International Series in
Operations Research & Manag

Written, Compiled an

Arjang A. Assad · Sau

Profiles in
Research

Profiles in Operations Research

Pioneers and Innovators

International Series in Operations Research & Management Science

Volume 147

For further volumes:
http://www.springer.com/series/6161

Profiles in Operations Research

Pioneers and Innovators

Written, compiled, and edited

by

Arjang A. Assad
School of Management
University at Buffalo, State University of New York

Saul I. Gass
Robert H. Smith School of Business
University of Maryland, College Park

Springer

Editors
Arjang A. Assad
School of Management
160 Jacobs Management Center
University at Buffalo
State University of New York
Buffalo 14260-4000
NY, USA

Saul I. Gass
Robert H. Smith School of Business
Van Munching Hall
University of Maryland
College Park 20742-1915
MD, USA

ISSN 0884-8289
ISBN 978-1-4419-6280-5 e-ISBN 978-1-4419-6281-2
DOI 10.1007/978-1-4419-6281-2
Springer New York Dordrecht Heidelberg London

Library of Congress Control Number: 2011922044

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

To the memory of my father,
who gave me my first history books.

Arjang A. Assad

To Trudy

For her continued encouragement,
patience, and
lost weekends

Saul I. Gass

Preface

Prologue

Operations research (OR) had its origins in the late 1930s when a group of British Royal Air Force officers and civilian scientists were asked to determine how recently developed radar technology could be used for controlled interception of enemy aircraft. The task required scientists from various disciplines to leave their academic and laboratory settings and participate in field operations, testing, and evaluation. This embryonic but seminal applied research activity was followed by the formation of OR groups to investigate military problems encountered by the services on land, sea, or in the air. The resulting methodological approach was called operational research in the U.K. and operations research in the U.S. The salient feature of this research activity was to bring scientists from diverse disciplines directly into the field to solve operational military problems and make related tactical and strategic recommendations. Throughout World War II (WWII), on both sides of the Atlantic, OR groups analyzed critical military problems. The solutions they produced led to changes in military strategy and tactics that greatly improved results. OR helped the Allies win the war.

At the end of WWII, the U.S. military services, recognizing the wartime contributions of OR, continued their support of OR groups with the problems now focused on logistics, combat modeling, and force planning. Similarly, senior scientists who had participated in wartime OR in the U.K and U.S. were convinced that OR could be used to solve management and operational problems of nonmilitary enterprises and government. OR groups were soon formed and employed by governmental entities and private companies in the U.K. and U.S., professional societies organized, OR consultancies established, and academic OR programs initiated. Today, OR is recognized worldwide as a modern, decision-aiding science that has proved to be of great value to management, business, and industry. The history of how this came about has been reported in many papers and books in the usual narrative form. In contrast, we chose to present this history by means of individual profiles of OR's pioneers and innovators.

What is Operations Research?

"Operations Research is a scientific method for providing executive departments with a quantitative basis for decisions regarding the operations under their control" [Goodeve, C. 1948. Operational Research. *Nature* **161**(4089) 377–384].

Operations Research is defined by "mathematical or scientific analysis of the systematic efficiency and performance of manpower, machinery, equipment, and policies used in a governmental, military, or commercial operation" (*The American Heritage Dictionary of the English Language* 1976, 921).

Operations Research is the science of decision making.

OR is a relatively young field. Many of its developers are still alive and records of their accomplishments are available from them and/or from colleagues and friends. Similarly, for those who have passed on, writings and reports of their OR activities are still reasonably accessible, and can be amplified with the memories of close collaborators or friends. These fortunate circumstances related to timely access led us to believe that the history of OR could be told in a comprehensive and interesting manner through individual profiles. We felt that we had a window of opportunity to capture the story of these pioneers as they charted their courses through the early years of OR and saw it mature as a field. To accomplish this objective, we drew upon historical and technical articles, autobiographies, biographies, interviews, the resources available via the World-Wide Web, and existing accounts of the history of OR. And, most important, we were able to find authors who, as close colleagues or friends, were in the best position to relate the professional and personal histories of the persons they profiled.

