aversion/decision analysis for capital projects; production/inventory planning; scenario generation & analysis for nitrogen strategy. | No | No |

¹ Originally and currently in that order. The first one is often the appointment of the official responsible for starting OR in company.

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TABLE XXV CONT'D
 FURTHER INFORMATION ON INDUSTRIAL COMPANIES IN QUEBEC
 THAT HAVE OPERATIONAL RESEARCH UNITS OR STAFF

| Company | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Planning to Expand OR | Use Outside OR Services |
|-----------------------------------|--------------------------------|---|---|-----------------------|-------------------------|
| Canadair | Vice President | Vulnerability & survivability of aircraft; cost effectiveness of unmanned aerial reconnaissance vehicles; forest fire control of water bombers. | Applications of unmanned aerial surveillance and reconnaissance. | — | Yes |
| CP Rail | Manager, Research | Train performance simulation; investment analysis models; grain transportation simulation model. | Estimation of fuel consumption in train operation; simulation of domestic container & of intermodal terminal operation; short-term freight car repair planning. | Yes | Yes |
| Dominion Engineering Works Ltd. | Manager, Research | Simulation of paper making machines. | Optimal use of scrap in foundry; simulation of grinding mills. | Yes | No |
| International Paper Co. of Canada | Director | Outfreight optimization; inventory control; project mix optimization. | Distribution planning; wood measurement; logistic & cost modelling; production planning & paper machine trim. | No | Yes |

Originally and currently in that order. The first one is often the appointment of the official responsible for starting OR in company.

Some further mention should be made of OR at Canadair. Briefly, in 1958, a small unit was in operation under John L. Hudson (now Director General Operational Research at National Defence Headquarters) working on the Sparrow missile for aircraft and using OR techniques. Later, this unit was absorbed into an Advanced Systems Planning Group under Stewart Geddes. Other members of the Group were J. Goodwin and D.H.J. Norman. Then in 1963, R.L. Deans became Chief, Operational Research and Systems Analysis. The first OR analysts all had prior experience in the aerospace industry and engaged mainly in R&D of weapon systems (aircraft and missiles). The company organization changed recently from a central R&D department, wherein OR existed, to a product-line organization where R&D is done, as required, for each product-line. In recovering from the low cycle of aerospace business in 1974/75, the company found it more appropriate to put more resources into market research and product promotion than into basic OR studies. Having accomplished its original objectives which were mostly concerned with military air operations and systems, the expertise within the OR group was eventually absorbed into product-line organizations as noted. The Advanced Systems Planning Group mentioned above practiced OR, as a discipline, and the OR name was introduced in 1963. The first Chief, Operational Research and Systems Analyst was R.L. Deans, as already noted.

Relevant information provided by other Quebec industrial companies making some use of OR is given below in brief, under the company names:

Chemicals Group DOMTAR Inc.

No OR units as such but some OR techniques are used in DOMTAR Inc. but not at Group level. DOMTAR (paper products) had an OR team (1974-77) which included C.L. Cockhill.

Iron Ore Company of Canada Ltd.

No organized OR unit. Some OR-type work has been done in studying the possible replacement of open pit operations using a computerized mine design.

Montreal Shipping Company Ltd.

As steamship agents, brokers, and operators have not used OR as such but a market analyst on staff assists in the investigation of cargo flows which will help in forward planning and policy decisions in the long term and steamship cargo sales in the short term.

Rothmans of Pall Mall Canada Ltd.

The Company has no OR unit but does make some use of OR techniques.

International Paper Co. of Canada

An OR unit was set up in the early sixties but due to insufficient implementation and acceptance of OR with development matters rendering difficult the proving of OR practicability, the OR (Benefits) Group was disbanded in 1971. However, OR activities are still been done with J.W. Campbell responsible for them and reporting to the Director, Corporate Information Management System Department.

Aluminium Company of Canada Ltd.

In 1956/57, Price Waterhouse did a study for the Company initiating the future use of computers and other matters. Among other suggestions, the study recommended the introduction of an OR unit. As a separate entity, an OR unit was never established but during the period 1957-1958 considerable OR was done. The head of OR activities has been Philip M. Aziz who has been with the Company since 1959. Basically, ALCAN consists of project centres each responsible for their own operations which are generally not very extensive. A few staff members had been engaged in OR work but soon got involved in information processing, but not as a central OR team. For a while, there were two persons in the Systems Development Department in Montreal doing OR related work. In general, it was found that operating departments were too small to support full-time OR staff.

GENSTAR

This Company makes use of OR techniques but does not have an OR unit as such. Econometric models are used in market projections made by divisions and within the Corporate office models have been built to simulate cash flows and perform financial analyses for project studies.

E.B. Eddy Forest Products Ltd.

Although some OR-type work was done in the early 1950's, initiated by E.J. O'Brien, no formal OR department or unit was established. Early OR workers were R. Noel-Bentley, D. Eastwood, and J.B. Davies.

Steinberg Incorporated

Steinberg replied to the questionnaire stating that they do not have an OR unit and provided no further information. However, a quote from Ref.22, which was prepared in November 1963, reads: "Director of Resources and Planning for Steinberg's Limited, Montreal, said 'while we have no full scale Operations Research Program at Steinberg's, we are embarking on some studies which will require operational research techniques'."

Operational Research in Ontario
Commercial and Industrial Companies

Earlier publications concerning operational research in Canada (Refs. 18,19,22,23) have given considerable information about OR in Ontario business and industries where the majority of OR units in the country are and have been employed. Although some use has been made of these references in preparing the present report and acknowledgements noted, details given in them are not repeated in the interests of brevity and to avoid duplication. The interested reader will find it both interesting and informative to refer to them for information not given here.

The following Tables present, in condensed form, much relevant information about OR in Ontario industry. The companies appearing in these Tables have active OR teams or units, or in a few cases, only some OR staff working on a part-time basis. Some of them no longer have OR units or services and the reasons given by these companies for the OR staff disbandment are mentioned later.

Table XXVI shows that starting in the early 1950's there has been a gradual increase in industrial companies with OR units and services and that these companies represent a wide range of industrial operations. The earliest use of OR as a recognized

TABLE XXVI

OPERATIONAL RESEARCH IN INDUSTRIAL COMPANIES IN ONTARIO
THAT HAVE¹ OPERATIONAL RESEARCH UNITS

| Company or Agency | Date of Introduction of OR | Persons First Introducing OR or Using OR ² | OR Staff 1980 |
|--|----------------------------|---|----------------|
| Ontario Hydro ³ | 1951 | G.B. Tebo P.J. Sandiford, W. Shelson | 8 |
| British American Oil ⁴ | 1953 | N.A. Grundy B.A. Wilson, N.A. Grundy, J.R. Jutras | |
| Steel Co. of Canada (STELCO INC.) | 1953 | J.W. Farlam J.W. Farlam, H.J.M. Watson, L. Smith | 6 ⁵ |
| Abitibi Paper Co. ⁶ | 1955 | A.E. Paull J.R. Walter, J. Bain | - |
| Imperial Oil | 1955 | P.J. Robinson C. Henderson | 3 |
| Labbat's Breweries of Canada | 1955 | -- | 25 |
| Algoma Steel | Nov.1957 | J.P. Rives D. Patterson | 4 |
| Dominon Rubber | 1958 | P.E. Gnaedinger | 3 |
| Union Carbide | 1958/59 | F.R. Denham | 0 |
| Lever Detergents | 1960 | (Technical Director) ⁷ | 0 |
| Gulf Canada | 1962 | N.R. Kilback A.H. Azmi, J.E. McMillan | 2 |
| Canada Packers | 1965 | D.F. Clark S. Atluru, G. Dominij | 9 |
| DeHavilland Aircraft | 1965 | R.D. Hiscocks R. Taborek, A.F. Toplis | 1 ⁸ |
| INCO Metals Co. (Ontario) - Copper Cliff | 1965 | P.W. Souter R. Stahlberg, G. Faulkner | - ⁹ |
| Falconbridge Nickel Mines | 1966 | A.G. Slade M. Mussan, M. de St.Jorre | 4 |
| INCO Limited Toronto | July 1968 | A.J. Paturzo A.J. Paturzo | 2 |

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TABLE XXVI (Cont'd)

OPERATIONAL RESEARCH IN INDUSTRIAL COMPANIES IN ONTARIO
THAT HAVE¹ OPERATIONAL RESEARCH UNITS

| Company or Agency | Date of Introduction of OR | Persons First Introducing OR or Using OR ² | OR Staff 1980 |
|-------------------------------------|----------------------------|---|-----------------|
| Ontario Paper Company | 1969 | K. Waldock K. Waldock | __10 |
| AVCO Financial Services | Mar.1970 | W.A. Galloway D.J. Sadler, P.O. Galloway | 5 |
| Kimberley Clarke of Canada | June 1970 | D.J. McClure D.J. McClure | 3 |
| SUNOCO Group (SUNCOR) ¹¹ | 1970 | K. Heddon A. Cowie, J. Bakker | 3 |
| Eaton's | 1971 | V. Murai | -- |
| Procter & Gamble | Aug.1972 | Manager Systems Group Manager Analytics | 2 |
| Campeau Corporation | 1974 | W. MacLean E. McCarthy | 3 |
| Dominion Foundries & Steel | Oct.1975 | G.L. Erbardt R. McLachlan, W. Potocic M. Levy | 6 |
| Honeywell Information Systems | 1977 | S. Rush | 1 ¹² |
| UNIROYAL | Nov.1978 | President | 4 |

¹Or have had OR unit or staff.

²Name(s) on first line refer to those introducing OR; those on second line to practitioners and first OR team leaders.

³See also Section on Ontario Government Agencies.

⁴Now Gulf Canada Ltd. - original OR personnel not known but J.R. Jutras, B.A. Wilson and N.A. Grundy were early OR staff members.

⁵From 4 to 6 now spend most of their time on OR.

⁶No OR unit as such now but this type of work is done "in a different guise."

⁷Graduates in Mechanical Engineering - names not available.

⁸Formerly 3 now less than 1 full-time.

⁹No OR full-time staff at present.

¹⁰OR functions as such ceased in 1976.

¹¹Formerly Sun Oil Co. Ltd.

¹²No OR unit in Canadian company; one or two work part-time on OR.

activity under that name in Canada was the work done by P.J. Sandiford, W. Shelton, and B. Bernholtz for the Hydro-Electric Commission of Ontario. A report on three of their early investigations covering lake-level forecasting, peak-demand forecasting, and vehicle replacement analysis is given in Ref.20.

The names of the companies appearing in Table XXVI indicate the wide range of industrial companies that have made use of OR. These include the categories of utilities, production (oil products, steel, paper, rubber, etc.), manufacturing, financial services, transportation, and marketing. Capsule cases of OR from the project files of Imperial Oil Ltd. prior to 1957 are presented in Ref.18. These cover a wide variety of studies, some of which are described more fully in references given in Ref.22.

None of the OR units included in this Table, other than Labatt's which reports that 25 staff members now spend most of their time on OR, has a large number of staff. The OR team with Canada Packers is currently the largest, being nine in number, with those of other companies varying from one or more on a part-time basis to as many as eight; the modal number is three. The average number for 19 companies with active OR staff is five. By way of comparison, the range of the number of OR staff in these Ontario companies is one to nine while that for the Quebec ones (Table XXIV) is three to 23. The OR units in the Quebec companies shown in the Table tend to be considerably larger than those in Ontario which, however, apparently are much more numerous.

Dominion Foundries and Steel Ltd. (DOFASCO) point out that the responsibilities of their OR group of six persons are not all strictly within the OR area. Their responsibilities include the organization of time studies, justifications of equipment and manpower, analysis of material handling problems, development of incentive standards, maintaining and using a computerized statistical package (for all departments), developing computer information systems and data bases, cost improvement studies, providing industrial engineering aid, and planning work for future expansion, as well as OR work including the development of mathematical and simulation models, linear programming, and inventory work. This statement is perhaps representative of the work many OR analysts who often get involved in almost any problem requiring quantitative analysis of some kind or another.

As already noted, some of these industrial companies in Ontario have made, and continue to make, use of outside management or OR consultants. In the early period of the introduction of OR in industry, this practice was perhaps even more common than at present when many of the companies now have their own in-house capability. It will be noted from Table XXII that management and consulting companies were applying OR techniques in the early 1950's and that industrial companies began using OR at about the same time. For example, in the case of British American Oil (Table XXVII) one of the earliest OR projects done for the company was done by Dr. H.V. Fullerton of KCS Data Control Ltd. in October 1956. It was the construction of a linear programming model of one of the companies refineries for planning operations. Similarly, Ref.26 reports on a study done by N.A. Grundy of this Company and P. Sandor of KCS Data Control for achieving flexibility in linear programming using a

The types of problems and activities that OR staff in these companies engage in are shown in abbreviated form in Table XXVII. It is clear that there is a great variety of these and that, in general, the scope and complexity of the problems undertaken are increasing with time, requiring increasingly sophisticated approaches, many of them involving modeling, simulation, and heavy use of computers.

Only nine of the 26 companies shown have used outside OR or management consultants. Only six of them plan on or are considering expanding the use of OR at this time. There has been little change over time in the level at which the OR units report into company management. Most of them do so at senior levels.

Of the companies listed in the above two Tables, seven have either discontinued OR services as such, disbanded their OR units, or incorporated OR with other related activities. The reasons for so doing vary considerably. Lever Detergents state that OR-type work is now being carried out by their Information Systems Department; DeHavilland disbanded its OR team in 1977 at a time of manpower reduction, but OR activity is now (early 1980) starting to grow in Sales Engineering; Inco Metals do not have a central OR group but rely on staff who are qualified and experienced in their field for meeting OR requirements; Ontario Paper Co. reports that the OR function is now partly fulfilled by a Planning Director well qualified in finance and model development; Eatons advises that organizational changes in the company resulted in the OR department being disbanded in 1974; Honeywell Information Systems Ltd. state that their OR resources are used sporadically and there is no continuing need for an OR unit.

TABLE XXVII
 FURTHER INFORMATION ON INDUSTRIAL COMPANIES IN ONTARIO
 THAT HAVE OPERATIONAL RESEARCH UNITS OR STAFF

| Company | Level at Which OR Unit Reports ¹ | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Planning to Expand OR | Use Outside OR Services |
|----------------------------------|---|---|--|-----------------------|-------------------------|
| British American Oil | — | Optimization of refinery operations. ² | — | No | Yes |
| Steel Co. of Canada (STELCO INC) | Superintendent Industrial Engineering | Fastener inventory simulation; metallurgical analysis; financial modelling. | Developing simulation models of all types; using regression and linear programming. | No | No |
| Abitibi Paper Co. | — | Optimum newspaper production; the trim problem. | — | — | — |
| Imperial Oil | — | Oil marketing; inventory control system; crude oil supply study. | Bulk product distribution; phosphatic plant tank size; marine scheduling tool (simulation). | Yes | Yes |
| Labatt's Breweries | Vice-President Operations | — | Applied & fundamental studies of the brewing process. | No | Yes |
| Algoma Steel Co. | Manager, Industrial Engineering | Sampling pig iron | Modelling steelworks & a tube division; incidence of lung cancer in foundry workers; nitrogen usage & storage. | No | No |

¹ First appointment for original OR unit, second for present one. First is usually appointment of official responsible for starting OR in the company.

² This work was done by H.V. Fullerton of KCS Data Control Systems.

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TABLE XXVII CONT'D

FURTHER INFORMATION ON INDUSTRIAL COMPANIES IN ONTARIO
THAT HAVE OPERATIONAL RESEARCH UNITS OR STAFF

| Company | Level at Which OR Unit Reports ¹ | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Planning to Expand OR | Use Outside OR Services |
|-----------------------|--|--|---|--------------------------------|-------------------------|
| Dominion Rubber Co. | — | Control of material flow through the processing; quality control work. | — | — | — |
| Lever Detergents | Technical Director | Inventory control; production planning. | (OR unit active for about 2 years only). | — | Yes |
| Gulf Canada Ltd. | Supervisor Management Science; Manager Technical Services | Optimization of refinery operations; simulation of refining & transportation; marketing of refined products. | Simulation of loading racks for refined products; rail-track distribution payoffs; truck scheduling. | No | Yes |
| Canada Packers | Vice President; Corporate Planning Advisor | Least cost product formulation; product mix allocation; inventory control system. | Inventory control system studies; plant location; facilities rationalization; marketing information system; productivity improvement; process control; production scheduling; risk analysis | Not at this time | No |
| De Havilland Aircraft | Director of Research & Future Products; Vice President Marketing & Sales | Cost trade-off studies (aircraft performance vs. runway construction); best mix of aircraft for military tactical support role; air-line simulation. | Transportation modal splits; modelling airline schedules. | Depending on market conditions | Yes |

¹ First appointment for original OR unit, second for present one. First is usually appointment of official responsible for starting OR in the company.

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TABLE XXVII CONT'D
 FURTHER INFORMATION ON INDUSTRIAL COMPANIES IN ONTARIO
 THAT HAVE OPERATIONAL RESEARCH UNITS OR STAFF

| Company | Level at Which OR Unit Reports | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Planning to Expand OR | Use Outside OR Services |
|---------------------------------------|--|---|---|-----------------------|-------------------------|
| INCO Metals Co. (Ontario Division) | Head Special Projects | Simulating mining transportation & chemical plant, and smelting; financial analysis. | Power plant & smelting simulation; inventory forecasting & scheduling; developing corporate financial models; financial analysis. | Yes | No |
| Falconbridge Nickel Mines | Mine Superintendent; Superintendent Mines Engineering Services | Modelling long-term mine production scheduling; storage, transportation & processing ore; maximizing use of tailing; simulating truck haulage system. | Optimizing program for mining operations; mine planning model; equipment replacement; developing model of tailing fill distribution & for project evaluation. | Yes | No |
| INCO Limited Toronto | Director Corporate Planning | Development of economic forecasting models; capital investment risk analysis. | Distribution analysis (using linear programming); project-scheduling; portfolio analysis; economic modelling. | No | No |
| Union Carbide | — | Data processing; distribution studies. | — | No | No |
| Ontario Paper Co. | — | Development of corporation & operating models. | (The ore man OR service was disbanded in 1976 but OR techniques are still used). | No | No |

1. First appointment for original OR unit, second for present one. First is usually appointment of official responsible for starting OR in the company.

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TABLE XXVII CONT'D

FURTHER INFORMATION ON INDUSTRIAL COMPANIES IN ONTARIO

THAT HAVE OPERATIONAL RESEARCH UNITS OR STAFF

| Company | Level at Which OR Unit Reports ¹ | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Planning to Expand OR | Use Outside OR Services |
|----------------------------|--|---|--|-----------------------|-------------------------|
| AVCO Financial Services | Senior Vice President/Canada; Senior Vice President/Canada | Not available. | Computerization of branch office accounting; forms control; marketing programs; standardization of branch operating procedures. | No | No |
| Kimberley-Clarke of Canada | Manager Information Services | Demand forecasting; developing woodlands model. | Simulation of newsprint production; production scheduling; simulation of wadding machine. | No | Yes |
| SUNOCO Group | President Planning Manager | --- | Tankage simulation for storage at refinery; warehouse location & inventory analysis; simulation of refinery to study impact of changing product mix. | No | No |
| Eaton's | --- | Manpower planning; use of linear programming & queuing theory in scheduling; developing models for allocating space and geographical areas; allocating space and layout in Eaton's catalogue for different departments. | (Or unit was disbanded in 1974). | --- | --- |

¹ First appointment for original OR unit, second for present one. First is usually appointment of official responsible for starting OR in the company.

TABLE XXVII CONT'D

FURTHER INFORMATION ON INDUSTRIAL COMPANIES IN ONTARIO
THAT HAVE OPERATIONAL RESEARCH UNITS OR STAFF

| Company | Level at Which OR Unit Reports ¹ | Types of Problems Undertaken by OR Units | | Planning to Expand OR | Use Outside OR Services |
|-------------------------------|--|--|---|-------------------------|-------------------------|
| | | Originally | Currently | | |
| Proctor & Gamble | Manager, System Groups; Manager Management Systems | (Confidential information) | (Confidential information) | No | No |
| Campeau Corporation | Directors & Senior Executives of Divisions | Analysis for housing markets. | Information feedback & planning assistance. | Not at present | Yes |
| Dominion Foundries & Steel | Manager, Manufacturing Controls; General Supervisor Industrial Engineering | Models for energy generation & distribution & oxygen production & distribution facilities. | Simulation of rail hot metal handling network & study of on-line predictive system; modeling melt shop (a steel making facility). | Yes (depending on need) | No |
| Honeywell Information Systems | Sales Manager | Feed grain mixture for customer software; study of carpet manufacturing. | — | No | No |
| UNIROYAL Ltd. | President; President | Reviewing and restructuring entire organization. | Production control; factory scheduling. | Not at present | No |
| Dominion Stores ³ | Vice President Corporate Planning | Warehouse withdrawal & economic order quantities; flow simulation of front ends; critical path applications. | — | Yes | No |

¹ First appointment for original OR unit, second for present one. First is usually appointment of official responsible for starting OR in company.

³ No OR unit as such but OR-type work done under Douglas Ward, Manager of Research.

'medium-sized computer' to build a mathematical model of the company's operations enabling questions raised by management to be answered quickly and at reasonable cost.