We have organized the 43 profiles of this book chronologically, in ascending order of the date of birth (by day, month, and year) of the profilees. The reader progressing from Patrick Blackett's profile (Chapter 1, born in 1897) through Ronald Howard's profile (Chapter 43, born in 1934), will be exposed to a history of the origins and early development of

OR—how it evolved—all interwoven with personal backgrounds, tales, vignettes, and pictures. An alphabetical listing of the profiles follows:

Profiles

Russell Lincoln Ackoff
E. Leonard Amoff
Egon Balas
Evelyn Martin Lansdowne Beale
Anthony Stafford Beer
Richard E. Bellman
Patrick Blackett
Alfred Blumstein
Seth Bonder
Abraham Charnes
C. West Churchman
William W. Cooper
George B. Dantzig
Jay Wright Forrester
D. Ray Fulkerson
Saul I. Gass
Murray Aaron Geisler
Ralph E. Gomory
Charles Frederick Goodeve
David Bendel Hertz
Ronald A. Howard
Ellis A. Johnson
Leonid Vital'evich Kantorovich
George E. Kimball
George Kozmetsky
Harold W. Kuhn
John D. C. Little
John F. Magee
Harry Markowitz
Hugh Jordan Miser
Philip McCord Morse
Howard Raiffa
Berwyn Hugh Patrick Rivett
Bernard Roy
Thomas L. Saaty
Herbert A. Simon
Jacinto Steinhardt
Albert W. Tucker
Steven Vajda
Andrew Vazsonyi
John von Neumann
Harvey M. Wagner
Philip Starr Wolfe

The main table of contents is given by name in birth order, followed by a secondary table of contents by name in alphabetical order.

Two tables in the Appendix summarize key information about the profilees: Table 1-Profiles Background, and Table 2-Profiles Honors and Awards. In Table 1, we list date and place of birth, and the discipline and year of the associated highest earned academic degree. From the dates of birth, we note an interesting feature of the early years of OR: the majority of those profiled fall into a fairly narrow generational band. The dates of birth of 31 of the 43 profilees lie in the 20-year period from January 1912 to December 1931 (from Kantorovich to Wagner). This forms a fairly compact cluster of individuals who were between 14 and 33 years of age at the end of WWII. An even narrower band emerges if we consider the year of completion of their formal studies. Out of this group of 31 profilees, 23 completed their formal studies during the period 1945–1960. For the 43 individuals profiled, mathematics, not surprisingly, was the preponderate study area of 21 of the them. The first Ph.D. in OR was awarded in 1955.

In Table 2, we summarize the impressive achievements of the 43 profilees by citing their major honors and awards. Such recognition includes Nobel prizes, governmental medals, national scientific society memberships, and professional association medals and prizes.

Profiles in Operations Research has been written for OR practitioners, OR academics, students of OR, scientists from related fields, as well as the general public interested in the origins and accomplishments of an applied science. For this broad audience, we note that OR problems, OR techniques, and OR solutions are a part of everyone's daily life—when making an airline or hotel reservation, finding the desired products on a supermarket's shelves, joining a waiting line at a bank or post office, having Internet purchases arrive as scheduled, filling an auto's gas tank with the correctly blended fuel—all as a result of OR analyses.

The choice of the persons profiled was based on our collective knowledge of the field. Aiming for a single volume of reasonable size, we limited our initial selection to 50 subjects, all of whom had a seminal or major influence on the development and growth of OR. Over time, some of our original choices did not materialize because we could not identify suitable authors, or find sufficiently rich sources of information, or relax time constraints that precluded possible authors from participating.

The 43 profiles were written by 40 authors, including the two editors. We wish to thank and express our appreciation to the authors who worked with us over many, many months of editing, re-editing, and more re-editing. Each went the extra research mile when encountering comments and questions from the editors. We appreciate the personal perspectives they provided drawing upon their extensive and detailed knowledge of the individuals they profiled. In many cases, the authors were students or colleagues of the persons they profiled, who often collaborated on key research contributions that continue to shape OR theory and practice. While editing for some measure of uniformity, the authors were allowed to present the profiles their way.

We thank the many families and friends of the persons who are profiled for their help in answering queries from the authors and the editors, making source and other documents available, allowing us to quote from personal correspondence, and for the use of family pictures. Their cooperation is sincerely appreciated.

We thank Ron Gass for his editing of many of the profile pictures—he is an expert in obtaining blemish-free pictures while improving their clarity and color. We are especially appreciative to Kluwer Academic Publishers and its editor, Gary Folven, under whose guidance we contracted to write this book, and to Springer Science + Business Media, Inc. and Neil Levine, who became our Springer editor when Kluwer was incorporated into Springer. And, we thank Fred Hillier, the Kluwer/Springer OR series editor for his support.

Saul wishes to express his appreciation to: the Robert H. Smith School of Business, University of Maryland, College Park, for its general support, with special thanks to its computer technical staff who saw him through a hard drive failure and replacement, a software system breakdown, and a myriad of other inflictions of the computer age; the University of Maryland, College Park library for support and use of its link to JSTOR (Journal Storage)—the online system of digitally archived journals; the inter-library loan staff and service of the National Institute of Standards and Technology (NIST); and the support of NIST's Mathematical and Computational Sciences Division.

Arjang wishes to acknowledge the partial research support provided in summer 2008 by the Robert H. Smith School of Business of the University of Maryland where this project started. He also wishes to acknowledge the library resources provided by the University at Buffalo (SUNY) where the bulk of his work was carried out. Arjang also wishes to express special thanks to Charles Lyons, business/management librarian at the SUNY University at Buffalo Libraries for his prompt, diligent, and valuable help in locating and securing various sources and documents. Finally, Arjang thanks Leslie Russo of the Dean's office at the School of Management at the University of Buffalo for the ongoing assistance she provided during the course of this project.

EPILOGUE

Early in our education, we, Arjang and Saul, developed an interest in the history of science driven by our own curiosity in the sciences, especially mathematics. We augmented our schooling by biographical tales from Eric Temple Bell's *Men of Mathematics*, the story of how mathematics developed across the centuries from Carl Boyer's *A History of Mathematics* and, later, we moved on to such works as Norbert Weiner's two-volume autobiography, *Ex-Prodigy* and *I am a Mathematician*, and Constance Reid's *Hilbert.* Thus, by the time each of us entered into a research-oriented course of training, we had developed an appreciation of the value of such historical accounts in shaping our views of how one matures as a scientist. Our interest in this area continued as we read John Stillwell's *Mathematics and its History*, or the collection of interviews in *Mathematical People,* edited by Donald Albers and Gerald Alexanderson. As we examined historical or biographical sources in other sciences, notably the physical, biological, and computer sciences, and came to appreciate the wealth of such sources, we were struck by the paucity of studies devoted to the history of OR.

In the past, there have been a few articles that recounted the early history of OR; Joseph McCloskey's three papers that appeared in *Operations Research* in 1984 come to mind. More recently, we have Maurice Kirby's book, *Operational Research in War and Peace,* and our book, *An Annotated Timeline of Operations Research: An Informal History*. We are believers in the need for such historical accounts. By neglecting this need, the failure to chronicle our field will mean that important lessons will be lost to the coming generations of OR researchers, practitioners, and students.

In writing and compiling *Profiles in Operations Research*, we were often stymied in our quest for information about particular profilees—there was little they wrote about except what was contained in their technical papers and reports. It would have been valuable to have background information, the why and how of the rest of the story. In contrast, other profilees diligently recorded their stories in articles, interviews, and autobiographies. These historical treasures enabled the profile author(s) to describe a more detailed and integrated account of a profilee's OR contributions and personal background. We encourage the reader who is engaged in OR innovations and developments to do the same. There is a need for historical accounts of all aspects of OR; we welcome others to delve into this fascinating field.