Limited relevant information has been obtained from questionnaires and telephone conversations from over a score of other industrial companies in Ontario. The following Table serves to present this information in abbreviated form.

None of these companies plan on expanding OR services but International Harvester Canada reports that future plans do not specify any involvement in detail, however, as a management decision tool, OR will play an important role. This company also remarks that OR techniques are used to a minor extent, and that in one of the divisions of the company a scheduling and inventory model has been used to test the profit and variable cost effect in a manufacturing plant as manufacturing schedules are varied in cycle and magnitude.

Some further comments on OR in Bell Canada and Northern Electric Co. Ltd. are warranted. In 1958, an OR team was formed in the Northern Electric Co. in Montreal. It consisted of a group leader (chemical engineer), an engineer, an accountant, and a mathematician (G.M. Lancaster). The recently acquired IBM 650 computer proved useful in simulation problems. In 1977, this Company* formed Northern Electric Research and Development Laboratories with an initial staff of four. Laboratories organized in Belleville and Montreal (staff 45) were moved to Bells Corners Ontario in 1959 (staff of 159). Other regional laboratories were also established but in 1971 a new corporation--Bell Canada-Northern Electric Research Ltd, or the Bell-Northern Research Ltd.--was formed with facilities in Ottawa. This company has no organized OR unit but several OR techniques and disciplines are used in many areas. For

*Now Northern Telecom Limited, Montreal

TABLE XXVIII

INFORMATION ABOUT OPERATIONAL RESEARCH IN COMPANIES IN ONTARIO
NOT HAVING OPERATIONAL RESEARCH UNITS OR STAFF

| Company | Has Used Outside OR Consultants | Use Some OR Techniques | REMARKS |
|---------------------------------------|---------------------------------------|------------------------------|---|
| Aluminum Co. of Canada | -- | Yes | |
| Chrysler Canada | -- | Yes | OR work relates to equipment problems to optimize throughput and is of industrial engineering type. |
| Consumers Gas | No | Yes | Each department manager acts as his own OR manager. |
| Dow Chemical of Canada | No | Yes | |
| Ford Motor Co. | -- | Yes | Within the scope of our Canadian marketing organization OR lacked meaningful projects or benefits. |
| General Motors | | Yes | OR-type work is used in various departments on a daily basis but not as a central service. |
| International Harvester | No | Yes | (See comments in text) |
| International Business Machines | | Yes | Marketing research. |
| Holiday Inns | -- | Yes | Some OR work is done in such areas as financial planning and data processing. |
| Hudson's Bay | No | Yes - minor | |
| Loblaws | -- | -- | All personnel are involved in a period of fairly dynamic growth and expansion; impractical to answer questionnaire. |
| John's-Manville Canada | -- | -- | All OR work is done for all sections of the Corporation by Headquarters staff in Denver. |

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TABLE XXVIII (Cont'd)

INFORMATION ABOUT OPERATIONAL RESEARCH IN COMPANIES IN ONTARIO
NOT HAVING OPERATIONAL RESEARCH UNITS OR STAFF

| Company | Has Used Outside OR Consultants | Use Some OR Techniques | REMARKS |
|--------------------------------|---------------------------------------|------------------------------|---|
| MacLaren Advertising | -- | -- | Consumer research as it applies to the development of effective communication. |
| Hawker Siddeley Canada Ltd. | -- | Yes | No formal OR departments in any Divisions. Each Division has its own management systems which are not formalized. |
| Noranda Mines | -- | Yes | |
| Parke Davis & Company | -- | Yes | Corporate service for OR available to affiliate divisions throughout the world. |
| Quaker Oats | Yes | Yes | OR done by Quaker Oats Co. Head Office, Chicago. |
| Laura Secord | No ¹ | To a limited extent | (See comments in text) |
| Shell Canada | -- | Yes | |
| Hiram-Walker Gooderham & Worts | -- | Yes | Simple production and inventory models are used by operational control and production planning departments. |
| George Weston Ltd. | -- | Yes | Model building - to determine an appropriate hurdle rate for capital expenditures |
| Bell-Northern Research Ltd. | No ² | Yes | See text for comments |
| Dominion Stores | No | Yes | No OR unit but plan to expand OR activities ³ |

¹However, see comments in text.

²Not to any extent.

³Manager of Research (Douglas Wart) responsible for OR activities. OR type work done has been warehouse withdrawal and economic order quantities, flow simulation of front ends, and a critical path project.

example, modelling is employed extensively in the analysis of complex operational situations and in making decisions about very complex alternatives for building telecommunications networks, in respect to both how-to skills and what methodologies to use. Other OR applications include constructing models of switching systems, the study of standards and performance equipment systems from the user's point of view, and planning for operational services. Indeed, OR techniques have spread throughout many of the research activities in engineering science, economics, etc.

It may be worth noting some features concerning the use of OR and the existence of OR units that render getting factual data difficult without an exhaustive review of company files which has not been attempted in the present study. The case of Imperial Oil exemplifies such features. In response to the questionnaire used herein, the Systems and Computer Services Department of Imperial Oil Ltd. reported that the Company, at present, has no OR unit as such, but that an OR unit started in 1962, under Patrick J. Robinson, and that he, George Henderson and two or three other analysts were the first OR workers in the Company. Further, the response states that although there is no OR unit as such, three people now (1980) spend over two thirds of their time on OR. In addition, to the on-going studies listed in Table XXVII, other current OR work includes a phosphatic plant offside storage study (Markov Mixed Integer Program), a polyethylene plant storage study (simulation and heuristics), and a short-term income model (cash flow) network algorithm. In Ref.18, P.J. Robinson gives some details of 11 cases of OR from the files of Imperial Oil Ltd. where he was employed at the time (1957). Also in Ref.22, it is stated that Mr. G.A. Henderson was head of the OR Department at Imperial Oil Ltd. in 1963, and lists eight publications involving OR by P.J. Robinson.

The response to the questionnaire (Appendix A) also states that "OR has never been formally grouped (to our knowledge) with a separate unit within our corporation." It also adds that Imperial Oil Ltd. has been heavily involved in OR activity since the early 1960's when the first powerful computing equipment provided the means for applying sophisticated OR techniques, particularly to the promising area of refinery scheduling using linear programming. Also, the replies note that with the recent advent of even more powerful computing equipment, the number of OR applications successfully implemented has grown, and that there are probably 10 to 15 people using OR techniques throughout the corporation.

Two observations may be made at this point. First, without detailed and time-consuming checking and searching of company or government department files it may often be impossible to ascertain whether central or other OR units actually existed officially or not. Secondly, there certainly seems to be a tendency for central OR units, over time, to be decentralized with some staff members engaged most of their time on what is recognized to be OR and others using OR techniques occasionally as required in the course of their work without being considered doing OR.

The Quaker Oats Co. has used OR in studying an inventory management system and in sales forecasting. At present, a capacity planning investigation is underway.

The Manager, Information Services of Laura Secord, R.J. Buttery, reports that although his organization does not have an OR unit as such, he himself is a full member of CORS and two members of his staff have degrees with OR as a minor. He has practiced OR for some ten years on three continents.

Types of OR studies presently underway under his direction are scheduling of a work centre with complex input-output relations, and a customer service study with outside consultant support, but not labelled as OR consultants.

George Weston Limited, a holding company with a small corporate staff, seldom gets involved in many areas of OR. However, various OR techniques are being applied at the subsidiary level. One of the subsidiaries is Loblaws.

From the foregoing, it is seen that in Ontario use is made of OR in a wide variety of industrial concerns, including some engaged in oil, steel, paper, rubber, food processing and packaging, mining and metal processing, financial services, retailing, and manufacturing (including detergents). It is also of interest to note that none of the big four automobile companies (American Motors, Chrysler, Ford, General Motors) have in-house central OR units but OR techniques are used by all except perhaps American Motors (which returned a completely void questionnaire).

Industrial Operational Research in Western Canada

Some sixty industrial companies in Western Canada (Manitoba, Saskatchewan, Alberta, British Columbia, Yukon and Northwest Territories) were requested to reply to the questionnaire (Appendix A) but only 21 responded. Of these, eight contained no information other than that they did not have staff engaged in OR, and did not use OR or OR techniques in any form. Other sources yielded little more relevant information so that the account of OR in Western Canada given herein is rather meagre.

In the Prairie provinces, 40 companies were canvassed with follow-up action in most cases but only 13 replies were received. Only six of these contained positive information.

In British Columbia, 21 industrial companies were approached and eight returned the questionnaire. Only one of these contained no relevant information.

No returns were received from the Yukon and Northwest Territories but only one industrial company in each was sent a questionnaire and other than sending them a follow-up letter, no further action was taken.

Results from companies for which the most information was obtained are summarized in the following Tables. Some comments are presented in the following paragraphs.

Although only a few industrial companies are included in Table XXIX, two of them have relatively large OR teams. Only one of the companies established its OR unit since the 1960's during which four of the five were started.

As is the case with most of the industrial companies with OR units, the OR units in these five Western companies report to management at senior levels. An increase in the scope and complexity of the problems undertaken by OR staff is indicated by the types of studies listed in Table XXX. Two of these five companies plan on expanding their OR services.

Limited relevant information concerning other Western companies is given below by company or corporation:

Bethlehem Copper Corporation (Vancouver)

Proposed new projects are examined through the construction and use of economic models by staff and consultants.

Canadian Forest Products (Vancouver)

Analysts using OR techniques are employed at the operational level rather than at Head Office. There are no OR units as such doing OR exclusively.

TABLE XXIX

OPERATIONAL RESEARCH IN COMMERCIAL AND INDUSTRIAL COMPANIESIN ESTERN CANADA THAT HAVE OPERATIONAL RESEARCH STAFF

| Company or Agency | Date of Introduction of OR | Persons First Introducing OR or Using OR ¹ | OR Staff 1980 |
|---|----------------------------|--|-----------------|
| Texaco Exploration (Calgary) | 1955 | J.G. Debanné | - |
| COMINCO (Trail) | 1961 | J.N. Robinson J.E. Roberts, D.N. Madge | 10 ² |
| Federated Cooperatives Ltd. (Saskatoon) | Jan.1965 | C. Kennedy ³ | 3 |
| MacMillan Bloedel (Vancouver) | 1966 | T.B. Boyle P.O. Dobson, C. Rasmussen A.E.J. Ferrie | 15 |
| Husky Oil (Calgary) | Nov.1968 | M.D. Ensign J.C. Heffer | 14 |
| CP Air (Vancouver) | 1973 | W.R. Ellwood E. Bollo | 3 |

¹Or have had unit or OR staff.

²Varies between 10 to 12

³Chemical engineer trained in linear programming.

⁴John C. Heffer, the only OR worker, spends half time on OR work. OR - type work began in early 1960's with the development of linear programming models on the engineering side of operations.

TABLE XXX
 FURTHER INFORMATION ON INDUSTRIAL COMPANIES IN WESTERN CANADA
 THAT HAVE OPERATIONAL RESEARCH UNITS OR STAFF

| Company | Level at Which OR Unit Reports ¹ | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Planning to Expand OR | Use Outside OR Services |
|------------------------------|--|--|--|-----------------------|-------------------------|
| COMINCO ² | Senior Research Engineer; Manager Technical Research | Production scheduling of fertilizer; mathematical programming of lead zinc operations; simulating truck movements; study of open pit operations. | Model development of mine planning & production schedules; logistics & transportation for product marketing allocation; experimental designs & factor analysis; energy systems; control studies; scheduling construction projects. | Yes | Yes |
| Federal Cooperatives Limited | Manager, Technical Division; Technical Director | Optimization of animal feed using linear programming; refinery modelling; study of petroleum distribution. | Optimization of refining process facility planning & location; planning & logistics for petroleum distribution; animal feed optimization; refinery process correlation. | | |
| MacWilliam Bloedel Ltd. | Corporate Comptroller; Director Operations Analysis | Plywood linear programming model; study of saw-mill-plywood mill log allocation. | Timberlands scheduling; linear programming models of pulp & paper mill; liner-board production & distribution; linear programming model for log allocation. | No at present | No |

¹ Originally and currently in that order. The first one is usually the appointment of the official responsible for starting OR in the company.
² Three major groups in COMINCO are included and there are also a number of individuals who possess the necessary skills and apply OR techniques to their specific needs. The three OR groups report to Manager Technical Research, Manager Engineering, and Manager Data Processing Services.

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TABLE XXX CONT'D
 FURTHER INFORMATION ON INDUSTRIAL COMPANIES IN WESTERN CANADA
 THAT HAVE OPERATIONAL RESEARCH UNITS OR STAFF

| Company | Level at Which OR Unit Reports ¹ | Types of Problems Undertaken by OR Units Originally | Types of Problems Undertaken by OR Units Currently | Planning to Expand OR | Use Outside OR Services |
|-----------|--|--|--|-----------------------|-------------------------|
| Husky Oil | Vice President, Planning & Economics; Technical Computer Coordinator | Canadian prairie asphalt study; general model for refining, transportation & marketing; gasoline blending model; optimized supply of briquet market. | Using refining/transportation marketing model; gasoline blending & associated analysis & generation of data. | --- | --- |
| CP Air | Director, Computing Services; Manager, Technical Support | (Records not available) | Schedule construction; manpower planning; airport staffing; crew pairing; crew block generation; aircraft take-off analysis. | No | Yes |

¹ Originally and currently in that order. The first one is usually the appointment of the official responsible for starting OR in the company.

Brascan Resources (Calgary)

Simulation models which emphasize cash flow are made of exploration and development opportunities to help management make investment decisions. Otherwise, no OR techniques are used nor is its use anticipated for future applications.

Canadian Cellulose Company (Vancouver)

The company had an OR unit which was disbanded ten years ago. The unit was primarily concerned with the optimum utilization of wood resources and in the judgement of management did not contribute significantly to the success of company operations. After it was disbanded, the work it had started was continued using other techniques and personnel. The closest the company now gets to OR is in the use of mathematics and logistic ability in the Finance Department.

Calgary Power Ltd. (Calgary)

Some OR is done in various areas of the company's operations; some financial forecasting models are used in studying capital investment requirements. OR has been used to deploy work crews and materials on the transmission and distribution system, and to test organizational methods and procedures. There is no OR unit as such and OR consultants are not retained. The OR that is undertaken is an auxiliary function of the company's Systems Development Group and is relatively small scale.

Petro-Canada (Calgary)

The Corporation, which includes the former Pacific Petroleum Ltd. does not have an OR unit as such. It does have corporate planning and project development departments within which applications are used similar in spirit and nature to OR

methodology, e.g. economic modelling, but no recurring applications of OR methodology are identifiable.

Syncrude Canada Ltd. (Edmonton)

Participating companies which own Syncrude supply some OR expertise on special projects, but there is no central OR unit. Mail simulation and utility plant models have been developed with the aid of outside OR consultants. Some consultation with these is still maintained on a periodic basis to make runs of programs or make cosmetic changes. Some OR techniques are used in-house but it is not planned to expand OR services.

It may be noted that four industrial firms in Manitoba and two insurance companies were requested to respond to the questionnaire. One insurance company and two industrial companies answered but all sent negative replies, with no relative information. There may not be much use made of OR staff or techniques in the province, other than in a few provincial government departments.

REMARKS

It may be noted that in some of the foregoing cases, the first use of OR by industrial companies was by outside management or OR consultants. In some cases, such work resulted in companies setting up their own OR units or hiring staff with OR background to work on OR part-time.

The data and material presented in this Chapter show that there has been a rather rapid growth in the use of OR in Canadian business, commerce and industry. For example, realizing that the preceding information was obtained from a rather small non-random sampling of companies, the following Table can be prepared.

TABLE XXXI

AGGREGATED DATA ON NUMBERS OF CANADIAN COMPANIES THAT HAVE, OR HAVE HAD,
OPERATIONAL RESEARCH UNITS

| Time Period | TYPE OF COMPANY OR BUSINESS | | | TOTAL |
|-------------|-----------------------------|--------------------------|--|------------|
| | Industrial | Management Consulting | Bank, Trust, Insurance, Institutes | |
| 1951-1955 | At least 6 | At least 3 | | At least 9 |
| 1956-1960 | At least 15 | At least 7 | | " " 22 |
| 1961-1965 | At least 24 | At least 8 | At least 1 | " " 33 |
| 1966-1970 | At least 35 | At least 8 | At least 2 | " " 45 |
| 1971-1975 | At least 40 | At least 12 | At least 1 | " " 53 |
| 1976-1980 | At least 42 | At least 15 | At least 2 | " " 59 |

It would appear then that the rate of increase in the number of OR units has been fairly uniform over five-year periods, although the 1955-1960 period had the highest growth rate. It must be remembered that these figures are probably minimum values and that over the whole period (early 1950's to 1980), a few companies decentralized OR services or disbanded OR units. Also, figures for end of year 1980 were not available at the time of writing, so the last time period of the Table is actually about end of June 1980.

Estimates of the numbers of OR staff in Canadian companies over this period were not obtained by the questionnaires. But for the end periods, it can be said that in the early 1950's not more than 10 or 12 persons were engaged in full-time OR work and that by 1980 this number had increased to about 250 in the 59 companies listed in Table XXXI. Again, the latter figure is not accurate and of course the numbers of persons working on OR in Canadian companies on a part-time, or as required, basis must be quite large.

Another observation is that a large number of Canadian companies make use of outside OR consultants. Of the companies canvassed, about 90% used such consultants but of the companies which have or have had OR units, about one third have also used outside OR consultants.

The geographical distribution of Canadian companies that have (or have had) OR units, use OR staff, techniques, or external OR consultants is interesting but not surprising. The greatest number of such companies is in Ontario, with Quebec and British Columbia next in order. Apparently, very few companies in the Atlantic and Prairie provinces make use of OR in any form, although a few do use some OR techniques in conducting their operations.

It may be observed that of eight drug and pharmaceutical companies that were canvassed, none reported having OR units or using OR techniques, other than Parke Davis & Co. which does use some OR techniques but has no OR staff although corporate service for OR is available (Table XXVIII). Similarly, based on the questionnaire returns, it does appear that newspaper and publishing companies, research foundations, banking and insurance companies, retail store chains, wholesale tobacco, and truck transportation companies have OR units or use OR as a recognized activity to any great extent. Some mining, engineering, and airline companies also reported having no OR units or services. No hospitals replied to the questionnaire, although it is known that some do use OR in their operations. As one example, John Stanley in Vancouver, a private consultant, is doing OR work with hospitals, particularly work in medical statistics.

Two other points already noted above are: first, the apparent growing tendency to decentralize OR activities by disbanding central OR units serving all divisions of a company and having OR conducted where and as required throughout the organization; and secondly, it is observed that a number of companies, business, commercial, or industrial, plan on expanding OR services. Some eighteen have indicated such intention.

CHAPTER IX

DEVELOPMENT OF OPERATIONAL RESEARCH IN CANADIAN UNIVERSITIES AND COLLEGES

INTRODUCTION

This Chapter outlines the origins and development of OR in Canadian universities, colleges, and institutes of technology. The major part of the treatment is concerned with universities and their departments or faculties offering courses in OR or related courses. Most of the information was obtained by means of questionnaires, but interviews and personal correspondence also provided relevant inputs. A copy of the questionnaire used is presented in Appendix A.

The returns showed that many OR-related courses have been, and are being, offered in various departments or faculties including management science, commerce, business administration, economics, mathematics, engineering, agriculture, forestry, combinatorics, optimization, quantitative methods, and computer science or systems. This wide dispersion indicates the growing variety of applications of OR that is noticeable throughout this survey in business, industry, and government.

As far as has been determined the first OR course in Canada was given at the University of Toronto in January-February 1956. An account of origin of these courses is given by Dr. William Shelson in Ref.32 which is paraphrased here. This first course was given on the invitation of Professor T.C. Graham, Director of the Institute of Administration at the University of Toronto. Lecturers were Drs. P.J. Sandiford, B. Bernholtz, and W. Shelson with guest lecturers Drs. A.E. Paull, and J.H. Chung, and Mr. P.J. Robinson. The invitation which followed earlier discussions on possible course content

and method of presentation was dated 4 November 1955. Professor O.W. Main was active in these discussions and in proposing the course to the Director. The course was included in the Institute's Administrative Development Program and announcements were sent to companies in the Toronto and Hamilton area and published in the Globe and Mail. The response was far greater than expected with 54 applicants from the managements of leading industrial and business organizations. Consequently, two parallel evening sessions were organized with ten lectures each starting January 18 and February 2, 1956, respectively. As a matter of historical interest, a copy of the course lectures and subject matters is given in Appendix E.

The course was repeated later and then continued in modified form for a number of years under various course directors including Dr. W. Shelson. The first introduction of OR studies in a degree program in Canada was in the Department of Industrial Engineering at the University of Toronto in 1958. The first full-time faculty member in the program was Professor D.J. Clough who proposed the establishment of the new Department which was formed in 1960/61. The program proposed by Professor Clough featured OR, control theory, computers, and human factors engineering in the core program. The program was administered temporarily by the Department of Mechanical Engineering and a steering committee in 1959-60 and the Department was formed in 1960/61 (Ref.33). Following the lead of the Department of Industrial Engineering at Toronto, various engineering departments and business schools in Canada developed OR courses during the 1960's.

All universities, colleges, and technical institutes in Canada were invited to reply to the questionnaire for universities and colleges. In view of the large number of replies, the information obtained has been divided into three regions, the Atlantic Region, the Central Region, and the Western Region. The following tables summarize the relevant information.