School of Management, University at Buffalo, State University of New York, Buffalo, NY, USA — Arjang A. Assad

Robert H. Smith School of Business, University of Maryland, College Park, MD, USA — Saul I. Gass

Quotations, References, and Sources

We have tried to be extra diligent in referencing material, especially the sources of quotes. U.S. English is used except for quotes and titles from a British English source. For a published book or article, quotes are cited by (author last name, year, page numbers); quotes from sources that are not paginated such as the Worldwide Web, letters, personal communications, and interviews, are cited by (author, year). Chapter reference formats: books are given by authors (last name first of initial author), year of publication, book title, publisher, city; papers (articles) are given by authors (last name first of initial author), year of publication, paper title, journal (or source), volume number, issue number in parentheses, followed by page numbers.

We wish to acknowledge and thank the many individuals and organizations that gave us permission to quote material and/or use pictures; their contributions are noted in the text. With respect to the pictures on the cover, we thank the following for their permission to use them: Patrick Blackett, courtesy Giovanna Blackett; William W. Cooper, © 2002 Peter Yang/Austin American-Statesman/Won; George B. Dantzig, Courtesy National Academy of Engineering; George E. Kimball, Courtesy National Academy of Science. To the best of our knowledge, and unless otherwise noted, unattributed pictures included in this publication fall under the fair use or public domain provisions of the United States copyright law. Upon reasonable notice and substantiation that a third party owns or controls the intellectual property rights to any of these pictures, we will remove them from any future printings in the event that good faith efforts by the parties fail to resolve any disputes.

Contents

Contents (Alphabetical)

1

Patrick Blackett

Maurice W. Kirby and
Jonathan Rosenhead

Patrick Maynard Stuart Blackett was one of the most distinguished experimental physicists of the twentieth century. He was elected a fellow of the Royal Society of London in 1933 at the early age of 36. His 1948 Nobel Prize was in recognition of his fundamental contribution to knowledge and understanding of cosmic radiation and nuclear physics. Within operational research (OR), Blackett is a towering figure rightly known as the father of the subject, arising from his role in World War II (WWII) as an outstanding practitioner of the nascent discipline and in securing its diffusion throughout Britain's military command structure. Blackett's main contributions to military effectiveness were the result of applying the scientific method to the air defense of Great Britain and the anti-U-boat war in the North Atlantic.

Blackett received no public honor in Britain specifically in recognition of his wartime service, although he was awarded the U.S. Medal of Merit in 1946 for his pioneering work in military OR. In 1965, Blackett was designated by the U.K. Operational Research Society (ORS) as a Companion of Honour, and, in 1967, was appointed to the Order of Merit, Britain's highest civilian honor. In 1969, at the age of 72, he was awarded a life peerage as Baron Blackett of Chelsea. Blackett served as president of the Royal Society of London from 1965 to 1970. The ORS honors him by sponsoring the annual Blackett Memorial Lecture. In 2003, he was inducted into the International Federation of Operational Research Societies' (IFORS) OR Hall of Fame (Kirby 2003b). The moon's Blackett Crater is named after him.

A.A. Assad, S.I. Gass (eds.), *Profiles in Operations Research*, International Series in Operations Research & Management Science 147, DOI 10.1007/978-1-4419-6281-2_1,

THE NAVY AND ACADEMIC LIFE

Courtesy Giovanna Blackett

Patrick Blackett was born in Kensington, London, on November 18, 1897. His father, Arthur Stuart Blackett, was a reluctant stockbroker who was more interested in leisure time pursuits in nature and literature (Blackett 2003). While his father's family originated from north-east England with a tradition of small-scale farming, the forebears of his mother, Caroline Frances Maynard, were Shropshire landowners who wielded local political influence. On this side of the family there was a tradition of military service: Blackett's maternal grandfather had been a major in the Royal Artillery, serving in India at the time of the Indian Mutiny, and an earlier ancestor had been a sailor in the Royal Navy during the Napoleonic era.

Blackett had two sisters, the younger of whom, Marion Milner, became internationally influential on art therapy and, more generally, on psychoanalysis. He entered Osborne Naval College as a naval cadet in September 1910 when he was 12 years old. On the outbreak of World War I (WWI) in August 1914, when he was studying at Dartmouth Royal Naval College, Blackett was assigned to the cruiser HMS *Carnavon* with the junior rank of midshipman. In December of that year, his squadron engaged with several German warships in the Falkland Islands. In the ensuing battle, two German battleships and two cruisers were sunk with the British ships experiencing only minor damage.