Atlantic Region

Eight universities in the Atlantic Region provided inputs from which it may be noted (Table XXXII) that the Nova Scotia Technical College and Dalhousie University were the first institutions to introduce OR courses in their curricula (1965, 1967). They were followed by Acadia, the University of New Brunswick, and Memorial University in academic year 1968/69. Courses in OR or related subjects are given by these institutions at both the undergraduate and graduate levels. The increase in enrolment since the first courses were started is noteworthy, from some 160 originally to over 800 in 1980. Undergraduate courses in OR predominate over graduate ones in universities in the Atlantic Region.

As an example of the introduction of OR and OR-related courses, it may be noted that at Dalhousie University, courses in OR subjects began formally in 1967/68 when Dr. M.J.L. Kirby gave a course on Linear and Integer Programming with Applications as an undergraduate subject. In the same year, however, courses were offered in the OR related subjects Statistical Decision Theory and Theory of Games, and Non-linear Probabilistic and Dynamic Programming with Applications. In the following year, a course was offered on Computer Applications of Operations Research as a graduate course by

TABLE XXXII

OPERATIONAL RESEARCH AT CANADIAN UNIVERSITIES
AND COLLEGES - ATLANTIC REGION

| UNIVERSITY OR COLLEGE & DEPARTMENT OF FACULTY | ACADEMIC YEAR OF FIRST OR COURSE | FIRST LECTURER(S) OR PROFESSOR(S) | DEGREES NOW OFFERED | NUMBER OF OR OR-related COURSES | | NUMBER OF STUDENTS & ENROLMENT IN OR OR-related COURSES |
|--|----------------------------------|-----------------------------------|------------------------------------|---------------------------------|----------------|---|
| | | | | Under-graduate | Graduate | |
| Memorial Nfld Commerce | 1968/69 | C.T. Lau | Nil | 3 | 2 | 30 295 |
| Prince Edward Island Business Admin | 1974 | W.E. Isenor H.R. Love | -- | 2 | | 13 20 |
| Dalhousie Mathematical Programming | 1967/68 | M.J.L. Kirby | | | | 4 ¹ 53 ¹ |
| Mount Allison Commerce Mathematics Engineering | 1972/73 1974/75 1977/78 | -- McCandless -- | none none none | -- All -- | -- -- -- | -- 13 -- 18 -- |
| Nova Scotia Technical College | 1965 | A.N. Swan J. Aherns | B.Eng. IE; M.Eng. IE; Ph.D. IE. | 3 | 2 | 20 60 |

¹See text for particulars.

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TABLE XXXII CONT'D

OPERATIONAL RESEARCH AT CANADIAN UNIVERSITIES
AND COLLEGES - ATLANTIC REGION

| UNIVERSITY OR COLLEGE & DEPARTMENT OF FACULTY | ACADEMIC YEAR OF FIRST OR COURSE | FIRST LECTURER(S) OR PROFESSOR(S) | DEGREES NOW OFFERED | NUMBER OF OR OR-RELATED COURSES | | NUMBER OF STUDENTS & ENROLLMENT IN OR OR OR-RELATED COURSES | |
|---|----------------------------------|-----------------------------------|--|---------------------------------|----------|---|--------------------|
| | | | | Under-graduate | Graduate | Originally Students | 1979/80 Enrollment |
| | | | | | | | |
| Acadia Commerce Economics Computer Science Mathematics Business Administration | 1968/69 | Olaf Isaacson | -- | -- | -- | 10 | -- |
| | 1968/69 | -- | -- | 1 | -- | -- | -- |
| | 1971/72 | -- | -- | 2 | -- | -- | -- |
| | 1972/73 | -- | 1 | -- | -- | -- | 158 ² |
| St. Francis Xavier Mathematics | -- | -- | BBA (Management Info Systems) | 3 | -- | 18 | 25 |
| | 1968/69 | T.C. Kim Y. Lee | BA or BSc in Math or Stats with Specialization in OR | 3 4 5 | -- 2 | 60 5 | 300 27 |

² Registration in Business Administration 280 - Elementary Quantitative Analysis.

³ A total of 16 such courses are offered, 6 terms by BBA, 5 terms by Math, 2 by Forestry, 2 by Computer Science and 1 term by Engineers. Of these 14 are undergraduate and 2 graduate courses.

Dr. Kirby. In 1969/70, a course was offered as well on Analysis of Inventory Systems. These courses were given by the Department of Mathematics. While such courses were continued in mathematics in 1970/71, in the Commerce Department, courses were given in quantitative analysis and computer application and business problems, and one in the Economics Department on econometrics, and in engineering a course was offered that year on communication and control theory.

In the original OR course in the Department of Mathematics on linear and integer programming with applications (1967/68), there were only four students and in a related course on numerical methods and Fortran programming there were less than 20. In the course on introduction to computer science that year the enrolment was 75. Statistics on other enrolments are not readily available but it is easily seen that there has been a large increase in both the number of OR and OR-related courses and in the enrolments. It is also noted that although OR-type courses began in the Mathematics Department, they are now being offered in Business Administration and Economics as well.

In 1977/78 the School of Business Administration gave courses in Operation Management, Operations Research, and case applications of operations research, and in the Department of Mathematics a new half-course called Introduction to Operations Research was offered and as a graduate course a statistics and operations research seminar. Also in the Graduate School of Business Administration, two courses in operations research were offered in that year. In the following academic year, the OR courses were continued in the Department of Mathematics and in Business Administration another course in accounting and operations research was added. In 1979/80, five undergraduate OR and OR-related

courses and two graduate courses were given by the Department of Mathematics with a total enrolment of 38 and approximately 15 respectively. The statistics and OR seminar when last given had less than 10 students enrolled. In Business Administration, the corresponding numbers of courses and enrolments were four undergraduate and two business administration courses with enrolments of 86 and 187 respectively.

Central Region

By far the greatest number of institutions of higher learning in the country are located in what is called herein the Central Region (Quebec and Ontario), and the most such institutions offering courses in OR are, of course, in Ontario and Quebec.

Although courses in OR were given by the Ecole des Hautes Etudes Commerciales in 1960, it was five years after the first evening course in OR was given at Toronto that Dr. P.J. Sandiford organized and gave the first course at McGill University's Graduate School of Business in 1961. In the following year, the first OR course was given at Laval University by Dr. Arnold Kaufman, a well-known French professor and scientist. The course was a series of lectures on optimization. Subsequently, at Laval OR became part of the curriculum in mining engineering, agriculture, forestry engineering, mathematics, economics, and administrative sciences. In 1965, courses in OR were being offered at the University of Montreal and in 1966 at Sherbrooke University. Further data on OR courses in Quebec are given in Table XXXIII. In this table, the final column showing students or enrolment in courses in 1979/80, the figures for French-speaking colleges and universities represent students and those for English-speaking ones represent enrolments.

TABLE XXXLIII

OPERATIONAL RESEARCH AT CANADIAN UNIVERSITIES

AND COLLEGES - CENTRAL REGION - QUEBEC

| UNIVERSITY OR COLLEGE & DEPARTMENT OF FACULTY | ACADEMIC YEAR OF FIRST OR COURSE | FIRST LECTURER(S) OR PROFESSOR(S) | DEGREES NOW OFFERED | NUMBER OF OR OR-RELATED COURSES | | NUMBER OF STUDENTS & ENROLMENT IN OR OR-RELATED COURSES | 1979/80 Enrolment |
|--|----------------------------------|-----------------------------------|---------------------|---------------------------------|-----------|---|--------------------|
| | | | | Under-graduate | Graduate | | |
| <u>Ecole des Hautes Etudes Commerciales</u> | -- | R. Stock | -- | 3 | 2 | 15 | 50 |
| <u>McGill</u> Graduate School of Business Management Faculty | 1961 ¹ -- | P. J. Sandiford | MBA, B. Comm. | -- 22 | -- 5 | -- 50 (approx) | -- 500 (approx) |
| <u>Laval</u> Mining Engineering Mathematics Economics Admin. Sciences Agriculture Forestry | 1962 | A. Kaufman | M.S.; MBA; Ph.D. | 2 | 6 | 60 (approx) | 200 |
| <u>Montreal</u> Mathematics Information & OR | 1965 1967 | G.T. Thérien | BSc, MSc, Ph.D. | -- 173 | -- 173 | -- 25 (approx) | -- 250 |
| <u>Sir George Williams</u> Commerce | 1965/66 | | | | | | |

¹ An evening course; later in 1963 the degree of MBA 2 2 undergraduate, 5 graduate, and 2 evening or extension 3 17 undergraduate, 17 graduate, and 3 evening or extension

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TABLE XXXIII CONT'D

OPERATIONAL RESEARCH AT CANADIAN UNIVERSITIES
AND COLLEGES - CENTRAL REGION - QUEBEC

| UNIVERSITY OR COLLEGE & DEPARTMENT or FACULTY | ACADEMIC YEAR OF FIRST OR COURSE | FIRST LECTURER(S) or PROFESSOR(S) | DEGREES NOW OFFERED | NUMBER OF OR or OR-related COURSES | | NUMBER OF STUDENTS & ENROLMENT IN OR or OR-related COURSES | |
|---|----------------------------------|-----------------------------------|----------------------------|------------------------------------|----------|--|------------------------|
| | | | | Under-graduate | Graduate | Originally Students | 1979/80 Enrolment |
| Quebec à Trois-Rivières Mathematics Administration Industrial Engineering | 1969 | G. Gaenleau | BA Admin. & Indus. Eng. | 154 | 0 | 15 | 80 (240) ⁵ |
| | 1969 | | | | | | |
| | 1969 | | | | | | |
| Loyola Economics Business Admin. | 1961/62 | | | | | | |
| | 1967/68 | | | | | | |
| Concordia ⁶ Quantitative Analysis Mathematics | 1966/67 | A. Berczi, Z. Popp | B. Comm., B. Admin | 25 | 7 | 400 | 7050 (enrol- ments) |
| | 1966/67 | J. Senez | BSc, B.A. | 2 (full) 2 (half) | 2 | 30 | 90 (students) |
| Sherbrooke Administration | 1966 | | | 4 | | 60 (approx) | 280 (approx) |

⁴ Eight in industrial, 5 strictly OR, 15 with a more general definition of OR (Systems, information, statistics).
⁵ Eighty in OR, 240 in industrial engineering.

⁶ See text below for further information on Concordia, Loyola and Sir George Williams.

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TABLE XXXIII CONT'D

OPERATIONAL RESEARCH AT CANADIAN UNIVERSITIES
AND COLLEGES - CENTRAL REGION - QUEBEC

| UNIVERSITY OR COLLEGE & DEPARTMENT OF FACULTY | ACADEMIC YEAR OF FIRST OR COURSE | FIRST LECTURER(S) or PROFESSOR(S) | DEGREES NOW OFFERED | NUMBER OF OR or OR-related COURSES | | NUMBER OF STUDENTS & ENROLMENT IN OR or OR-related COURSES | |
|--|----------------------------------|---|---|------------------------------------|----------|--|-------------------|
| | | | | Under-graduate | Graduate | Originally Students | 1979/80 Enrolment |
| à Rimouski Mathematics Administration | 1970/71 (Winter) | Y. Bourassa, P. Desjardins D. Perron | Nil in OR | 2 | | 27 | 74 (total) |
| | 1971/72 (Autumn) | | | 4 | | 32 | |
| Centre d'études universitaire dans l'Ouest Québécois Administration | 1970/71 ⁷ | J. Mackle | BA Administration or Applied Math, MA Management Science | 7 | 3 | 8 | 17 |
| | 1978/79 ⁸ | | | | | | |
| Management Science | | | | | | | |
| Bishops Business Admin. | 1978/79 | M. Kattenbach | Nil in OR (BBA) | 1 | 0 | 10 | 12 |
| Ecole de Technologie Supérieure Mathematics ⁹ | — | | | | | | |

⁷ à Rouyn ⁸ à Hull

⁹ No courses in OR as such. OR techniques covered in mathematics courses e.g. SH4-451-Quantitative Methods in Management (Gestion)

TABLE XXXIV

OPERATIONAL RESEARCH AT CANADIAN UNIVERSITIES
AND COLLEGES - CENTRAL REGION - ONTARIO

| UNIVERSITY OR COLLEGE & DEPARTMENT OF FACULTY | ACADEMIC YEAR OF FIRST OR COURSE | FIRST LECTURER(S) or PROFESSOR(S) | DEGREES NOW OFFERED | NUMBER OF OR OR-related COURSES | | NUMBER OF STUDENTS & ENROLLMENT IN OR or OR-related COURSES | |
|--|----------------------------------|---|------------------------------|---------------------------------|----------------|---|--------------------|
| | | | | Under-graduate | Graduate | Originally Students | 1979/80 Enrollment |
| Toronto Business Admin. | 1955/56 | P.J. Sandiford, W. Shelton, B. Bernholtz D.J. Clough | --- | | 0 ¹ | 54 | --- |
| Industrial Eng. | 1958/59 | | B.Sc, M.A.Sc, M.Eng. Ph.D | 112 | 20 | 32 | 261 |
| Other Faculties Management Studies | --- | --- | | 6 | --- | --- | 870 |
| | --- | --- | | --- | 15 | --- | 888 |
| Ottawa --- | 1959/60 | G.S. Glineski | Evening Course | 1 | --- | 15 | --- |
| --- | 1961/62 | J.W. Mayne | Evening Course | 1 | --- | --- | --- |
| Administration Management Science 2a | 1969 | I. Sahin O. Achou | B.Admin, BMS MBA, MSS | 10 | 10 | --- | 700 |
| McMaster Business Admin. (Political Economy) | 1960/61 | G.W. Torrance | MBA, Ph.D | 1 | 5 | 6 | 100 |
| Mathematical Science | 1979/80 | K. Redish, E. Mead, S.G. Mohaney | | 11 | 0 | 147 | 10 (4th yr) |

280

¹ Evening course - see text

² Also 8 in evening courses leading to Diploma

2a The Department of Operations Research and the OR program since 1970 have been directed by Prof. J.G. Debanné, Dean of the Faculty of Management Science. The Department of Electrical Engineering was offering courses in control theory and other OR subjects prior to 1969. Enrollment in a required introductory course in OR is about 700 per year. The undergraduate program in Management Science in 1980/81 has an enrollment of 75 students.

TABLE XXXIV CONT'D

OPERATIONAL RESEARCH AT CANADIAN UNIVERSITIES
AND COLLEGES - CENTRAL REGION - ONTARIO

| UNIVERSITY OR COLLEGE & DEPARTMENT OF FACULTY | ACADEMIC YEAR OF FIRST OR COURSE | FIRST LECTURER(S) OR PROFESSOR(S) | DEGREES NOW OFFERED | NUMBER OF OR OR-RELATED COURSES | | NUMBER OF STUDENTS & ENROLLMENT IN OR OR OR-RELATED COURSES | |
|---|--|-----------------------------------|---|---------------------------------|----------|---|--------------------|
| | | | | Under-graduate | Graduate | Originally Students | 1979/80 Enrollment |
| Queens Business Mining Engineering Mathematics Chemical Eng. Computing & Info Science Mechanical Eng. | 1960/61 | G. Shaw | BCom, MBA, PhD | | | 9 | 4414 |
| | 1965/66 | E.B. Willson | BSc, MSc | | | | 62 |
| | 1968/69 | B. Kirby | BSc, MSc | 93 | 15 | | |
| | 1968/69 | D. Bacon | BSc, MSc | | | | 16 |
| | 1970/71 1974/75 | G. McEwen N. Kerr | BSc BSc, MSc | | | | 14 |
| Western Ontario Business Admin. | 1962/63 | A. Grindlay | None in OR. All business students take at least one 2 term course in management science | 35 | 45 | 65 | 5456 |
| Mathematics | 1966/67 | | | | | | |
| Carleton Mathematics Economics | 1963/64 | J.W. Mayne | Evening Course | 1 | | 10 | |
| | --- | --- | | 27 | 0 | --- | 126 |
| Waterloo Management Sciences | 1969/70 | E.A. Silver D.J. Clough | MAsc, PhD | 8 | 12 | 30-35 | 30-35 |
| | <p>3 Total of 24 half courses 4 Total of 562 semester students including 4 PhD students; total of 164 MA/MSc candidates. 5 One undergraduate in OR as such, and 2 Graduate, 6 Seventy-five in OR, 400 in Management Science, 70 in Management Information Systems, 7 A formal degree program is being proposed for Fall 1980 in the Math Department. The two undergraduate courses are listed in both the Economics Department & the School of Commerce. Several OR courses are offered.</p> | | | | | | |

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TABLE XXXIV CONT'D

OPERATIONAL RESEARCH AT CANADIAN UNIVERSITIES
AND COLLEGES - CENTRAL REGION - ONTARIO

| UNIVERSITY OR COLLEGE & DEPARTMENT OR FACULTY | ACADEMIC YEAR OF FIRST OR COURSE | FIRST LECTURER(S) OR PROFESSOR(S) | DEGREES NOW OFFERED | NUMBER OF OR OR-RELATED COURSES | | NUMBER OF STUDENTS & ENROLMENT IN OR OR-RELATED COURSES | |
|--|----------------------------------|---|---|---------------------------------|----------|---|-------------------|
| | | | | Under-graduate | Graduate | Originally Students | 1979/80 Enrolment |
| Waterloo (cont'd) | | S.S. Sengupta D. de Werra | | | | | |
| Combinatorics & Optimization Mechanical Eng. Mathematics | before 1965 | Dr. Berman | BSc (Math & OR) | | | | 300 |
| Windsor Business Admin. | 1965/66 | M. Basic ⁸ | | 3 | 2 | 20 | 190 |
| Royal Military College Engineering and Management Mathematics | 1966/67 1967 | W.L. Price | BEng | 3 | | 15 | 54 |
| York Computer Science & Mathematics Administrative Studies Mathematics (Arts) | 1969/70 1969/70 1975/76 | M. Mandelbaum G.C. Shaw A. Stauffer | BSc, MA Nil (in OR as such) BSc, MA | 2 ⁹ 1 | 110 2 | 17 20 30 | 22 25 60 |
| Guelph Mathematics & Stats. | 1970/71 | D.M. Jamieson | | 211 | | 11 | 22 |

282

8 Course title Systems Analysis 9 Both Evening Courses 10 Cross Listed 11 Expansion to 4 courses under consideration

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TABLE XXXIV CONT'D

OPERATIONAL RESEARCH AT CANADIAN UNIVERSITIES
AND COLLEGES - CENTRAL REGION - ONTARIO

| UNIVERSITY OR COLLEGE & DEPARTMENT OR FACULTY | ACADEMIC YEAR OF FIRST OR COURSE | FIRST LECTURER(S) OR PROFESSOR(S) | DEGREES NOW OFFERED | NUMBER OF OR OR-RELATED COURSES | | NUMBER OF STUDENTS & ENROLLMENT IN OR OR-RELATED COURSES |
|--|--|-----------------------------------|-----------------------------------|---------------------------------|----------|---|
| | | | | Under-graduate | Graduate | |
| Laurentian Commerce & Admin. | 1970/71 | D.J. Hilldrup | BCom (Honors with OR requirement) | 1 | 1 | 25 185 ¹² |
| Brock Mathematics Admin. Studies | 1973/74 | J.P. Mayberry | Nil Interdepartmental degree | 613 | 0 | 12 150 |
| Wildred Laurier Business | 1974 | Keller | | 1 | 1 | 200 500 |
| Ryerson Poly- technical Institute Mechanical Technology Business Admin. Industrial Engin. Mathematics & Physics | 1963/64 1965/66 1969/70 1971/72 | N. Dempster J MacLeod | | 315 2 3 | | 35 200 — 20 180 ¹⁴ 200 — 90 |

12 One course is undergraduate and one graduate, enrolments are 120 and 65,
13 Six undergraduate courses, 2 in summer, and 2 in evening or extension,
14 Two courses offered in the Diploma programmes, one in the Degree programme
15 Enrolment in Industrial/Mechanical Engineering Technology in 1979/80 was approximately 180.

As this table shows, degrees in OR, or in other disciplines with considerable OR content, are given in the Quebec universities at the bachelor, master, and doctorate levels. At Laval and Montreal, PhD degrees are granted. The number of students taking or enrolled in OR courses in Quebec has risen from about 600 in the 1960's to over 3500 in 1980. Here too, undergraduate courses in OR greatly outnumber graduate courses.

Some remarks must be made about Concordia University. Founded in 1974 by the amalgamation of Loyola and Sir George Williams, Concordia now offers many courses in OR and OR-related subjects. Table XXXIII gives some data on OR in all three institutions. The first OR course under that name at Sir George Williams, offered in 1965/66 in the Faculty of Commerce, was called Quantitative Analysis 411 - Introduction to Operations Research, and the following year the Department of Mathematics offered its first course in OR methods of operations research. In 1967/68 a Department of Quantitative Methods was organized with Assistant Professor Andrew Berczi as chairman. Five courses were offered, one of which was titled Managerial Operations Research - Introductory. Other professors in the Department were Z. Popp and R.O. Wills. The data given in Table XXXIII for the origins of OR courses in Concordia refer to Sir George Williams as they antedate the establishment of Concordia. The large number of enrolments for the OR courses in Quantitative Methods results from a very large commerce enrolment including both day and night students, with courses offered in many sections.

Although a course in quantitative methods in business administration called Operations Analysis was offered at Loyola in 1967/68, earlier in 1961/62 a course in operations analysis and economic theory was offered in the Department of

Economics while courses in game theory and mathematics for social and managerial sciences were being given by the Department of Mathematics.

Currently (1979/80), the Department of Quantitative Methods at Concordia offers 26 courses all of which are in the OR field. In particular, courses in managerial OR, OR and production systems, optimization techniques, business decision analysis, OR models in the social environment, inventory, replacement, maintenance models, and data processing systems and applications are offered. The total number of students enrolled in these courses in 1979/80 was 6803 and 1000 in summer 1979 courses. In the Department of Mathematics, in addition to several OR-related courses, two courses (Deterministic Methods of OR and Probabilistic Methods of OR) are offered. Under the Master of Business Administration program in the Faculty of Commerce and Administration, seven courses in quantitative methods, one in management science and several in management and marketing are offered. The number of students enrolled in four of these quantitative methods courses in 1979/80 was 249. Concordia is launching an Industrial Engineering option in 1981/82 and considering a programme on actuarial mathematics. Both of these will affect OR courses.

In Ontario, at least fifteen institutions offer courses in OR, and at least nine of them grant degrees in OR or OR-related subjects. These degrees include bachelor's, master's, and doctorates. Four of them, McMaster, Queen's, Toronto, and Waterloo grant the PhD degree in OR or OR-related subjects (management science, industrial engineering, or business administration).

Following the University of Toronto in 1956, the next universities to offer courses in OR in Ontario were Ottawa in 1959/60, McMaster in 1960/61, and Queen's in 1960/61. These were followed by Western Ontario in 1962/63 and Carleton in 1963/64. Most of these original courses were given in evening extension sessions and later full credit courses were offered. The names of some of the pioneers in OR in Canada show up in Table XXXIV which summarizes relevant information about OR courses in OR and OR-related subjects in Ontario universities.

It will be noted from this table that OR courses and OR-related courses are offered in many different university departments and faculties. In most cases, the original OR courses were given as extension courses in the evening to interested persons who already held university degrees. Such was the case at the University of Toronto, Ottawa, and Carleton, among others. In other cases, courses with OR content were offered under courses in economics, mathematics, statistics, business administration, or later management science and industrial engineering.

Some further remarks should be added about OR at the University of Toronto. The growth of OR and OR-related courses since 1956 has been rapid and are now being offered in several faculties and departments. In 1979/80, in the Faculty of Applied Science and Engineering, three undergraduate courses in OR were given in the Department of Industrial Engineering with an enrolment of 261 representing about 150 different students. In nine OR-related courses in management science, the total enrolment was 651. Also in the Faculty of Arts and Sciences (undergraduate), enrolments in OR-related courses in four departments in 1979/80 were: Commerce, 53 (one course); Computer Science, 311 (2 courses); Economics, 445 (2 courses); Applied Mathematics, 61 (one course).

In the Faculty of Management Studies (Graduate), some 67 courses are offered in a two-year program. Of these, 15 were deemed to be OR-related. In 1979/80, the total enrolment in these 15 courses was 888. From the enrolment figures, it is evident that at least 237 students took OR-related courses in the first year program and at least 76 in the second year. A minimum total number of students in this faculty taking OR-related courses in 1979/80 was accordingly over 300. The total number of students taking OR and OR-related courses is not readily calculated from these enrolment figures but assuming each student in 1979/80 took three such courses during the year, the total number of students would have been about 900; it may have been somewhat higher.

Some of the original OR scientists in Canada were the first lecturers in OR courses at universities in Ontario. For example, Drs. Sandiford, Shelson, Bernholtz, D.J. Clough, A.E. Paull, and Mr. P.J. Robinson at Toronto, J.W. Mayne at Ottawa and Carleton, Dr. J.W. Abrams and C.E. Law at Queen's and Dr. W.L. Price at the Royal Military College, Kingston. At Queen's, Dr. J.W. Abrams lectured in OR as part of a Master of Business Administration Course in 1964. This OR course was soon expanded to three graduate and two undergraduate courses in 1966 by Professor C.E. Law (Ref.34).

In these Ontario universities, although the figures shown are not complete, the numbers of undergraduate and graduate courses offered are approximately the same. There has been a vast increase in the number of students or enrolments in OR and similar courses since the first such courses were offered (less than 1200 students) and the present enrolment number (over 6500).

Western Region

Data on universities and institutes in Western Canada, similar to those given in the preceding tables, are presented in Table XXXV. From this Table it is noted that although an introductory course in OR was offered at the University of Saskatchewan's Department of Agricultural Engineering in 1961/62, it was not until the late 1960's and early 1970's that other OR courses were given in Western universities. However, by 1969 degrees in OR or OR-related programs were being granted at all three of the normal university degree levels.

In the case of the University of British Columbia for example, although a few sporadic courses in OR were offered in 1967 and 1968, the first degree programme was the PhD in Management Science which was approved and initiated in 1969. (Ref.36). The programme was given by the Management Science Division of the Faculty of Commerce and Business Administration and the OR courses in the programme were taught by faculty of the Management Science Division. The programme was a full-time, day school activity. The second programme in OR was the Master of Science degree, one in Management Science which was offered first in 1972 by the same Division.

According to the figures shown in Table XXXV, in the Western universities, particularly in British Columbia, graduate courses in OR or OR-related disciplines outnumber undergraduate courses. We also see that there has been a great increase in enrolment in OR and OR-related courses since OR courses were originally offered, the increase being from approximately 700 initially to 3000. As the footnotes make clear, many of these enrolments are in OR-related courses rather than in specific OR courses. A similar remark pertains for the figures about enrolments mentioned earlier.

TABLE XXXV

OPERATIONAL RESEARCH AT CANADIAN UNIVERSITIES AND COLLEGES
WESTERN REGION (PRAIRIE PROVINCES AND BRITISH COLUMBIA)

| UNIVERSITY OR COLLEGE & DEPARTMENT or FACULTY | ACADEMIC YEAR OF FIRST OR COURSE | FIRST LECTURER(S) or PROFESSOR(S) | DEGREES NOW OFFERED | NUMBER OF OR or OR-related COURSES | | NUMBER OF STUDENTS & ENROLMENT IN OR or OR-related COURSES | |
|---|----------------------------------|-----------------------------------|--------------------------------------|------------------------------------|-----------------------|--|-------------------|
| | | | | Under-graduate | Graduate | Originally Students | 1979/80 Enrolment |
| Manitoba Actuarial & Business Mathematics Applied Mathematics Business Admin. | 1969/70 1975/76 | T.S. Major | BSc (Hons), MSc BComm (Hons), MBA | 5 | 6 | 31 | 2051 53 |
| Winnipeg Economics Mathematics | 1968/69 — | — — | — — | 3 1 | — — | — — | 52 5 |
| Saskatchewan Engineering (Agricultural) Commerce Finance and Management Sciences | 1961/62 1968/69 1967/68 | T. Pepper — A. Whitmore | BComm, MBA BComm | 2 11 | 2 (several MBA) | 2 50 | 178 300 |
| Regina Administration Engineering | 1967/68 1972/73 | P. Gross ² — | — | 6 | 0 | 6 | 250 — |

289

¹ Total registrations including 53 in Quantitative Analysis for Management
² For further information on OR courses at the University of Regina see Ref. 35.

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TABLE XXXV CONT'D

OPERATIONAL RESEARCH AT CANADIAN UNIVERSITIES AND COLLEGES
WESTERN REGION (PRAIRIE PROVINCES AND BRITISH COLUMBIA)

| UNIVERSITY OR COLLEGE & DEPARTMENT OF FACULTY | ACADEMIC YEAR OF FIRST OR COURSE | FIRST LECTURER(S) OR PROFESSOR(S) | DEGREES NOW OFFERED | NUMBER OF OR OR-RELATED COURSES | | NUMBER OF STUDENTS & ENROLMENT IN OR OR-RELATED COURSES | |
|---|----------------------------------|-----------------------------------|---------------------|---------------------------------|----------|---|-------------------|
| | | | | Under-graduate | Graduate | Originally Students | 1979/80 Enrolment |
| Southern Alberta Institute of Technology Business Education | 1967 | A. H. Colquhoun | | 1 | | 95 | 265 |
| Northern Alberta Institute of Technology Business Admin. Computer Systems | 1970/71 1970/71 | J. Marshall S. Suttraun | Courses | 3 ³ | | 55 ⁴ | 260 ⁴ |
| Calgary Management | -- | -- | -- | 3 | 2 | -- | 390 ⁵ |
| Alberta Business Admin. & Commerce | 1968 | P. Winters | BComm, MBA | | | 430 | 500 |

³ One course in OR; two in Quantitative Analysis.

⁴ In OR courses, 25 and 52 respectively.

⁵ Graduate 350; undergraduate 40.

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TABLE XXXV CONT'D

OPERATIONAL RESEARCH AT CANADIAN UNIVERSITIES AND COLLEGES
WESTERN REGION (PRAIRIE PROVINCES AND BRITISH COLUMBIA)

| UNIVERSITY OR COLLEGE & DEPARTMENT OR FACULTY | ACADEMIC YEAR OF FIRST OR COURSE | FIRST LECTURER(S) OR PROFESSOR(S) | DEGREES NOW OFFERED | NUMBER OF OR OR-RELATED COURSES | | NUMBER OF STUDENTS & ENROLLMENT IN OR OR-RELATED COURSES |
|--|----------------------------------|-----------------------------------|---------------------------------|---------------------------------|-----------------|--|
| | | | | Under-graduate | Graduate | |
| British Columbia Commerce & Business Administration | 1967/68 | L.G. Mitten | MSc & PhD in Management Sci. | 2 ⁶ | 28 ⁶ | 12 |
| | 1970 | | | | | |
| Forestry Mathematics Management Science | 1970 | | | | | |
| | 1968/69 | F.D.K. Roberts | | 1 | | 15 |
| Victoria Mathematics Public Administration Computer Science | 1974/75 | T.A. Lamb | | 1 | | 30 |
| | — | — | | 4 | | 106 |
| Royal Roads Military College Mathematics | 1970 ⁶ | G.M. Lancaster | | — | | — |
| Simon Fraser Economics Commerce | 1967/68 | — | | 2 | | 459 |
| | 1967/68 | — | | 3 | | 1160 |

⁶Brief introduction to OR given as part of course in Linear Algebra (Math 252); one titled Introduction to Systems Analysis.
Also 2 in Extension or Evening Program.

⁷Overall total for 32 courses.

Some relevant data on two of the newer universities in the Western Region have been obtained. Simon Fraser, which opened on 9 September 1965, originally offered no courses related to OR. By 1967/68, courses in quantitative methods in economics (by the Economics Department) and in quantitative methods in business, market research and OR (by the Commerce Department), and advanced programming in mathematics (by the Department of Mathematics) were being offered, all as undergraduate courses. In 1968/69, an undergraduate course in computer programming and numerical methods was offered (in Mathematics). In 1969/70, a Master of Business Administration program in OR was first offered. A course in econometrics was first offered in the Graduate School by the Economics Department. Later, other OR-related courses were added to the curriculum including operations management and management science in the Department of Business Administration, computer science and linear programming in the Department of Mathematics, model building in Business Administration and Economics in the Department of Economics.

The University of Winnipeg, established in July 1967, offered no OR or OR-related courses originally. However, in 1968/69 a course in mathematical economics was introduced (Department of Economics) and in 1969/70 one in mathematical programming (Department of Mathematics). Later (1972/73) a course in computer programming was offered and one in quantitative methods for business administration in 1973/74. A course in gaming and linear programming was offered in 1975/76 and subsequently such courses as linear optimization (in the Department of Mathematics), quantitative economics (in the Department of Economics), and in quantitative methods and marketing research (in Administrative Studies) were offered.

GENERAL COMMENTS

At least nine of the schools either offer or plan on offering an inter-departmental degree or program in OR. These are the universities of Montreal, Brock, Carleton, York, Manitoba, British Columbia, Royal Military College, and Centre d'études dans l'ouest québécois.

Of the 45 schools mentioned in the preceding Tables, 12 report that changes in the number or level of OR courses are planned. They are Memorial, McGill, Carleton, McMaster, Guelph, Wilfrid Laurier, York, Manitoba, and Calgary universities, Royal Military College, Centre d'études dans l'ouest québécois, and Ryerson Polytechnical Institute. The more interesting of these developments are at Carleton where a formal degree program in OR is being proposed, and at McMaster where both an increased level and additional courses in OR are planned for a new PhD programme. Changes underway or planned in other institutions vary from new and extra courses to inter-disciplinary programs, and new graduate courses and programmes. The University of Lethbridge, which now has no OR courses, reports that the Management Arts Department has applied for Faculty status, and if this is approved the curriculum would "undoubtedly include courses in operational research."

It appears, accordingly, that the number and level of OR courses in Canadian schools of higher learning, and support for OR and OR-related programmes are on the increase, an encouraging observation for the future of OR in Canada.

It must be noted, however, that of the 41 schools from which dates of introducing OR courses have been received, two began OR courses in the latter part of the 1950's, 20 in the 1960's, and nine in the 1970's. There are not more than about 20 other institutions of higher learning in the country and some of these emphasize the arts and humanities rather than business, commerce, engineering, or the sciences. Thus, there may not be many more academic institutions introducing OR courses in the near future. At least not at the high rate that occurred in the 1960's.

Most universities and colleges in Canada now offer OR or OR-related courses. Beginning in 1956 with an introductory course at the University of Toronto (Appendix E), there was quite a rapid increase in institutions offering such courses. The rate of increase can be seen from the following Table.

TABLE XXXVI

NUMBER OF UNIVERSITIES AND COLLEGES IN CANADA
OFFERING COURSES IN OPERATIONAL RESEARCH
BY PERIODS

| P E R I O D | R E G I O N | | | Total |
|-------------|-------------|---------|---------|-------|
| | Atlantic | Central | Western | |
| 1956-1960 | 0 | 5 | 0 | 5 |
| 1961-1965 | 1 | 14 | 1 | 16 |
| 1966-1970 | 5 | 24 | 9 | 38 |
| 1971-1975 | 7 | 26 | 9 | 42 |
| 1976-1980 | 7 | 26 | 9 | 42 |
| TOTALS | 7 | 26 | 9 | 42 |

Although these figures may not be exact, we see that the five-year periods of greatest growth in the number of institutions offering OR courses were 1966-1970 and 1961-1965 and that in the Central Region the increase was about the same in these two periods. The greatest rate of growth was in the Western Region in the 1966-1970 period.

Figures are not readily available for enrolment in OR courses by year or period. However, the original night course in OR at the University of Toronto had 54 students and the 1979/80 enrolment in the institutions for which data are available was over 18,000. The total original enrolment in OR or OR-type courses, spread over some 20 years, was approximately 2800. It is clear that there has been a large increase in the number of students enrolled in OR and OR-related courses over the last 25 years.

This short account of OR in Canadian universities, colleges and institutions indicates the rate of development of academic interest, and the resultant provision of courses in OR across the country. It also gives some evidence of the interaction between exponents of OR in government (particularly the Defense Research Board of the Department of National Defence) and business, and those in academic circles. It is also worth noting that within a dozen years or so of the first use of OR in Canada, courses in the subject were being organized in the universities.

The first formal instruction in OR in the UK was in the form of summer schools of 1-2 weeks duration in 1949-51 and 1953. These were given by the Department of Engineering Production of Birmingham University. Sir Charles Goodeve was one of the early speakers (Ref.37). Birmingham also gave the first masters course in the UK in 1958. University courses in OR

began in the U.S.A. in 1952/53 at Johns Hopkins University and the Massachusetts Institute of Technology, followed by Case Institute in 1955/56 (Ref.34). So we see that Canada was not far behind in the development of OR programs in the universities and colleges and the process is still continuing.

Mention has been made earlier about the contributions of the academicians to the early growth and development of OR in Canada. There can be little doubt that the academic training of students in the theory and practice of OR has been one of the essential and main factors in this development. As will be noted in the next chapter, university staff members also are the major contributors of publications on OR and OR-related subjects in the professional journals dealing with OR, industrial engineering, and management science. In the case of Canada, these journals are particularly the former Journal of the Canadian Operational Research Society and its successor the Canadian Journal of Operational Research and Information Processing (INFOR).

In this connection it is interesting to note relevant remarks made by Dr. O.M. Solandt in his Presidential Address to the CORS at its Second Annual Conference in May 1960 (Ref.38). He referred to two kinds of OR people, "those who are truly doing research and those who are applying the results of this research to the solution of practical problems." He then added: "Both kinds of people are urgently needed in the OR community; however, we must make sure that the research people are given adequate encouragement and full credit for their accomplishments. Without the backing of a continuing programme of productive research, the future prospects of the practitioners of OR would be very limited."

While recognizing that both kinds of people are urgently required, there often appears to be little communication between them and advancing theory may be of little observable value to the practitioner, at least in the short run. In this connection, it is interesting to note a comment made in Ref.39 to the effect that after six years of trying "I still have not applied any of these super OR techniques I learned at university, but I do not think that makes me any less a practitioner of OR." However, the reference adds that "certainly this knowledge allowed me to conceptualize a system that made these applications feasible." How to narrow the gap between theory and practice in OR is an interesting question which may warrant more attention from academicians and practitioners. The consensus of informed personnel with whom this matter was discussed is that such a development would be mutually beneficial and augur well for the future of OR in Canada.

Some further remarks on the usefulness of OR theory and professional journals are given in Chapter XIII.

CHAPTER X

THE CANADIAN OPERATIONAL RESEARCH SOCIETY

ORIGIN AND DEVELOPMENT OF THE SOCIETY

As befits a new and growing branch of applied science, steps were taken in the late 1950's to form a professional society for operational research scientists in Canada. By 1957, as the foregoing testifies, OR had been firmly planted in Canada and some thought was being given to forming a Canadian Section of the Operations Society of America of which many Canadian scientists were members. At about the same time, preparations were being made for an International Operational Research meeting at Oxford, England in 1957. Sir Charles Goodeve, a Canadian scientist prominent in wartime OR in Britain, in 1956, when he was visiting Canada in connection with the forthcoming Oxford Conference, suggested that a Canadian OR society might be formed. Sir Charles at that time was Director of the British Iron and Steel Research Association.

This proposal was taken up by Dr. O.M. Solandt, then Assistant Vice-President, Research and Development of the Canadian National Railways, and in 1957 Vice-President. The matter was discussed with Peter B. Wilson and Peter J. Sandiford. Following these discussions, Dr. Solandt suggested to Dr. J.W. Abrams, then Superintendent of the Operational Research Group (ORG) of the Defense Research Board, that a Canadian society should be formed. As Dr. Abrams was going to be away in Europe for some time, Dr. Solandt asked Dr. N.W. Morton, the former Superintendent of the ORG, to form a committee to explore the possibilities (Ref.40). The

elected committee consisted of C.E. Law, K.J. Radford, and Dr. N.J. Hopkins, all of the ORG. They met with various representatives from the OR Society of Toronto which had been formed in 1955 by the Ontario Hydro OR team of Bernholtz, Shelson, and Sandiford (Ref.41). They also prepared a questionnaire which was signed and sent out by Dr. Hopkins. A letter was drafted by Peter Wilson with assistance from Peter Sandiford (Ref.40) suggesting that a national organization would be a satisfactory arrangement. It was approved by Dr. Solandt and distributed as part of the debate. As a consequence, but only after several months, and several meetings with interested OR personnel under Dr. Solandt's leadership, the OR Club of Montreal was formed and the Toronto and Montreal societies were amalgamated with the ORG of DRB to form the Canadian Operational Research Society (CORS). The official starting date for the new Society was April 14, 1958.¹ A comprehensive account of the origin and growth of CORS is given by Peter J. Sandiford (Ref.41) and further details will not be reproduced here. The first annual symposium of the new society was held in May 1959. It featured 18 papers including the presidential address by Dr. O.M. Solandt and a presentation on the long range future of operational research by Dr. Ellis A. Johnson, Director of the Operations Research office of the U.S. Army.

Although membership in the Canadian Operational Research Society (CORS) has been increasing, it certainly does not include many of the scientists, engineers, and others practicing OR. At the time of writing (May 1980) total membership

¹The Operations Research Society of America, to which many Canadian OR people belonged was started in 1952.

is 1077. Of these, only 166 are full members, 675 are associate members, and 236 are student members. Over half of these are members of the Toronto, Ottawa, and Montreal Sections with 239, 197, and 165 members respectively. Of these, 40, 38 and 30 respectively are full members.

PUBLICATIONS

By the end of 1963, the CORS published the first issue of its journal, the Journal of the Canadian Operational Research Society. The first edition, Volume 1, No. 1, December 1963, had an editorial by K.J. Radford, the first Editor, and five articles. Publication was made possible through the generosity and support of 11 Canadian organizations. By way of comparison, the first issue of the corresponding UK Journal, the Operational Research Quarterly, Vol. 1, No. 1, was published in March 1950 and the first issue of the USA Journal of the Operations Research Society of America was Vol. 1, No. 1, November 1952.

The CORS journal was published for seven years but after Volume 8, No. 3, was issued in November 1970, the next issue, Volume 9, No. 1, March 1971, was published jointly by the CORS and the Canadian Information Processing Society. It appeared under a new cover and was called the Canadian Journal of Operational Research and Information Processing - abbreviated INFOR. The policy of joint publication under that title has continued since then until the present.