Two years later, when he was 18 years old, Blackett experienced a far more substantial naval engagement while serving as a sub-lieutenant on HMS *Barham*, flagship of the Fifth Battle Squadron located in British home waters. The occasion was the Battle of Jutland when the Royal Navy had its only major encounter with the German High Seas Fleet. Although more British ships were sunk or damaged than their German counterparts, the fact that the High Seas Fleet withdrew to its homeports and remained inactive for the duration of the war, has led naval historians to conclude that the battle honors should be awarded to the Royal Navy.


HMS Barham (sunk in WWII)

At the end of the war, Blackett was first lieutenant on the destroyer HMS *Sturgeon*, serving as gunnery officer. In the autumn of 1918, he began to consider his future. His reasoning was as follows:

> I enjoyed my four years at sea during the war, but I was very doubtful if I would enjoy the peacetime Navy. There seemed to me to be two attitudes I might take if I decided to stay in the Navy. I could treat the Navy as providing a pleasant way of life and an introduction to the best clubs around the globe, or I could take the technological problems of naval warfare very seriously and so become orientated to fighting another war. As I put it to myself rather crudely: I enjoyed shooting at the enemy during the war—would I enjoy shooting at targets? I decided I would not. So I decided to resign from the Navy as soon as the war was over (Blackett 2003, 11).

In any event, it was the Admiralty that pointed Blackett in the direction that was to determine his future career as a physicist. Before he had the chance to resign his commission, he was sent as one of approximately 400 young officers to the University of Cambridge for a short course of lectures with the object of instilling "some general culture" (Blackett 2003, 12). Three weeks into the course, Blackett resigned his commission in order to undertake undergraduate study, initially in mathematics and then in physics. In 1921, having obtained a first class degree in natural sciences (physics), he became a Fellow of King's College Cambridge following his recruitment as a research student in the Cavendish Laboratory under the direction of the eminent physicist Sir Ernest Rutherford, an expert on radioactivity. (Rutherford was awarded the 1908 Nobel Prize in chemistry for his investigations into the disintegration of the elements and the chemistry of radioactive substances—his experiments created the foundation of nuclear physics.) Blackett worked as a postgraduate research student at the University of Cambridge in the early 1920s. There he met Costanza Bernadina Bayon, a talented language student. They were married in March 1924 and were parents of a daughter, Giovanna, and a son, Nicolas.

COSTANZA

Costanza came from a far more cosmopolitan background than Patrick. Her mother was 47 when she was born, an English woman married to an Italian, who was not Costanza's father. She was adopted by an English family, who gave her the name Dora. But in adulthood, she was always called Pat—with the result that she and her husband were commonly known as the two Pats. It was a marriage of equals, and they formed a strong team. Pat was bitingly clever, and did not suffer fools gladly. It seems that Patrick ran significant decisions in his life and career past her. And had there been any temptation for her husband's commitment to an activist socialism, she would have seen to it that he held the line. Her instincts were democratic. The party she organized to celebrate Patrick's Nobel Prize became quite famous through her insistence that all the staff of the department he headed should be invited, including secretaries, technicians, and cleaners. At least in 1948 this was a shocking breach of protocol.

THE TWO PATS

Patrick and Costanza (Pat)
Courtesy of Giovanna Blackett.

From the start, Blackett's career flourished. By the end of the 1920s, he was already well known internationally for his work in the fields of cosmic rays and atomic physics. In 1930, he was appointed to a university lectureship at Cambridge and, in 1933, he accepted the position of Professor of Physics at Birkbeck College, a constituent part of the University of London. Anxious to develop his own laboratory, Blackett intensified his work on cosmic rays, and it was in recognition of his achievements in this field that in 1937 he accepted the invitation to take up the prestigious position of Langworthy Professor of physics at the University of Manchester.