Publication by the first OR workers in Canada were on military subjects and lists of titles of these publications are given in Appendix B. A partial bibliography of OR articles published by residents of Canada up to the end of 1963 is given in Appendix 9 to Ref.22 and will not be repeated here.

The chief vehicles for publishing OR papers by Canadians have been the CORS Journal and its successor INFOR. The number of articles appearing in these journals has been gradually increasing. For example, in March 1967, it may be noted that three volumes of the CORS Journal contained 24 articles (Ref.42) and that thereafter four volumes (Nos.5-8) contained 67 articles, while eight volumes of INFOR (Nos.8-16) had 209 articles. It is worthy of note that a high proportion of the articles appearing in the CORS Journal and in INFOR has been contributed by professors at Canadian and other universities. A similar remark applies to articles on OR and OR-related subjects in other professional journals.

Canadian OR personnel have also published articles on OR in the Journal of the Operations Research Society of America, as already noted, and in the U.K. Journal, the OR Quarterly, as well as in INTERFACES, a TIMS-ORSA Journal,¹ and elsewhere. Many other papers by them have appeared in the proceedings of conferences and meetings and at international conferences on OR. Indeed, the bibliography of publications by Canadian OR workers is quite extensive and too much so to be included in the present report. Even a

¹Published by the Institute of Management Science in cooperation with the Operations Research Society of America, at 1462 Westminster Street, Providence, R.I. 02903.

brief look at the journals mentioned, particularly INFOR, reveals the wide range of subject matter covered by OR publications. Such a check also indicates that OR is being applied to new areas of application and in this development Canadian OR scientists are playing their part. For example, Ref.43 is an article on operational research and criminal justice which lists 44 papers of bibliography, nine of which are OR-type articles. The abstract to this article reads: "During the last decade, there has been increased activity in the application of OR to the analysis of crime and criminal justice." It has been noted in Chapter V that the Department of the Solicitor-General has been active in OR and OR-type work for some time. As reported in Chapter VIII only one Canadian bank has an organized OR unit (Canadian Imperial Bank of Commerce) and it is of recent origin. Although no publications on OR in banking in Canada have been referenced here, such publications are becoming common in the U.S.A. (Refs.44 and 45), and can be expected to appear in Canada soon.

Although even a casual review of OR publications reveals the extensive contributions made by OR workers and teachers to theory in many areas such as queuing theory, dynamic, integer, and linear programming, model construction, production and inventory control, game theory and transportation analysis, it appears that the only really original theoretical work done by OR staff in the pursuit of OR was in laying the foundation of a general methodology in developing a theory of search. This original development was done during WW II by the U.S. Antisubmarine Warfare Operations Research Group (Ref.46). Accordingly, the theoretical part of OR has consisted, largely, of extending and refining existing theories and methodologies rather than in developing new theories.

In this process, Canadian OR personnel particularly, but certainly not exclusively, those on university staff have played a prominent role.

Areas in which these extensions and refinements have taken place include linear, dynamic and integer, and economic programming, queuing theory, decisive analysis game and simulation theory, among others. Also, OR has certainly given much impetus and stimulation to modelling as a means for representing and studying operations and systems.

CHAPTER XI

THE IMPACT OF OPERATIONAL RESEARCH

ON DECISION MAKING IN CANADA

INTRODUCTION

It is not feasible to assess the contribution and impact of OR on decision making with any high degree of confidence. In some cases, to the author's knowledge, OR studies have been a major influence in important decisions made by senior Canadian and NATO military staff and the civilian authorities to whom they reported. But in general, OR findings constitute only one input to decision making, and usually the relative impact or importance is difficult to judge or ascertain. Certainly, the process of decision making is not yet at a stage where the impact of inputs can be assessed quantitatively, if indeed such a stage is ever reached. Nevertheless, in preparing this report, an attempt has been made to obtain some relevant information on this question in a general qualitative way through correspondence, interviews, and literature search.

GENERAL

In reply to the question: "What impact has OR had on decision making in Canadian government, business, and industry?" some thirty opinions were received from senior executives, managers, OR practitioners, and professors in Canadian business, government, industry, and universities. In the case of university professors, all have had experience in practising and applying OR and the OR practitioners were senior directors or OR programs and advisers to respective managers and decision makers. Some of the senior executives had been OR analysts in their careers.

The replies covered a wide range of opinions from some suggesting that OR has had rather limited impact on decision making in Canada, others claiming very great impact for OR. One pertinent reply stated that: "I do not believe that we understand the process (of decision making) well enough to determine the deciding factor in most cases. OR has certainly contributed to decision making but it has had to compete with other factors such as politics and pigheadedness. We cannot usually say that a decision which was in accord with OR recommendations was necessarily due to the OR nor that one which was opposed to the OR recommendation was not influenced by it." These are apt observations. There can, for example, be little doubt that a decision to introduce an equipment or process which has been shown by an OR study to be less cost-effective than competing ones must have other stronger factors in its favor if it is chosen, and thus the OR work had an impact in this sense. As one reply put it, decision-makers "were very reluctant to take a course of action when an OR study recommended otherwise."

One interesting observation was that although major decisions seem sometimes to be made capriciously, they are usually followed by a series of decisions designed to make the results more successful, or at least less disastrous than they otherwise would have been and that it is in relation to these secondary decisions that OR makes the largest contribution. Another general comment was that in some way it is "unfortunate that OR arrived on the private sector scene almost coincidentally with the computer. Because of their background and training, many OR analysts got involved in the development and application of data processing and OR itself was able to make considerable progress in applying techniques that had previously been more theoretical than

operational through the use of computers (e.g. linear programming, simulation, Monte Carlo). These events meant that for many managers, "OR and computers have become synonymous."

Mention was made by respondents of the beneficial impact of OR in decision making in the defence field, the National Energy Board, and in the transportation industry, and manufacturing industries. One reported that "OR has now become so widespread and so commonplace in North American industry that almost every large company has some complement of OR personnel. Most of these do not consider themselves OR people, nor is their work labelled OR, but the OR philosophy has had a great deal to do with their decision making practices and ability. I would say that the almost universal presence of OR courses within MBA and Business Curricula is an indication of the influence which OR has had on decision making, including the theory of decision making and indeed, the general theories of business itself. Optimization modeling, linear programming, mathematical programming, simulation, critical path, dynamic programming, forecasting, inventory control have all become such commonplace parts of the language of business that their OR origins are almost entirely forgotten."

While the great majority of the replies expressed the general opinion that OR has had significant positive impact on decision making in Canadian business, industry and government, a few were less laudatory and mentioned certain reservations and caveats. One reply stated that OR has "improved decision making in Canadian government in some degree, although not nearly as much, or in the way that many of its proponents had hoped." Another reported that OR has made a contribution to the science of management and the improvement of decision making in Canada, but, "I do not believe that

management science (or operational research) has lived up to the euphoric claims of the promoters." Still another states that in many cases, the costs of fact-finding and of delay in making decisions (if an OR study is done) far outweigh the improvement in the decision. Further, the practitioners of OR often claim (in advance) potential improvements in reaching an "optimum" decision which cannot be (and are not) achieved in practice. "Clearly," he writes, "we need to be much more selective in using OR techniques and we must make decision makers more aware of their limitations." A related remark was that "there is now an acceptance of the need to look for optimum solutions (to problems) rather than simply better solutions. Consequently, many business and government decisions are only taken after alternatives are assessed after using OR techniques. In other words, fact-finding is now more thorough prior to making the decision." Another opinion was to the effect that over the years, OR has been by and large successful. There have been customary problems of communications between scientifically oriented and business oriented people and sometimes recommendations by OR people were considered by the client to be too theoretical to apply. However, "such instances were more than offset by the benefits coming from the introduction of practical and reasonably simple quantitative techniques to improve some dimension of a management function" (e.g. a managerial decision).

Another response notes that "it is my impression that OR has not made a substantial impact on the way decisions are made in business and industry," but goes on to remark that many engineering and business school graduates since about 1960 have entered the ranks of management with a new perspective concerning the use of formal methods of modeling and analysis including OR. Then the statement is

made that "the OR community has perhaps played a large role as 'honest broker' in propagating formal methods into various areas of engineering and management. In fact, OR may have served the most useful purpose in this regard, and may now be declining because other disciplines have adopted and further built on all of the now classical OR methods."

A somewhat different reply stated that in some areas such as planning and allocation of oil and chemical products, OR has completely changed the approach to decision making, and also in such areas as life insurance and certain financial enterprises. This reply also notes that other areas, such as production and inventory control, OR is still making progress but is not yet fully exploited, while in areas such as marketing, business strategy, etc., while OR has had some influence, there is still considerable scope for more improvement. In this connection, it may be noted that the Directorate of Strategic Analysis of the Operational Research and Analysis Establishment of the Department of National Defence (Chapter III) has always employed OR techniques in its studies and analyses wherever it has been feasible to do so.

It is interesting to contrast three replies from the West Coast. One says: "From experience in British Columbia, OR has had little impact on decision making;" another says "OR has had a significant impact." A third believes that for small industries, the OR impact has been minimal but for larger companies there has been a significant impact. The latter respondent continues to say that the lack of more OR impact on decision making may be due to a misunderstanding of the OR community of how complex decisions that are actually made, as opposed to how OR people think they ought to be made.

Still another respondent has doubts about the impact that OR has had on decision making in Canadian government, business, and industry, but believes that if the definition of OR is broadened to include the 'entire scientific approach' to decision making, then the effect has been significant. He adds that in his opinion OR has become equated with the application of rigorous mathematical formulas through observations of the real world and that the degree of distraction necessary for the mathematical solution has often resulted in the model being too far removed from reality so that the solution is less than the best.

A further general reply observes that the loose definition of the subject matter (of a problem) and the unrealistic delineation of the study, in comparison with the constraints of timing, money, and available skills are the main reasons that OR has little chance to evolve and transform the present approach to decision making. It adds that the main advantage of OR studies may be a more systematic structure of uncertainty and a greater awareness on the part of decision makers of often neglected or unnoticed alternatives.

Two brief replies were to the effect that OR has had only a qualified impact on decision making and that with the exception of the defence area, OR would appear to have had little impact on decision making in the Canadian government. However, the latter response adds that individuals trained in OR have, perhaps through a different perspective, been able to apply OR thinking to their particular areas of responsibility. Two more positive replies were as follows: OR had a major effect in decision making (in the areas with which the responder was most familiar) by supplying quantitative data which would otherwise have been lacking or by analyzing and portraying information in a way

that facilitates decision making; OR has been effectively used in many industries in Canada (petroleum, petrochemicals, chemicals, food production and distribution, transport and transport planning, mining, fuel and paper) which demonstrate improvements in production efficiency, flexibility of marketing, more effective inventory control, reduction of bottlenecks, breadth of planning, and overall profitability.

Without going into detail, a few other replies were to the effect that OR has had considerable impact on decision making in Canada. One did qualify the statement by adding: "There are many negative impacts as well as some very substantive positive impacts." One other replied to the question by stating that OR has had an impact on decision making in Canada through "the view that OR is a technique that should be more widely spread."

Another reply expressed the belief that specific OR studies have had an impact in certain of the more operationally oriented government departments (e.g. Defence and Transport), the most significant impact of OR may have come from the way it has trained people to think about problems even some of the more abstract policy problems. This reply went on to say: "the significance of my OR training has been that it taught me to structure problems in an organized way and to try to identify the alternatives and assess them as accurately as possible, even though many of the assessments were qualitative rather than quantitative in nature."

A response from the military field mentioned that there OR has both positive and negative impacts on decision making. The negative type prevents bad decisions and the positive type influences making the better or right decisions. These are not confined to decisions about major procurements, but also include those concerned with tactical, operational, and

command level problems and improvements in such areas as readiness and times required for doing various military tasks.

Certainly, the great majority of these written replies support the view that OR has had considerable or significant impact on decision making in Canada in government, business, and industry. They also confirm that the beneficial impact of OR has been both in respect of making specific decisions and of improving the general approach to decision making and the way managers and decision makers think about and structure problems.

At the 1980 Canadian Operational Research Society Annual Meeting in Quebec City, a panel discussion was held to address three questions: a) What factors have been most influential in the development and growth of OR in Canada? b) What impact has OR had on decision making in Canadian government, business, and industry? c) In what direction is OR in Canada going now, and in what direction should it develop to be more beneficial to Canadian managers and decision makers? Responses to the first question have been incorporated in the foregoing (Chapter IV) and discussion on the third question will be made below (Chapter XII). Comments made to the second question are summarized in the following paragraph.

The replies included the statement that OR has indeed had significant impact but that much remain to be done in regard to implementing OR findings; the fact that OR in the military field has been expanded into the study of strategic problems, integrated logistics, and social and economic problems with attendant beneficial effect on decision making; the opinion that major decisions rely heavily on OR analyses and inputs, that OR analyses impart credibility to

recommendations and identify fruitful areas for research and development; and that examples of OR studies had important inputs to decisions concerning oil refinery operations in Quebec City and federal government actions, with the observation that once one organization started using OR and quantitative methods, others must follow suit.

Two remarks are pertinent here. First, it may be noted that none of the replies referred to above suggested that OR techniques could not improve decision making although some did state that the impact of OR was not very great. Secondly, the replies stating that OR has had significant effect on decision making were made by those who, in the author's opinion, are best qualified to assess the impact of OR. It may be stated that the effectiveness of OR should be judged by the quality of the decisions made by managers tasking OR personnel. Although it is not easy or simple to assess the quality of decision making, the above discussion leaves the distinct impression that the use of OR has definitely improved the quality of decisions made in Canadian business, industry, and government, and will continue to do so in the future.

OTHER FINDINGS CONCERNING THE IMPACT OF OPERATIONAL RESEARCH

During personal interviews with senior representatives of business, industry, federal, provincial, and civic governments, and research councils who are tasking OR staff and using their output the following questions (amongst others) were raised:

- a. What has been the impact and importance of OR findings on decision making?

- b. What has been the relationship of OR contributions to other factors influencing major decisions?
- c. Has OR contributed to a more quantitative and scientific approach to the preparation and evaluation of plans and programs, and to better quality decisions?
- d. What has been OR's greatest contribution to your business, department, or university?

Respondents were aware that neither they nor their company or organization would be identified and were asked for qualitative statements about their personal assessments. There was a high degree of conformity in the responses received from over thirty interviews, and these are summarized in the following Table.

Considerable elaboration was offered in most of the responses but the table entries are accurate reflections of the comments. The few slight reservations shown in the table were from respondents whose experience with OR staff and findings has been limited because of time or small staff numbers. Thus, in general, the summarized qualitative assessments of the table indicate that OR has, indeed, had much impact in various ways and to varying degrees on decision making and has made important contributions to a more quantitative approach to preparation of plans and programs in those agencies where it has been used. These interview comments add considerable positive support to the preceding discussion on the impact of OR on decision making in many areas of Canadian activity.

A further interesting and relevant comment is that the Eighth Annual Review (September 1971) of the Economic Council of Canada is devoted to the examination of the major aspects of government decision making processes and to

TABLE XXXVII

Summary of Replies to Interview Questions on
OR Contributions to Decision Making in Canada

| Nature of Impact | Relative Impact | OR Contribution to More Qualitative Approach | Greatest Contribution of OR |
|--|-------------------------------------|--|--|
| Significant (7) | Varies but generally important (19) | Yes, very great (1) | Certain specific studies (4) |
| Considerable (11) | Usually one of several (3) | No doubt about it (3) | Improvement in the quantitative approach (7) |
| Very important (1) | Often very important (5) | Yes, at all levels (1) | Improving decision-making & analysis (2) |
| Very useful or strong (2) | Not always main factor (1) | Yes (21) | General increase in quantitative thinking (5) |
| Immediate & direct (1) | Sometimes key (3) | Very decidedly, yes (1) | More logical approach to problem solving (3) |
| Quite good (2) | Major, sometimes (2) | Yes, in certain cases (2) | More efficient use of resources (3) |
| Profound in some cases (2) | One of main factors (1) | Yes, in a minor way (1) | More emphasis on analyses (4) |
| Significant to small (1) | One of several (3) | In a general way, yes (4) | Better structuring of problems (2) |
| Varies (1) | Vital (2) | Less than it should have (1) | Renovations in operating procedures (2) |
| Yes (2) | | Selecting and developing alternatives (1) | Identifying problems and developing options (1) |
| Gradually being recognized (1) | | Yes, has made decision makers aware of often neglected or unnoticed alternatives (2) | Better gathering and analysis of relevant data (1) |
| Yes, but slight to date (1) | | | |
| Small but some (2) | | | |
| Notable in some cases, less so in others (2) | | | |

N.B. Numbers in brackets are the numbers of the respective replies.

possible means for their improvement. The approaches reviewed include social indicators, operational research, futurism, system analysis, and policy science.

CHAPTER XII

FUTURE DEVELOPMENTS AND PROSPECTS

POSSIBLE DEVELOPMENTS

In discussing the future of OR in Canada and in what direction it might develop to be more useful to decision-makers and management, the following points were made during the panel discussion at the Annual CORS Meeting in Quebec City in May 1980: more emphasis on risk analysis; a method for tying together such diverse factors as industrial benefits, operational capability, and side-effects on the natural and social environments; ensuring that OR results get to the higher management levels and OR spokesmen are included in the decision-making; OR must infiltrate to decision-making levels and senior OR personnel should have management know-how and be in tune with local management styles which are changing.

At a meeting of the Ottawa Section of CORS in October 1980, a discussion was held on the topic 'whither OR today?' There was no consensus, some arguing that OR techniques are not diffusing and that OR staff should not be decentralized without, at least, a common core or holding unit. It was also argued that some characteristics other than knowledge of, and competence with, OR techniques should distinguish the OR practitioners.

A large number of middle and senior level management and executives were asked during interviews what ways OR should develop to be more meaningful and useful to senior executives and decision-makers. There was much similarity in their replies which can be summarized as follows:

- a. OR scientists should learn to speak the same language as managers, be more familiar with modern management style and thinking, and be in closer touch with management;
- b. They should develop improved measures of effectiveness that are quantitative, socially acceptable, and economically justified;
- c. They should develop a better understanding of how managers make decisions and be better able to take account of institutional and social aspects of decision-making rather than concentrate too much on OR technical and economic aspects of their work;
- d. They should improve explaining what they do, avoid technical jargon, and involve clients in studies to a greater degree;
- e. They need to know a lot more about the operations, industry, or business, and the structures of the organizations they are investigating;
- f. There should be much more emphasis on timeliness in reporting and completing studies;
- g. In general, OR should be more problem-oriented and less technique-oriented;
- h. Credibility in OR personnel and their work must be developed to a greater degree than is the case at present;
- i. OR staff should learn how to predict requirements for research and foresee the needs of the organizations they serve;

- j. They should see the 'big picture' and improve presentation methods;
- k. OR leaders should accept more responsibility for following up on OR findings and seeing that they are implemented;
- l. Practitioners of OR, at least in defence, should strive to keep in touch with the very broad spectrum of experimental scientists so that they can rally a broader team should the need arise;
- m. An interesting comment was that OR staff must be seen to be useful;
- n. Future developments in OR will depend to some extent on the state-of-the-art in various relevant fields;
- o. What OR does must be rigorous, practicable, and verifiable;
- p. The areas in which OR will be applied will broaden;
- q. There will be a need for OR to develop more capability in risk analysis and to improve the assessment of the downstream impact of decisions;
- r. OR should develop more readily used decision support systems;
- s. OR should get more involved in investigating the consequences of bad decisions;
- t. There is a requirement for OR staff to improve communications with those whose responsibility it is to implement their findings;

- u. OR programs should be developed for a year ahead or longer if possible;
- v. OR work should be directed more at decision makers;
- w. Should not try to 'sell' managers with mathematics.

It is not the intention of this report to assess or comment on these observations and suggestions. But they do warrant attention and consideration by both OR leaders and staff and the managers whom they serve. They represent a large number of ways in which the practice of OR may well be improved. Some will, of course, be more applicable in some cases than in others, but these points, along with those mentioned above, provide what may well be a very useful checklist.

A further comment is relevant here. In Ref.30, the remark is made that "It may also be the case that OR has been so widespread and so well established that most people either don't know they are doing OR, or don't care." If, indeed, this is the case, OR as a central service for decision makers may be on the wane. There is, however, not much evidence in the foregoing to support this possibility.

PROSPECTS

From preceding Chapters, it may be noted that there has been a general increase in the breadth and complexity of the problems undertaken by OR staff. This pattern may be expected to continue as well as the gradual expansion into new areas of application. One such development in the field of social services is described below (Chapter XIII), others

are program evaluation which is being increasingly practiced in various government and other agencies, and the areas mentioned in the following paragraphs.

In Ref.47, it is stated that "OR has not scored many successes in large problems of long range planning with social, psychological, or political content. It appears probable that this type of project will be undertaken by organizations working in system analysis and futures research, using interdisciplinary teams. For many studies, one of the necessary disciplines is likely to be OR." These remarks serve to support the observations made in the preceding paragraph.

Other areas wherein OR may expand in the near future include improvements in determining measures of effectiveness (Ref.42), criminal justice (Ref.43), banking operations (Refs. 44 and 45), and network analysis. There may also be advances in theory relating to OR perhaps mainly in the form of refinements to present theory such as queuing theory and the various types of programming. Apart from the World War II work in developing a theory of search (Ref.46), there has, to the author's knowledge, been no real OR theory developed by practising OR scientists directly for OR applications, other than such refinements as just noted and those cited in Chapter X.

During interviews and discussions, the question was asked: "Does your Company (ministry, department or agency) look for employees with OR or management science training or experience? The majority of replies was in the affirmative, several were affirmative but added that related training or experience in quantitative methods, finance, commerce, business administration, or engineering was normally required.

Other replies were 'not explicitly' but training or experience in allied areas was sought, and other replies were 'yes, occasionally', 'yes, we are moving in this direction', and 'yes, to a limited extent'. One reply was 'normally no, but possibly', depending on the perceived requirement. Thus, there is evidence that students trained in OR and OR-related subjects will continue to be sought after in the future.

The findings of this report indicate that there are some areas in Canadian business, commerce, industry, and government which have made very little or no use of OR and thereby suggest areas into which OR might be introduced with success. These include some provincial and regional, or civic, government departments and agencies, regional municipalities, such commercial enterprises as banking institutions, trust companies, insurance and finance companies, research foundations, and pharmaceutical and drug companies. Others appear to be publishing enterprises, retail food store chains, newspaper companies, wholesale tobacco companies, wholesale distributors, hospitals, some mining, engineering, truck, and air transport companies. Such companies, organizations, and operations that do not already use OR could, no doubt, benefit from doing so. There is also the possibility that OR techniques could and will be applied more widely in small businesses and industrial companies which may not care to have central OR teams, or OR-trained personnel doing OR only.

In view of the increasingly large number of university students taking OR and OR-related courses (Chapter IX), it is clear that there will be a large pool of personnel, academically trained to undertake OR and the application of management science and quantitative methods. There is

evidence of a growing awareness of the need for such skills by managers in all sectors of government, business, and industry. Coupled with the growing confidence in the usefulness of these attributes, it is perhaps not incautious to say that the prospects for OR-related activities in Canada are indeed bright.

CHAPTER XIII

DISCUSSION AND REMARKS

GENERAL

The difficulty in deciding whether or not OR is being employed arises mainly from the numerous and diverse methods and techniques that are normally associated with, or considered as coming under, the term OR. Included in the methodology of OR one usually thinks of both deterministic and stochastic models. The former may include linear programming, integer programming and combinatorics, graph theory, network flows, geometric programming, non-linear and large scale programming, and optimal control techniques. Stochastic modelling may include stochastic processes, queuing theory, value theory, decision analysis, game theory and gaming, search theory, simulation theory, action-simulation, and dynamic programming. On the other hand, OR techniques and tools are sometimes considered according to the type of process to which they are applicable. These classes of processes include inventory, allocation, waiting time, replacement, competitive, combined, and sequencing processes. It is, accordingly, evident that such OR techniques and processes may be used widely by research workers and engineers who do not claim to be OR workers or users of OR methodology. The range of these techniques and their growing application in many fields explains, in part at least, the tendency, already noted, to decentralize OR activities in some organizations. The range of OR techniques also serves to explain the use of the phrases "OR or OR-type" and "OR-related" in the above discussion work and courses of study.

ORGANIZATION OF OPERATIONAL RESEARCH

As mentioned earlier, there have been a number of cases in Canadian governments, businesses, and industries wherein centrally organized OR units have been disbanded and their staff reassigned to do OR and related work in branches, divisions, or directorates rather than as a central service. The reasons for doing so have varied and the question of the organization and use of OR warrants some comment.

In the course of conducting interviews and discussions, three questions, other than those already mentioned, were posed. The first of these was "For your company (ministry, department, agency) is a centralized OR service better than having OR staff members with OR capabilities in selected divisions, units, or branches?" The replies, not surprisingly, were divided between the two arrangements and a third which was a combination of centralized and decentralized. However, over 75% of the responses favored the central organization, about 5% the decentralized one, and 20% mentioned the combined arrangement. Some replies stated that the best organization for OR services depends on the purpose which the OR is intended to serve, others that it varies with the client organization's structure and function, and others that the central OR organizations is best only for large companies or ministries.

Among the arguments in favor of centralized OR services are: duplication of work and effort is avoided; cross-fertilization and the development of better expertise are possible; more supervision and better quality of work; a 'critical mass' of personnel and the team approach are required for effective OR; a small number of analysts tend to become too limited in outlook and skills; more objectivity is obtained; appropriate facilities are not usually available

to small OR units scattered throughout an organization; a central OR team is less affected by daily operations and routine problems; a central OR unit gets a better overall view of what an organization does and what its problems are; it is more disciplined and can be directed onto larger scale problems; it will have a broader approach and present a wider range of points of view concerning problems and how to attack them; the head of a central OR team has access to management at a more senior level than is the case for decentralized units; a central team will avoid 'blind spots'; a central organization for OR provides opportunities for staff rotation and better career prospects than does a decentralized one. It was also observed that a central OR team has a better chance of earning credibility and exerting some impact on high level decisions than have several small disparate units, and that decentralized OR units tend to lose their identity.

It may be noted that the OR organization in the Department of National Defence, the largest in Canada, and the one with the longest history, benefits from most of these characteristics. Although a highly central establishment at National Defence HQ, we have seen that it has small units at military commands, and at some foreign posts, and rotates staff among the many positions and units. It also reports at a high level and is staffed by both civilian scientists and qualified military officers.

Among the arguments for decentralized OR services were: a better understanding of operations is obtained by OR personnel; a central unit may not always be fully and usefully employed; resentment and impatience with technology at high levels are avoided; a centralized OR unit tends to get too remote from operational problems; some senior

managers (e.g. vice-presidents) like to have their own research staff whom they use and support rather than competing for the services of a central research staff.

IMPLEMENTING OPERATIONAL RESEARCH

The question of the responsibility of OR staff following up on the findings, conclusions, and recommendations of their studies was discussed with interviewees. The replies varied from the statement that once a study was completed and a report submitted to the tasking or requesting authority, no further action was required, to one claiming that if an OR finding was important and not being implemented, the OR leader should pursue the matter until appropriate action is taken. There is no apparent consensus on this matter but many OR people feel that too little action has been taken by OR workers in implementing the findings and conclusions of their work. On the other hand, one respondent said that if implementation is a problem, there must be something wrong with the tasking authority, the reporting or presentation by the OR staff, or with relations between the tasker and the OR unit.

OPERATIONAL RESEARCH AND SOCIAL SERVICES AND SCIENCES

In the foregoing, mention has been made of the use of OR in several government departments and ministries concerned with social services, i.e. the federal Departments of Health and Welfare, Manpower and Immigration, and Secretary of State, the PEI Department of Social Services, the NB Department of Health, the Ontario Ministry of Environment, and Community and Social Services, the Manitoba Department of Health and Community Services, the Department of Continuing Education in Saskatchewan, Alberta's Department of Education, and the BC Ministries of Education and Consumer and Corporate Affairs.

Also, OR techniques are used by the Social Services Department of Nova Scotia, by the Social Services Department of the City of Edmonton, and by the Personnel Department of the City of Brandon.

Interviews and discussions with representatives of these departments and ministries have provided ample evidence of the important role being played by OR in analyzing problems and affecting decisions in social service work and policy making in Canada. For example, one of the very successful undertakings involving OR by the PEI Department of Social Services has been the design, validating, and refining of a management information system.

The Directorate of Social and Economic Analysis of the Operational Research and Analysis Establishment of the Department of National Defence makes much use of OR techniques in the conduct of the research program. These include model construction, econometrics, regression analysis, and other statistical methods as well as much numerical common sense. To date, the Directors have had long successful careers in OR before becoming the Directors of Social and Economic Analysis.

As a more general comment, it may be noted that it has been said (Ref.48) the OR is, perhaps, the first attempt in the history of science to socialize scientific method on a planned and conscious basis. This reference adds that "the social implications of the methods of OR are of a vast and imposing nature."

While none of the Departments of Sociology in Canadian universities offer courses in OR as such, there is increasing emphasis in these departments on mathematics and quantitative analysis which are basic to OR. In graduate courses, particularly, this emphasis can be discerned. For example, a

textbook used in some graduate courses in sociology is called Mathematical Sociology (Ref.49) which includes such OR techniques as model building, basic measurement concepts, probabilistic methods, and theory of games, as well as other mathematical concepts and methods.

USEFULNESS OF THEORY AND JOURNALS

Among the questions raised during interviews and discussions was one concerning the usefulness of OR theory and articles in OR and management science professional journals. In this case, the question was discussed with senior OR analysts and a number of executives who have tasked OR staff. The responses can be put into two general classes: those that were favorable and those not favorable. The corresponding percentages were approximately 30% and 70%. At least just over 70% were dissatisfied with the journal articles and do not find them of much use to the OR practitioner. A very few of these, however, commented on the general need for theory without which new applications would suffer.

The negative responses, mostly relevant to the usefulness of current journal articles, varied from 'not useful at all' through 'very little' and 'occasionally some help', to 'too mathematical' and 'can't understand them'. Mention was also made of such features as they contain quite a bit of superfluous material, few important theoretical articles are written, more liaison between practitioners and researchers is required, articles are too erudite and many seem to be written because of the 'publish or perish' syndrome at universities. Favorable comments included: journal articles are of some help for scanning and literature search purposes; some of them have provided some basic ideas (e.g. articles

in Interfaces), the theory articles are good for developing concepts, they are useful to keep us aware of thinking and developments in the field, but often it is difficult to make practical applications.

Again, it may be noted that these reservations support, in general, those made earlier in Chapter IX. There is no doubt that there is considerable dissatisfaction about the relationship between theoreticians and practitioners in the OR field in Canada.

PERSONAL CONTRIBUTIONS

At the end of Chapter III, a short account is given of those who were most instrumental in reactivating OR in the military sphere after the end of World War II. Some of these also contributed heavily to the development of OR in Canada generally. Certainly, Drs. Solandt, Abrams, and Lindsey have done so. Dr. Solandt organized the OR group in the CNR, and was a founding father and past-president of the Canadian Operational Research Society (CORS). Dr. Abrams was also active in founding CORS and was its first vice-president. He has been prominent in OR in the military and with the Department of Industrial Engineering at the University of Toronto. Although Dr. Lindsey's career in OR has been entirely with the military, he has been president of CORS and influential in Canadian, NATO, and international OR fields.

Another scientist whose influence on OR in Canada has been very great was Peter J. Sandiford who introduced OR into the Ontario Hydro Commission, Price Waterhouse Associates, and Air Canada, and offered the first course in OR at the universities of Toronto and McGill; he was the first secretary of CORS. Others who have contributed much to OR in Canada are: Dr. A.E. Paull, who began OR work in the

Abitibi Paper Company, early 1950's and is now in the Department of Industrial Engineering at the University of Toronto; Peter B. Wilson in military and industrial OR and in CORS; C.E. Law in military, industrial, academic, and CORS work; K.J. Radford in CORS, and the military and academic fields. Indeed, all those mentioned above as original leaders and workers in OR deserve honorable mention as contributors to the introduction and development of OR in Canada.

Without going into further details, the following scientists are mentioned for their early, and in most cases continuing, contributions and support to OR in Canada: Dr. B. Bernholtz, R.F. Couch, D.J. Clough, Dr. J.G. Debanné, A.R. Demirdache, Dr. F.R. Denham, A.E.J. Ferrie, Prof. H.V. Fullerton, Dr. H.S. Gellman, John Gratwick, N.A. Grundy, Dr. Josef Kates, Prof. W.L. Price, J.E. Roberts, P.J. Robinson, W. Shelson, D.J. Steele, and J.R. Walter who, in addition to his OR work already noted above has done OR studies for the Canadian Medical Association, and the Canadian Hospital Association. There are many others who might be mentioned but the list would be quite extensive and most of them have already appeared in the foregoing or in Appendices C and D.

CHAPTER XIV

S U M M A R Y

GENERAL

We have seen from the foregoing that, after beginning in the Canadian Armed Forces in the early 1940's and a slow-down in the practice of OR in the Department of National Defence in the late 1940's, there was in the 1950's a gradual growth of OR in Canada in terms of OR units and applications. This moderate development was followed by a rapid expansion of OR in Canadian business, government, industry, and universities in the 1960-1970 period followed by a levelling off in the 1970's. In this process, OR has extended its applications into almost all aspects of business and industry while universities continue to expand their OR programs and courses and these are being introduced into the curricula of universities not previously offering them.

Reviewing across the regions, it is noted that the first use of OR in the Atlantic Provinces was at the Nova Scotia Research Foundation in February 1967, and that some two years later OR began in government departments--first in the Department of Health in New Brunswick. In the Central Provinces (outside of military applications) OR was being used in the Ontario Hydro Commission in the early 1950's and in Ontario government departments by 1965 (Environment). Based on the questionnaire returns, OR came late to Quebec, other than in Air Canada and the CNR, and is still not very widely practised or recognized in Quebec government ministries and agencies. In the Prairie Provinces, OR was being used by provincial agencies of Alberta in the early 1950's but not in provincial departments until 1963. On the other hand, OR was introduced into government departments and agencies of British Columbia in the 1950's. The preceding

findings also show that in Ontario and British Columbia, provincial government departments, ministries, and agencies adopted OR earlier and use it more widely than is the case in the other provinces.

It appears from the above that little OR work as such is being done in Newfoundland, Prince Edward Island, New Brunswick, and Saskatchewan, although some provincial government departments and agencies in these provinces do use OR as a recognized activity. Apparently, no OR is being used under that name in Yukon and Northwest Territories. However, in all of the provinces, university courses in OR and OR-related subjects are being offered.

Although some eighteen companies and government departments and agencies reported that they are planning to expand their OR facilities, the intention is far from being widespread. On the other hand, several universities are expanding their OR and OR-related (e.g. management science and quantitative methods) programs, and the number of enrolments in such courses is increasing. And the prospects for the use of OR in new areas and applications in Canada appear promising.

Three factors that should be influential in promoting a still wider use of OR are the growing respect and credibility of OR as an aid to decision making, the fact that OR personnel are joining the ranks of managers and decision makers, and the increasing enrolment in university courses in OR and management science. A further relevant influence that relates in some measure to all three of these factors is the growing complexity of problems confronting modern management in all spheres of activity. It is also clear from the preceding treatment that OR has proven to be quite

adaptable and capable of being applied to increasingly complex situations.

A further observation is that business, industry, and governments in Canada make frequent use of outside consultants who apply OR and management science techniques. The frequency and extent of their usage varies widely but appears to be on the increase.

There does not appear to be a high degree of correlation between the increasing numbers of students enrolled in OR and OR-related courses and programs in universities and the number of members in CORS, or doing OR work under that label in business, industry, and governments. This phenomenon is no doubt related to the development mentioned earlier concerning the organization and use of OR.

There is some evidence and expression of opinion that consideration should be given to bringing the theorists and practitioners in OR in Canada into closer accord and communication. Such a development should be mutually beneficial.

SUMMARY OF EARLY USES OF OPERATIONAL RESEARCH

For purposes of summarizing and ready reference, the dates of the first reported use of OR in Canadian governments and business and industry are presented in Tables XXXVIII and XXXIX respectively. Similar data for the introduction of courses in OR for universities and colleges are presented in Table XL.

TABLE XXXVIIIDATES OF FIRST USE OF OPERATIONAL RESEARCH

(Canadian Government Departments and Agencies)

| | Department or Element | Date |
|--|---|------------|
| <u>FEDERAL GOVERNMENT:</u> | | |
| Dept. of National Defence | Air Force | Sept. 1942 |
| | Navy | July 1943 |
| | Army | Nov. 1943 |
| Post WW II Dept. of National Defence | Air Force | Nov. 1948 |
| | Defence Research Board | Jan. 1949 |
| | Navy | Mar. 1949 |
| | Army | Jan. 1950 |
| Air Canada | -- | 1956 |
| CNR | -- | 1957 |
| <u>PROVINCIAL GOVERNMENTS:</u> | | |
| Newfoundland | Newfoundland Hydro | June 1971 |
| Prince Edward Island | Department of Education | 1970 |
| Nova Scotia | NS Research Foundation | Feb. 1967 |
| New Brunswick | Department of Health | Apr. 1969 |
| Quebec | Hydro-Quebec | 1970 |
| | Energie et Ressources | 1975 |
| Ontario | Ontario Hydro | Sept. 1955 |
| | Dept. of the Environment | 1965 |
| Manitoba | Health & Community Services | May 1972 |
| Saskatchewan | Sask. Wheat Pool | 1962 |
| Alberta | Energy Resources Conservation Board | May 1952 |
| | Petroleum & Natural Gas Conservation Board | 1956 |
| | Dept. of Housing & Public Works | Early 1970 |
| | Dept. of Agriculture | Apr. 1950 |
| British Columbia | BC Research | Mar. 1970 |
| <u>CIVIC GOVERNMENTS</u> | | |
| Edmonton | Water & Sanitation Dept. | Early 1960 |
| | Finance Department | 1965 |
| Vancouver | Engineering Department | 1962 |
| Toronto | Services Department | July 1965 |

TABLE XXXIX

DATES OF FIRST USE OF OPERATIONAL RESEARCH
(Canadian Business, Commerce, and Industry)

| <u>Type & Name of Company</u> | <u>Location</u> | <u>Date</u> |
|--|-----------------|---------------------|
| <u>BANK</u> | | |
| Imperial Bank of Commerce | Toronto | Dec. 1969 |
| <u>INSURANCE</u> | | |
| | | (No data available) |
| <u>TRUST</u> | | |
| Canada Trust | Toronto | June 1976 |
| <u>CONSULTING</u> | | |
| Adalia | Toronto | 1954 |
| Price Waterhouse | Montreal | 1954 |
| Josef Kates | Toronto | 1954 |
| H.S. Gellman | Toronto | 1956 |
| <u>INDUSTRIAL & COMMERCIAL</u> | | |
| British American Oil | Toronto | 1953 |
| Steel Co. of Canada | Hamilton | 1953 |
| Abitibi Paper | Toronto | 1955 |
| Imperial Oil | Toronto | 1955 |
| COMINCO | Trail | 1961 |
| Canadian Industries Ltd. | Montreal | 1962 |
| Canadair | Montreal | 1963 |
| Saskatchewan Federated Cooperatives ¹ | Saskatoon | Jan. 1965 |
| MacMillan Bloedel | Vancouver | 1966 |
| Husky Oil | Calgary | 1968 |
| National Sea Products Ltd. | Halifax | Apr. 1971 |

¹Included here for time-comparative purposes.

TABLE XL

DATES OF FIRST INTRODUCTION OF OPERATIONAL RESEARCH COURSES
IN CANADIAN UNIVERSITIES AND COLLEGES, BY PROVINCES

| <u>PROVINCE</u> | <u>UNIVERSITY or COLLEGE</u> | <u>DATE</u> |
|-----------------------------|--|--|
| <u>Newfoundland</u> | Memorial | 1968/69 |
| <u>Prince Edward Island</u> | Prince Edward Island | 1974/75 |
| <u>Nova Scotia</u> | Nova Scotia Technical College Dalhousie | 1965/66 1967/68 |
| <u>New Brunswick</u> | New Brunswick | 1968/69 |
| <u>Québec</u> | Ecole des Hautes Etudes Commerciales McGill Laval | 1960/61 1961/62 1962/63 |
| <u>Ontario</u> | Toronto Ottawa Queen's McMaster | 1955/56 1959/60 1960/61 1960/61 |
| <u>Manitoba</u> | Manitoba | 1969/70 |
| <u>Saskatchewan</u> | Saskatchewan Regina | 1961/62 1967/68 |
| <u>Alberta</u> | Southern Alberta Institute of Technology Alberta | 1967/68 1968/69 |
| <u>British Columbia</u> | British Columbia Victoria | 1967/68 1968/69 |

N.B.: Some of the original courses were one semester or night courses, e.g. the first one at Toronto was scheduled for autumn 1955 but was given in early 1956.

CONCLUDING COMMENTS

While many suggestions concerning ways in which OR in Canada could become more useful and meaningful to managers and decision makers have been mentioned, it should also be noted that there appear to be many opportunities for the further development and expansion of OR in direction, new areas of application, and in regions of the country where OR has still not been introduced to any great extent. Conditions seem to be favorable for continued growth of OR with such positive relevant factors as those cited in Chapter IV still obtaining, a supportive professional society, the increasing training in OR and related subjects in universities, the growing credibility of OR in all areas of application, and the intensifying complexity of modern managerial problems. It is pertinent to note (Ref.50) that the Science Council of Canada thinks that "among the root causes of our economic crisis is that managerial, scientific, and technical skills are not being applied to goods production at the same rate as in the countries of our competitors." OR has demonstrated that it can make very valuable contributions to overcoming such shortcomings in the industrial world and to improving decision making in industrial and other areas of application.

As the old proverb says, forecasting is a very difficult procedure, particularly insofar as it applies to the future, but it may not be injudicious to say that, on the basis of this review, OR would appear to have a promising future in Canada. Accordingly, the title of this report might better have been the one originally chosen--The Origins and Early Development of Operational Research in Canada.

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APPENDIX A

DATA SOURCES AND QUESTIONNAIRES

The purpose of this Appendix is to identify data sources and exhibit the questionnaires used to obtain inputs for the report. Many of the sources of input are given in the list of References provided in the report. Other sources include selected volumes of the Journal of the Operations Research Society of America, the Canadian Journal of Operational Research, and INFOR (the Canadian Journal of Operational Research and Information Processing). To a lesser extent use was made of UK publication the Operational Research Quarterly and Interfaces, a TIMS-ORSA Journal. Other sources were Operations Research in Canada 1963 a publication of the School of Business Administration, University of Western Ontario and several of the Proceedings of Annual Conferences of the Canadian Operational Research Society, the first of which was issued in May 1959, and Proceedings of the International Conference on Operational Research, the first of which was published in December 1957.

In addition to completing and returning questionnaires many responding agencies forwarded covering letters with relevant information that was useful in preparing this document. As well, a large number of persons both users and practitioners of OR provided valuable inputs by means of private correspondence. These have been acknowledged earlier in this report.

Useful information was also obtained at a panel discussion during the 22nd Annual Conference of the Canadian

Operational Research Society in Quebec City, 20-22 May 1980.

The questions were:

- a. What factors have been most influential in the development and growth of OR in Canada?
- b. What impact has OR had on decision making in Canadian government, business, and industry?
- c. In what direction is OR in Canada going now, and in what direction should it develop to be more beneficial to Canadian managers and decision makers?

Panelists were: Professors M. Oral and W.L. Price of Laval University, Brigadier General R.D. Manson, Canadian Armed Forces, Dr. J.J. Conn of ORAE, and Mr. L.E. Parker of TEE Consulting Services, Ottawa. Their contributions have been incorporated in the text. Other sources were personal interviews, discussions, and phone calls.

Use was also made of the Canadian Key Business Directory 1979 (Dun & Bradstreet Canada Ltd.), the 1979 Corpus Almanac of Canada (CORPUS Publishing Services Ltd.), the Directory of Canadian Universities and Colleges (Association of Universities and Colleges of Canada), and the Directory of Associations of Canada. These publications provided names, addresses and other relevant information helpful in selecting addresses.

The main source of information was the questionnaires. Three of these were used: one for federal and provincial governments and agencies; one for business, commerce, and industry, and one for universities and colleges. The first of these was also used for civic, municipal, and regional governments, and the second for consulting firms, research institutes, and councils as well as for business and industrial companies. In most cases, with follow-up action where deemed advisable or necessary, response was quite good.

Questionnaires in French were used for government departments, most business and industrial companies, and educational institutions in Quebec, and wherever else seemed appropriate.

Copies of the questionnaires and covering letters are included in this Appendix for information and reference purposes. These are presented here in English only, although, as mentioned, a French version was used for Francophone addressees.

Dear Sir:

The Social Sciences and Humanities Research Council of Canada has awarded me a small grant to prepare a report on the origins and development of operational research in Canada. It is my intention to gather the necessary material from available literature, interviews, and questionnaires.

In the case of federal and provincial government departments the questions that I would like to have answered are set forth in the enclosed questionnaire. I shall be very grateful if arrangements can be made to have the questionnaire completed and returned to me. It is realized that some federal departments have provided me with similar information several months ago for a short paper I was writing then. The forthcoming report will be more comprehensive than the earlier paper, and I trust that this request will meet with your cooperation.

In addressing these questions it is suggested that the term 'operational research' be interpreted as including OR and such related activities as systems analysis, cost-effectiveness or cost-benefit analyses, and similar quantitative methods and techniques. However the main concern is with OR and related research work done by units or teams specifically organized to provide quantitative inputs to decision makers, and whose members are engaged in OR on a full-time basis or as their major activity.

Any help that you may be able to give me in this regard will be greatly appreciated. It may be convenient, in some cases, to let me have the name and phone number of a suitable staff member or members whom I could interview as convenient.

Your cooperation will be very helpful and I shall be much obliged for it. Thank you.

Yours sincerely,

QUESTIONNAIRE ON OPERATIONAL RESEARCH
FEDERAL AND PROVINCIAL GOVERNMENT
DEPARTMENTS OR AGENCIES

(Please use the reverse side of this form or extra sheets if additional space is required for relevant or explanatory information)

1. When was Operational Research (OR) as a recognized activity first practiced in your Department (or its predecessor)?

Year _____ Month _____

2. Was OR first used by a team or unit organized to do OR, or by individuals on a part-time basis? Please check.

By a team or unit _____

Individuals part-time _____

3. Was OR originally, or ever, set up to become by a central team or unit to serve several Branches, Divisions or elements of the Department?

Originally Yes _____ No _____

Later Yes _____ No _____

If later, when? Year _____ Month _____

4. Who was instrumental in getting OR work started in the Department?

Name _____ Appointment _____

5. Who was the first head or leader of an OR unit in the Department and to whom did he report?

Name of first leader _____

.../

Official to whom he reported: Name _____
Appointment _____

6. Who were the first OR workers in the first OR unit?

Names _____

7. What types of problems were first undertaken?

8. If more than one OR team was set up in the Department, please answer the following questions:

| <u>Name of Unit</u> | <u>When formed</u> | |
|---------------------|--------------------|-------------|
| Unit 1 _____ | Year _____ | Month _____ |
| Unit 2 _____ | Year _____ | Month _____ |
| Unit 3 _____ | Year _____ | Month _____ |

Types of problems undertaken:

Unit 1 _____

Unit 2 _____

.../

Unit 3 _____

9. How many OR staff members are presently employed in your Department and what types of problems are they analyzing?

Number: _____

Types of problems: _____

To whom do they report?

Name _____

Appointment _____

10. Has your department made use of outside consultants or management firms to conduct OR studies?

Yes _____ No _____

11. If yes to Question 10, how many OR studies have been so conducted in the past 5 years?

Number _____

Types of problems done by consultants _____

12. If your Department does NOT have an OR unit or team are such OR devices as model construction, inventory models, linear programming, queuing theory, replacement models, or game theory used in departmental studies?

Yes _____ No _____

If Yes which ones _____

Dear Sir:

The Social Sciences and Humanities Research Council of Canada has given me a small grant to prepare a report on the origins and development of operational research (OR) in Canada. My intention is to gather the necessary material from available literature, interviews, and questionnaires.

The questions about OR in your business or organization which I would like to have answered are set forth in the enclosed questionnaire. I shall be very grateful if arrangements can be made to have the questionnaire completed and returned to me.

It is realized that some of the companies that are being asked to provide information on OR have already replied to earlier requests for similar information by myself and other researchers. But I believe that some of the questions now being submitted differ from earlier ones and that others are original ones. Accordingly, it is hoped that your cooperation in this matter will be forthcoming. It will be greatly appreciated. Thank you.

Yours sincerely,

QUESTIONNAIRE

Operational Research in Canada

(Please use the reverse of this form or extra sheets of paper if additional space is required)

1. Is there an Operational Research department, division, branch or unit in your company or organization?

Yes _____ No _____

2. If there is, or was, when was the Operational Research unit started?

Month _____ Year _____

3. Who was responsible for starting the original Operational Research unit?

What was his official appointment?

4. Who were the first Operational Research analysts in your organization?

5. Who is the present head of Operational Research activities in your organization?

6. What is the title of the person to whom he reports?

.../

7. How many people in your organization now spend the most of their time (over two thirds) on Operational Research?

8. Has your organization used outside Operational Research consultants?

9. What were the names of the first two or three studies undertaken by the original Operational Research unit?

10. What types of studies are presently under investigation by your Operational Reserach Staff or by Operational Research consultants? Please specify which:

11. Does your organization plan on expanding the Operational Research?

Yes _____ No _____

.../

12. If your organization has had an Operational Research unit but has disbanded it, please state the reasons for doing so.

13. If your company or organization does not have an OR unit or team are such OR devices as model construction, inventory or replacement models, linear programming, queuing theory, or game theory used in projects and studies undertaken by your company?

Yes _____ No _____

Dear Sir:

The Social Sciences and Humanities Research Council of Canada has awarded me a small grant to prepare a report on the origins and developments of operational research (OR) in Canada. My intention is to gather the necessary material from available literature, interviews, and questionnaires.

The questions about OR in your institution which I would like to have answered are set forth in the enclosed questionnaire. I shall be very grateful if arrangements can be made to have the questionnaire completed and returned to me.

In some institutions OR courses may be offered in more than one faculty or department. In such cases please request the departments concerned to submit separate replies. Extra copies of the questionnaire are included for that purpose.

Some staff members of some Canadian institutions have already been approached for similar information about OR courses for a short paper that I wrote last spring. The report now under preparation will be more comprehensive than that paper and I trust that this more extensive request will meet with the cooperation of your institution. It will be greatly appreciated. Thank you.

Yours sincerely,

QUESTIONNAIRE FOR CANADIAN
UNIVERSITIES AND COLLEGES

OPERATIONAL RESEARCH IN CANADA

(Please use the reverse of this form or extra sheets of paper if additional space is required for relevant information)

1. Does your institution (university or college) offer course(s) in operational research (OR) under that name or as quantitative analysis, or as part of a program in Business Administration, Management Science, or Industrial Engineering? Yes _____ No _____

2. If yes, when was the first course in operational research given either under that name or as part of what program?

OR-Academic Year _____ Other Program (please specify _____)

Academic Year _____

3. What was the name of the first lecturer(s) or professor(s) giving the first OR or related course and in which Department or Faculty?

Course title _____

Lecturer(s) or Professor(s) _____

Department _____

4. When were OR courses first offered in other Departments?

Department _____ Year _____

_____ Year _____

_____ Year _____

5. What degrees, if any, are offered now in OR or OR-related programs? _____

6. Is an interdepartmental degree or program in OR offered?
Yes _____ No _____

7. If yes, what Departments or Faculties are involved? _____

8. How many courses in OR as such are now offered? _____

9. How many of the OR courses referred to in Item 8 are:

Undergraduate _____

Graduate _____

Non-credit _____

Summer _____

Evening or Extension _____

10. Are any changes planned in the number or level of OR Courses?

Yes _____ No _____

11. If yes (Item 10) please give details: _____

12. How many students enrolled in the first OR courses given by your institution?

Department _____

Number of students _____

13. What was the latest (1979/80) enrolment in OR courses?

APPENDIX B

LIST OF EARLY CANADIAN MILITARY OPERATIONAL RESEARCH
PUBLICATIONS

INTRODUCTION

The purpose of this Appendix is to provide listings of the titles of early publications by the original OR units in the Canadian Armed Forces during WWII. The order of presentation follows that used in the main text in describing the WWII activities. Further details about these publications are given in Ref. 10 and Ref. 11, Vol. II. the listings presented herein are not necessarily complete.

REPORTS BY THE OPERATIONAL RESEARCH SECTION OF EASTERN AIR
COMMAND

No. of
Report

Title

Date

ORS/EAC

| | | |
|---|--|---------------|
| 1 | Attacks on Submarines: Relation of Tactics to Bombing Accuracy | May 8, 1943 |
| 2 | Attacks on U-Boats: October 1, 1941 to June 30, 1943 | July 21, 1943 |

| <u>No. of Report</u> | <u>Title</u> | <u>Date</u> |
|----------------------|---|------------------|
| <u>ORS/EAC</u> | | |
| 3 | Attacks on U-boats: October 1, 1941 to December 21, 1943 | January 15, 1944 |
| 4 | Analysis of Airborne RDF Log Sheets: November, 1943 to February, 1944 | March 15, 1944 |
| 5 | The Meeting of Shipping by Aircraft of Eastern Air Command, with special reference to the use of Procedure B. | April 20, 1944 |
| 6 | Report on Procedure B: March to May, 1944 | July 7, 1944 |
| 7 | Analysis of Airborne Radar Log Sheets: March to June, 1944 | August 5, 1944 |
| 8 | Report on Accidents to BR* Aircraft of Eastern Air Command: January, 1943, to May 1944 | August 18, 1944 |
| 9 | Six-month Summary of Eastern Air Command BR Operations: January to June, 1944 | October 28, 1944 |

*Bomber Reconnaissance

| <u>No. of Report</u> | <u>Title</u> | <u>Date</u> |
|----------------------|---|--------------------|
| <u>ORS/EAC</u> | | |
| 10 | Operation "Salmon": March 18-19, 1944 | May 10, 1944 |
| 11(a) | Operation "Perch" | August 26, 1944 |
| 11(b) | 11 (a) Phases I, II August 6-13, 1944, 11 (b) Phases III, IV, August 15-28, 1944 | September 9, 1944 |
| 12 | Operation "Salmon": September 8-9, 1944 | September 26, 1944 |
| 13 | Air-Sea Rescue Procedure | February, 1944 |
| 14 | Utilization of Aircraft | November, 1943 |
| 15 | Searches for Missing Aircraft (Revision of ORS/EAC Report No. 13, Air-Sea Rescue Procedure) | February 7, 1945 |
| 16 | Three-Dimensional Model for Tactical Analysis and Demonstration of Aircraft Patrols | February 28, 1945 |

| <u>No. of</u> <u>Report</u> | <u>Title</u> | <u>Date</u> |
|--------------------------------|--|----------------|
| <u>ORS/EAC</u> | | |
| 17 | Six-month Summary of BR Operations in EAC July-December 1944 | March 26, 1945 |

REPORTS BY THE OPERATIONAL RESEARCH SECTION OF WESTERN AIR
COMMAND

| <u>REPORT</u> <u>NUMBER</u> | <u>TITLE</u> | <u>DATE</u> |
|--------------------------------|--|-----------------------|
| 1. | Results and Reports on Examinations held by Second Aircrew Assessment Board. | April 1943 |
| 2. | Report on Preliminary Bombing Test - 120 BR Sqn. | |
| 3. | Attack on Submersible Target (French Float) with Radar Approach. | |
| 4. | Results and Report on Examinations held by Third Aircrew Assessment Board. | September 1943 |
| 5. | Operational Flying Statistics. Six Month Summary | June-November 1943 |
| 6. | Cumulative Record of Search for Missing BR Aircraft. | |
| 7. | Analysis of flying effort by BR Squadrons in WAC*. | |

*Western Air Command

| REPORT NUMBER | TITLE | DATE |
|------------------|--|---------------------------------|
| 8. | Report on Investigation into Broadcast Interference | 8 January 1944 |
| 9. | The Role of Operational Research in Aircrew Assessment at WAC. | |
| 10. | Abnormal Propagation in WAC. | May - June 1944 |
| 11. | Operational Flying Statistics - Six Month Summary. | December 1943 - May 1944 |
| 12. | Analysis of Airborne Radar Logs. | June to September 1944 |
| 13. | Operational Flying Statistics- Six Month Summary. | June to November 1944 |
| 14. | Reserved. | |
| 15. | Navigation Errors in WAC. | |
| 16. | Analysis of Airborne Radar Logs II. | October 1944 to January 1945 |
| 17. | Simulation of Bombing by Photography. | |

REPORTS BY ROYAL CANADIAN NAVY OPERATIONAL RESEARCH STAFF

Air coverage of the Entrance of the Gulf of St. Lawrence

Summary of the Acoustic Torpedo and Its Uses

Preliminary Estimate of the Relative Numbers of Escort Carriers and Land-Based VLR A/C Required to Cover 14.5 N. Atlantic Convoys per Month

Comments on Admiralty's Signal 272125A (Nov.) re "Appreciation of the Present Trend of the U/B War"

Report on the Conversation with Lt-Colonel Marsden, C.B., MC., Director of Scientific Research for New Zealand

Operaton "SALMON"

Notes on Present U/B Situation

Resumé of Recent Comparisons of Shipborne A/S Weapons

Probability of U/B Attacks on Unescorted Ships - A Special Case

Probable Operational Returns of an R.C.N. Squid Installation Program

Effectiveness of Convoy Radar Screens

The Canadian Bearing Deviation Indicator (B.D.I.)

An Anti-U-Boat Barrier in Cabot Strait

The Value of Mid-Ocean Escort Vessels in Saving Merchant Shipping in N. Atlantic Convoy Routs

An Estimation of Canada's Post-War Naval Expenditure

Effectiveness of Ahead-Thrown Charges Against Fast U/B's

Estimated H.E. Ranges of Asdic Set on Mark XXI U/B's

Escorting of Convoys in Area Partolled by Fast U/B's

A Nomograph on Sono-Buoys

Anti-U Boat Operations of the Royal Canadian Navy (1940-44)

Provisional Standing War Orders of the U-Boat High Command No. 172.

Comments Upon U-Boat Operations off Halifax as Described by Personnel from the Surrendered U-Boats U-190 and U-889

The Employment of Bow Overlap in Poor Asdic Conditions

Comparison of A/S Hunts in Canadian and British Waters

Proposed Organization of Scientific Research in the R.C.N.

Anti-U-boat Operations of the Royal Canadian Navy (1940-1945)

MEMORANDA BY ROYAL CANADIAN NAVY OPERATIONAL RESEARCH STAFF

Preliminary Discussions on Hunting Fast U-boats

Expendable Noisemakers

Stationing of Escorts

Degree of Roll Compensation Required on H/H Mountings

Report on Recent Enemy Mines

Asdic Ranges in the Canadian Coastal Zone

Lethal Probabilities for Rocket Propelled Hedgehog
Projectiles

A/S Operations of U.S.N. CVE's

Estimation of Speed Made Good By Mark XXI U-boats with
Schnorkel

Possible Speed and Endurance of Stream-lined U-boats

Possible Employment of a MAC Ship With an Anti-U-boat Search
Force

Stationing of Escorts in Convoy ONF 252

Memorandum on outward Spiral A/S Search

Spacing between Ships in A Gamma Search

Surface Damaging Probabilities of Stream-Lined D/C Patterns

Tables for Obtaining Time to Drop D/C's on Echo-Sounder
Contacts

Hunting U-boats in Coastal Areas - A Special Case

Infra-Red Detection of Schnorkel

Policy re Fitting of CAT Gear in Certain Ships on Regular
Coastal runs which have speeds greater than 10 knots and less
than 20 knots

Bearing Deviation Indicator, Model X-2

High speed U-boat (Mk. XXI)

Ranges Obtainable by Directional Sonobuoys

Canadian Coastal Convoys

Post-War Research in the R.C.N.

The use of Sonobuoys by aircraft

"CHEATER"

The Interception of U-boats on transit to the Canadian
Coastal Zone

Boundaries of Regions of Submerged Approach for Type
XXI-U-boats

Streaming of Cat Gear by Destroyers Escorting Monsters

Sector Retiring Search

Losses of Cruisers & Aircraft-Carriers During the First Four
years of War

Tow Length of Cat Gear

Addition of Asdic Set Type of 147B to Corvettes

A Review of the Present Status of Schnorkel Detection, April
1945

Evolution of CIC

Reasons for U-Boat Surfacing Following D/C Attacks

Analysis of a U.S.N. A/S Search

Preliminary Report of U-889

Notes on A/S Problems in the Pacific

Post-War Naval Research

Dr. Walter and Walter Works at Kiel

Japanese Submarines of Less than 500 tons

Notes on Suicide Air Attacks and A/S Convoy Protection

Suicide Attacks on Naval Units by Japanese Aircraft

Japanese Submarines and A/S Warfare in the Pacific

An Investigation into the Arc of Asdic Sweep.

An Analysis of Otter Operations

Convoys and Weather.

Analysis of Operation "Leech".

Analysis of Naval Operations in the St. Lawrence River and Gulf of St. Lawrence.

Local Convoys and the Present U-boat Situation.

The High Speed (MK. XXI) U-boat.

Analysis of Attack upon Convoy B.X. 141.

Analysis of Operations Resulting from Torpedoing of H.M.C.S. "CLAYOQUOT".

Naval Escort Requirements for the Protection of North Atlantic Convoys.

U-boat Contacts off Halifax, February 11-18, 1945.

CANADIAN ARMY OPERATIONAL RESEARCH GROUP REPORTS

- 6387 Project K15 - Selection Test,
Signals, Trades (Preliminary
Studies)
- 6388 General - Report on Attachment
to Allied Land Forces South
East Asia (ALFSEA)
- 6389 Relative Calculated 23 Feb 44
#1 Effectiveness Cdn 20 mm Quad
AA Guns and Other Equipments,
R.W. McKay, J.S. Vigder,
- 6390 Blast Measurements for 15 Mar 44
#2 Anti-Tank Mine Clearance,
R.W. McKay, H.H. Clayton.
- 6391 Comparative Lethality of HE
#3 and CW, R.W. McKay,
- 6392 Use of Tump Line for Mar 44
#4 Transporting Military
Equipment, R.W. McKay for
D.C. Rose,
- 6393 Blast Measurements for 2 June 44
#5 Anti-Tank Mine Clearance,
R.W. McKay, H.H. Clayton,

| | | |
|-------------|--|------------|
| 6394 #6 | Interrelations of the Selection and Training Procedures of Tank Gunners, D.C. Rose, | 20 June 44 |
| 6395 #7 | Waterproof Map, C.D. Niven | 18 July 44 |
| 6396 #8 | Field Examination of Ground Targets and Projectiles with Experimental K-Band Radar Sets, J.T. Wilson, | 12 Aug 44 |
| 6397 #9 | Fragmentation Data for Surgeons, D.C. Rose, With Appendices dated 1 May 1945, | 12 Aug 44 |
| 6398 #10 | Visibility of Blackened .303 Cartridge Cases, R.W. McKay, H.H. Clayton, | 6 Sept 44 |
| 6399 #11 | Rifle Sights for Poor Light, D.C. Rose, C.H. Charlewood, | 14 Aug 44 |
| 6400 #12 | Film and Research TEWT CH and HE, C. Sanford, | 20 Aug 44 |
| 6401 #13 | Wireless Direction Keeping R.W. McKay, | 9 Sept 44 |
| 6402 #14 | Smoke Fog Trials, S.A. Simmons, T. Verschoyle, | |

| | | |
|-------------|---|-----------|
| 6403 #15 | Smoke Fog Trials, R.W. McKay, | 3 Oct 44 |
| 6404 #16 | Value of .22 Calibre Rifle in Training, K.C. Fisher, | 23 Oct 44 |
| 6405 #17 | Cross Bow and Big Ben, D.C. Rose, | 7 Nov 44 |
| 6406 #18 | Summer Storm Echoes on Radar N.E.Wl, J.S. Marshall, R.C. Langille, W.M. Palmer, | 28 Nov 44 |
| 6407 #19 | Training the Manipulation of the Tank Gun Controls, K.C. Fisher, | 29 Nov 44 |
| 6408 #20 | Analysis of the Field Service Questionnaires, J.T. Wilson | 21 Feb 45 |
| 6409 #21 | Insect Repellant Trials, D.C. Rose | 6 Dec 44 |
| 6410 #22 | Visibility of Signals Panels from Aircraft, R.W. McKay | 27 Feb 45 |
| 6411 #23 | Analysis of Field Service Questionnaires, D.C. Rose | 26 Mar 45 |
| 6412 #24 | Probable Errors in Predicted Fire, D.C. Rose | 27 Apr 45 |

| | | |
|-------------|---|------------|
| 6413 #25 | Exercise Lemming, J.T. Wilson | 24 May 45 |
| 6414 #26 | S-Band Radar - Echoes from Snow, R.C. Langille, W.M. Palmer, L.G. Tibbles | 14 June 45 |
| 6415 #27 | Number and Distribution of Japanese Balloons, R.W. McKay | 16 May 45 |
| 6416 #28 | Exercise "Polar Bear" J.T. Wilson | 15 July 45 |
| 6417 #29 | A New Method of Teaching 1A on the .30 Browning, R.W. McKay | |
| 6418 #30 | Analysis of Storm Echoes in Height Using MHF Equipment, J.S. Marshall | 25 June 45 |
| 6419 #31 | Analysis of Field Service Questionnaires, J.T. Wilson | 17 July 45 |
| 6420 #32 | CODENT, Signal Training Selection Test, J.E. Morsh, | Sept 45 |
| 6421 #33 | Theory of Accuracy Test by Double Theodolite Fixes, G.R. Lindsey, J.S. Marshall | 12 Sept 45 |
| 6422 #34 | Accuracy of Wind Measurements by Radar AA No. 3 MK .1, R.W. McKay, G.R. Lindsey | 19 Sept 45 |

| | | |
|-------------|---|------------|
| 6423 #35 | Vimy Adaptation of the Code Voice Method of Morse INSTRUCTION, J.E. Morsh | 19 Sept 45 |
| 6424 #36 | Retention of Training by Morse Operators, J.E. Morsh | 19 Sept 45 |
| 6425 #37 | Retention of the QF 6 Pdr. and 17 Pdr. Anti-Tank Gun Drills, R.W. McKay | 31 Oct 45 |
| 6426 #38 | Gun Drills for the QF 6 Pdr. and 7 Cwt. Anti-Tank Gun, R.W. McKay | 31 Oct 45 |
| 6427 #39 | Morse Operating Achievement Test, J.E. Morsh | 8 Nov 45 |
| 6428 #40 | Radar Weather Messages, W.M. Palmer | 19 Nov 45 |
| 6429 #41 | Written Test for Tank Gunner, K.C. Fisher | 4 Dec 45 |
| 6430 #42 | "Bright Bank" Storm Echoes, L.E. Eon | 19 Nov 45 |
| 6431 #43 | Film and Tech Memo #3 - The Interrelation of Soil Mechanics and the Design and the Design and Operation of Vehicles, J. Kastner | Nov 45 |
| 6432 #44 | Morse - Speed and Spacing, J.E. Morsh | Feb 46 |

CANADIAN ARMY OPERATIONAL RESEARCH GROUP MEMORANDA

Memo.

| <u>No.</u> | <u>Title</u> | <u>Date of Issue</u> |
|------------|---|----------------------|
| No. F-9 | Time and Motion Study of the Army's Part of the AA Control and Reporting System | |
| No. 1 | Aerial Ropeways, R.H. Self | 25 Apr 44 |
| No. 2 | Scientific Research and Snow Camouflage, C.D. Niven | 24 Apr 44 |
| No. 3 | Tin Pest, C.D. Niven | 17 May 44 |
| No. 4 | Problem of the Japanese Bunker, J.S. Marshall | 5 June 44 |
| No. 5 | Design of Military Sleighs, J.T. Wilson | 14 June 44 |
| No. 6 | Reproduction of Accurate Relief Maps, R.H. Self | 30 June 44 |
| No. 7 | Sensitivity of Magnetic Airborne Detectors Against Tanks, J.D. Barber | 23 Aug 44 |
| No. 8 | Camouflage Signal Cable, C. Sanford, R.H. Self | 21 Sept 44 |

Memo.

| <u>No.</u> | <u>Title</u> | <u>Date of Issue</u> |
|------------|--|----------------------|
| No. 10 | Visual Preception Test and Accuracy of Anti-Tank Gunners, K.C. Fisher | 5 Nov 44 |
| No. 11 | Safe Thickness of Ice for Transport, J. Kastner | 2 Nov 44 |
| No. 12 | Text, Disinfestation Vault RSD - Ottawa | 30 Nov 44 |
| No. 13 | Mould Growth on Map Paper, W.C. Woods | 2 Dec 44 |
| No. 14 | Factors Predicting Success in CAC Operators Course, K.C. Fisher | 14 Dec 44 |
| No. 15 | Night Cable Drill, J.E. Morsh | 9 Jan 45 |
| No. 16 | Use of Synthetic Motion Pictures to Develop Radar Observing Technique, J.S. McBride | |
| No. 17 | Scores in Application Shoots During Training of Tank Gunners, K.C. Fisher | 24 Jan 45 |

| Memo. | <u>No.</u> | <u>Title</u> | <u>Date of Issue</u> |
|-------|------------|---|----------------------|
| | No. 18 | Ability of Newly Qualified Tank Gunners, K.C. Fisher | 26 Jan 45 |
| | No. 19 | Balloon Incidents Sask. and NWT Pt. 1 and Summaries 1-13 Pt. 2, Pt. 3, and Pt. 4, R.W. McKay | |
| | No. 20 | Mobility Over Snow and Ice, J. Kastner, R.H. Self | 23 Feb 45 |
| | No. 21 | Trainer for the Elimination of Backlash Use of Instruments and Carrying out Fire Orders | 17 May 45 |
| | No. 22 | Visit of Professor K.C. Fisher to UK, K.C. Fisher | 31 July 45 |
| | No. 23 | Waterproof Maps, W.C. Woods, | 7 Aug 45 |
| | No. 24 | Comparison of Optical and Radar Measurement of Upper Winds, G.R. Lindsey | 11 Aug 45 |
| | No. 25 | Transmission of Radar Weather Echoes, R.C. Langille | 27 Aug 45 |
| | No. 26 | Message Pads, W.C. Woods | 22 Aug 45 |
| | No. 27 | Misfire Drill for Anti-Tank Guns, C.H. Stewart | 5 Dec 45 |

Memo.

| <u>No.</u> | <u>Title</u> | <u>Date of Issue</u> |
|------------|--|----------------------|
| No. 28 | Selection of Morse Operators, J.E. Morsh | 15 Nov 45 |
| No. 29 | Notes on Training for Field Arty Individual Training, US Army, J.C. McBride | 14 Dec 45 |
| No. 30 | Notes on Tank-Destroyer Individual Training, Training for Field Arty in US Army, J.S. McBride | 14 Dec 45 |
| No. 31 | Notes on Small Arms --Training for field Arty in US Army, J.S. McBride | 14 Dec 45 |
| No. 34 | Remedial Training Tapes for Morse Operators, J.E. Morsh | 29 Jan 46 |
| No. 35 | Test for Training Tank Gunners, K.C. Fisher | 27 Apr 46 |
| No. 36 | Baker Lake Force, G.W. Rowley, (C.O.) | Feb-Mar 46 |
| No. 37 | Exercise Muskox and Film (Sent to DSIS - 14-6-60) | 1946 |

Memo.

| <u>No.</u> | <u>Title</u> | <u>Date of Issue</u> |
|------------|--|----------------------|
| No. 38 | Course in Morse Operating, J.E. Morsh | 26 Jul 46 |
| No. 39 | Army Meteorological Requirements | 5 May 48 |

APPENDIX C

OPERATIONAL RESEARCH PERSONNEL IN CANADIAN ARMED FORCES DURING WORLD WAR II

INTRODUCTION

The purpose of this Annex is to present listings of personnel serving in OR units with the Canadian Armed Services during WWII. Personnel who served with the RCN are named in the main text (Chapter II) and their names are not repeated here. The listings for those serving with the RCAF is complete (Ref. 11) but that for Canadian Army OR personnel is not. Further names and details about the latter can be found in Annex M to Ref. 11.

OPERATIONAL RESEARCH -- PERSONNEL WITH THE ROYAL CANADIAN AIR FORCE DURING WORLD WAR II

Civilian Personnel

Prof. Colin Barnes
Dr. G.M. Harris
Dr. J.W. Hopkins
Dr. C.W. Leggatt
Dr. A.G. Nickle
Dr. E.C. Smith
Dr. J.H. Soper
Dr. J.W.T. Spinks
Prof. J.O. Wilhelm

Service Personnel

S/L J.W. Abrams
 F/L A.D. Bent
 F/O R.P. Carter
 F/L W.H. Clarke
 F/L W.H. Forrest
 S/L A.P. Guinand
 F/L E.M. Kershaw
 Fl/O M.M. McEwen
 S/L P.M. Millman
 F/L J.M. Morton
 S/L B. Priestman
 S/L J. Stanley

OPERATIONAL RESEARCH PERSONNEL WITH CANADIAN ARMY DURING
WORLD WAR II*Directorate of Operational Research - Ottawa

| | | |
|--------|----------------|----------|
| Col | J.T. Wilson | Director |
| Brig | G.A. McCarter | OBE |
| Lt-Col | C. Sanford | |
| Lt-Col | P.D. Baird | |
| Major | R.H. Ozburn | |
| Major | L.M. Hunter | |
| Major | C.H. Stewart | |
| Major | G.R. Davidson | |
| Major | J.E. Edgar | |
| Capt | W.C. Woods* | |
| Capt | J.V. Clinch | |
| Capt | J. Kastner | |
| Capt | A.J. MacLennan | (CWAC) |

*These lists pertain particularly to the years 1945 and 1946 and are not comprehensive.

| | | |
|-----------|---------------|-----|
| Lieut | G.B. Morin | |
| Miss | C.E. Jellyman | |
| SM (WO I) | L.J. Dukes | MBE |

| | | |
|-------|------------------|--------|
| CSM | Dunn J.J. | |
| S/Sgt | Bullock J.E. | |
| S/Sgt | MacCallum D.S.L. | |
| S/Sgt | Montagnon N.B. | |
| Sgt | Devor J.R. | |
| Sgt | Jaffray M.M. | |
| Sgt | Lush M.L. | |
| Sgt | Yerex C.W. | |
| Cpl | Cade B.A. | (CWAC) |
| Cpl | Erlandson C.A. | |
| Cpl | Layton R.P. | |
| Cpl | Payne B.L. | |
| L/Cpl | Christy P.I.E. | |
| L/Cpl | Schlivert G.H. | |
| L/Bdr | Thompson E.P. | |
| Pte | Boucher V.L. | |
| Pte | Decarie P.E. | |
| Pte | Hedges L.G. | |
| Pte | Mullin I.E. | |
| Pte | Spademan J.A. | |
| Spr | Taylor J.W. | |
| Gnr | Searle C.A. | |
| Miss | Anne Johnston | |
| Mr. | Douglas Edwards | |

CANADIAN ARMY OPERATIONAL RESEARCH GROUP

| | | |
|--------|-----------------|------------------------|
| Dr. | T.W. Cook | Detachment Camp Borden |
| Dr. | R.W. McKay | CAORG Ottawa |
| Dr. | J.S. Marshall | CAORG Ottawa |
| Mr. | W. McK. Palmer | CAORG Ottawa |
| Dr. | R.C. Langille | CAORG Ottawa |
| Dr. | K.C. Fisher | Detachment Camp Borden |
| Prof. | J.E. Morsh | Detachment Kingston |
| Lt-Col | L.G. Eon | CAORG Ottawa |
| Lt-Col | S.A. Simmons | CAORG Ottawa |
| Capt | A.F.B. Stannard | Detachment Kingston |
| Capt | J.S. McBride | Detachment Camp Borden |
| Capt | G.R. Lindsey | CAORG Ottawa |
| Lieut | C.R. Graham | Detachment Kingston |
| Mr. | A. Kastner | CAORG Ottawa |
| Capt | G.H. Charlewood | |
| Capt | J.S. Vigder | |
| Capt | G.W. Haug | |
| Major | F.G.B. Maskell | |
| Major | J.I. Thompson | |
| Lieut | J.E.D. McCord | |
| Lieut | R.M. Donovan | |

APPENDIX D

EARLY OPERATIONAL RESEARCH STAFF IN THE FEDERAL GOVERNMENT OF CANADA

INTRODUCTION

The purpose of this Appendix is to list the names of early OR workers in federal government departments and agencies of Canada. The names of original and later OR staff in the Department of National Defence have been given in the text tables and charts of the first three chapters of this report and in Appendix C. They are not repeated here.

EARLY OPERATIONAL RESEARCH STAFF IN THE FEDERAL GOVERNMENT

In view of the large number of OR workers in provincial and civic governments and in business and industrial firms, the names are not being given in this report for reasons of brevity. Also, the coverage of these organizations is not complete in the present work, and the names of most of the early OR staff in the organizations for which data are available from replies to questionnaires appear in the foregoing text and tables. All federal government departments and most of the federal agencies have submitted returns so that, in most cases, names of early OR personnel for them are at hand.

The names of these early federal government OR staff are listed in Table D-1 in the same order as that used in Table V and VII. The data are limited to information received from questionnaires (Appendix A) and personal communications and interviews. In presenting this list, no distinction is made between staff members of OR units and those who have done OR or similar work part-time or incidentally. Some of those listed were instrumental or influential in having OR introduced rather than OR workers as such.

TABLE D-1

EARLY OPERATIONAL RESEARCH STAFF MEMBERS IN FEDERAL
GOVERNMENT DEPARTMENTS AND AGENCIES

| <u>Department or Agency</u> | <u>Names of Early OR Staff</u> |
|--------------------------------------|---|
| Revenue Canada | J. Morrissey, T. Charsky, S. Brown, M. Sprott |
| Canadian Broadcasting Corporation | E. Rickey, K. O'Cahan, M. O'Shaugnessey, L. Waitman |
| Defence Production | A. Kuhn, J.B. Massicotte, G.L. White C.J. Boyle, R.M. Lee, P.H. McCartney, P.J. Reynolds |
| National Energy Board | D. M. Jamieson, J.G. Debanné |
| Supply and Services | A.R. Demirdache, L. Nemesuary, B. Howell, J. Williams, F.Knight, D. Deziel |
| Canada Post | F. Johns, G.McDonald, W. Terentiuk, K. Bhojwani, C.Hobbs |
| Manpower & Immigration (Manpower) | D.R. Campbell, P.B. Fay, F.D.Upex, S. Magun, R.A. Jenness |

| <u>Department or Agency</u> | <u>Names of Early OR Staff</u> |
|--|--|
| Indian and Norther Affairs | A. Netherlon |
| Canadian Transport Commission | G.A. Clark, P. E. Earle, E.D.Cully, J.M. McPherson, R.M. Soberman |
| Transport Canada | A. Malacki, E. Woodhouse, R.Hoverty, D. Delaney, C. Perry, J.Grant, J. Subramani, J. Evangelista, E. Greco |
| Manpower and Immigration (Immigration) | C.J. Boyle, W. Nelles, H.B. Lind, J. Tycoles, R.T. Wilson |
| Agriculture Canada | T.C. Kerr, about 20 others |
| Fisheries and Oceans | B. Shackleton, J. Hockman, D. Paterson, D.L. Simmermon |
| Canada Mortgage and Housing Corporation | W. Mulvihill, A. Stubel, E.A. Goracz |
| Environment Canada | B. Holling, D. Brown, J. Beaman |
| Unemployment Insurance Commission | D.J. Steele (Consultant) |
| Consumer and Corporate | R. McKenna, H. Samek, J. Baker |

| <u>Department or Agency</u> | <u>Names of Early OR Staff</u> |
|-----------------------------------|---|
| Public Works Canada | T. J. Jones, A.R. Durston |
| Regional Economic Expansion | R. Marshall, T.Tait, J. Dawes |
| National Harbours Board | Y. Gagnon, H. Thoroval |
| Health and Welfare | G. Richard, A.K. Liljefors, P. Fortier, A. Grenon, D. Cogliati, F. Sully, J.A. Schriel, W.J. Bradley |
| Science and Technology | D.M. Francis |
| The Seaway Transport Canada | J. B. McLeod, W.A. Davison, A.A. Landry, A.K. Hempel |
| Secretary of State | M. Boivin, R.S. Mayne, M.A. Comber, T. Brecher |
| Treasury Board Planning Branch | D. Hartle, R. Dobell, W. Porteus, B. Carin J.W. Mayne Jr. |

N.B. Not all these were in organized OR units but all were doing OR works or applying quantitative analysis techniques.

APPENDIX E

FIRST COURSE IN OPERATIONAL RESEARCH UNIVERSITY OF TORONTO - JANUARY 1952

I Introduction

A general review of the history and accomplishments of operations research. Introductory discussion of organization, personnel and techniques. An outline of the content of succeeding sessions.

Dr. P.J. Sandiford, Ontario Hydro
Wed., Jan. 18 and Thurs., Feb. 2.

II Attacking Management Problems

The role of decisions in managing. The part played by operations research. Finding the right questions. Sub-optimization. Game theory in the analysis of strategic decisions.

Dr. P.J. Sandiford, Ontario Hydro
Wed., Jan. 25 and Thurs., Feb. 9

III Choice and Chance

A survey in elementary terms of basic notions in probability, sampling, statistical inference and the analysis of industrial data.

Dr. B. Berholtz, Ontario Hydro
Wed., Feb. 1 and Thurs., Feb. 16

IV Queuing Theory

Some simple theory illustrated with an experimental display. Illustrative case histories.

Dr. W. Shelson, Ontario Hydro
Wed., Feb. 8 and Thurs., Feb. 23.

V Linear Programming A

Basic theory illustrated with simple examples.

Dr. B. Bernholtz, Ontario Hydro
Wed., Feb. 15 and Thurs., Mar. 1

VI Linear Programming B

Case Histories.

Dr. A. Paull, Abitibi Power and
Paper Company Limited
Wed., Feb. 22 and Thurs., Mar. 8

VII Computers and Business Management

Case Histories.

Dr. J.H. Chung, Computation Centre,
University of Toronto
Wed., Feb. 29 and Thurs., Mar. 15

VIII Equipment Replacement Policy

Analysis of various theories of equipment replacement.
Outline of essential features in equipment replacement.

Application to truck fleet replacement.

Dr. W. Shelson, Ontario Hydro

Wed., Mar. 7 and Thurs., Mar. 22.

IX Inventory and Production Scheduling

Case Histories.

Mr. P.J. Robinson, Imperial Oil Ltd.

Wed., Mar. 21 and Thurs., Apr. 5.

X Organization for Operations Research

Dr. P.J. Sandiford, Ontario Hydro

Wed., Mar. 21 and Thurs., Apr. 5.

Part of each lecture will be devoted to group discussion.

All lecturers begin at 7:30 p.m. in the Economics Building
273 Bloor Street West. The Wednesday series takes place in
Room 151 and the Thursday night series is in Room 254.

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| 10. DISTRIBUTION STATEMENT Unlimited distribution | | |
| 11. SUPPLEMENTARY NOTES | 12. SPONSORING ACTIVITY ORAE Social Sciences and Humanities Research Council of Canada | |
| 13. ABSTRACT This history of operational research in Canada presents an account of its origins and development in the military and non-military areas. It includes some details about the origin and growth of operational research in World War II but is concerned mainly with its beginning and evolution in the several fields of application in Canada. An account is given of the introduction and growth of military operational research in Canada since World War II and of how and when OR was started in federal and provincial government departments, ministries, and agencies, in civic and municipal governments, and in business, commerce, and industry, and research centres. Included also is a description of the development of courses of instruction in operational research in Canadian universities and institutions of learning and some information about the Canadian Operational Research Society. An attempt is made to assess the impact of OR on decision making in Canada, in a qualitative sense. Some comments are offered on future developments and prospects and a few relevant topics are considered in a section on discussion and remarks. Much of the data concerning personnel and types of OR studies undertaken are summarized in tables and charts. A short summary is also included in a final chapter. | | |

KEY WORDS

Operational Research
 Origins
 Development
 University courses
 Industrial applications
 Business applications
 Decision making in Canada

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