It was here, and with "remarkable speed," that Blackett developed and presided over "a major research centre for cosmic rays" in his department (Lovell 1975, 29). He returned to his post in Manchester after WWII, and was there when he was awarded the Nobel Prize for physics in 1948. The citation was for contributions to cosmic radiation and nuclear physics, but his active part in two world wars was also mentioned. (He was regarded as having been unlucky not to share the Nobel Prize for the discovery of the positron in 1936.)

In 1953 Blackett accepted an invitation to take up the chair of physics in succession to Sir George Thomson at the Imperial College in London. Blackett remained there, working on rock magnetism and the geophysics of continental drift, until his retirement in 1964.

Blackett used his status as an outstanding physicist and Nobel Prize winner actively to promote "the scientist's responsibility to society and the public's need to understand scientific or technical evidence supporting or calling into question public policies." Possessing high moral fervor, a commanding physical presence and patrician manner, Blackett epitomized "the twentieth century scientist as public citizen" (Nye 2004, 181). In what follows, we note Blackett's unswerving belief that science is not value free and politically neutral, a stance that led, on occasion, to public criticism and even ostracism. This was especially the case in relation to his views on nuclear weapons where what some people saw as pro-Soviet bias was to draw him to the attention of the British and American security services.

The Tizard Committee and Preparations for War

Blackett's first engagement with defense research was in 1934 when he was appointed to the Aeronautical Research Committee (ARC) as a scientific member. The ARC fulfilled a coordinating role for civil and military research projects: significantly, it was chaired by the eminent scientist, Henry Tizard, then Rector of Imperial College. At that time, fear of aerial bombardment was a growing public concern in view of the fact that most of the British Isles were within striking distance of German airfields, rendering the country vulnerable to a first strike or knock out blow.

A key policy aimed at offsetting this strategic weakness was to provide an effective defense against aerial bombardment, of which one element proved to be the development of radio detection and ranging (radar). The director of Scientific Research at the Air Ministry, H. E. Wimperis, and his principal assistant, A. P. Rowe, recommended that an official Committee for the Scientific Survey of Air Defense (CSSAD) should be established to consider how far recent advances in scientific and technical knowledge can be used to strengthen the present methods of defense against hostile aircraft. The original scientific members of the committee, in addition to Tizard (as chair) and Wimperis, were the distinguished physiologist and Nobel Prize winner, Professor A.V. Hill of University College, London, and Patrick Blackett, the youngest member.

The work of the CSSAD, or Tizard Committee as it came to be called, has been well recounted (Kirby 2003a; McCloskey 1987; Rowe 1948; Watson-Watt 1957; Zimmerman 2001, 2003). The initial focus was on the possibility of destroying an aircraft with a death ray; Tizard asked Robert Watson-Watt of the National Physical Laboratory to explore the potential of this idea. Instead, Watson-Watt proposed that radio waves be used to detect and locate enemy aircraft. Pioneering experiments were undertaken at Bawdsey Manor on the Suffolk coast from 1936 to the outbreak of WWII in 1939 to develop this radar concept.

It was during the course of this work that the term operational research first emerged. This was in the summer of 1938, when the embryonic radar system of aircraft interception was tested successfully during air exercises (Larnder 1978). Watson-Watt and Rowe detached a small group of Bawdsey scientists and engineers to increase the operational effectiveness of the radar system. It was realized that the effectiveness of interception would be dependent not only on the hardware of air interception (radar stations, fighter aircraft), but also on the creation of a man–machine system, including civilian scientists, engineers, and serving RAF officers. RAF officers became accustomed to working in partnership with scientists—institutional barriers were broken, fruitful working relationships were developed, and a climate conducive to the development of OR was created. Solly Zuckerman, a scientific adviser to the British government during WWII, was to describe OR as "the bastard born out of a secret liaison of scientists and airmen" (Zuckerman 1964, 287). Robert Watson-Watt actively promoted this novel OR activity to the extent that some have designated him as the father of OR, though most observers give that title to Blackett.

At the end of the war, Charles Goodeve estimated that radar had been responsible for increasing the probability of fighter interception by a factor of ten, with the work of OR analysts increasing the probability by a further factor of two. Goodeve's conclusion that the contribution of OR to the air defense of Great Britain "was out of all proportion to the amount of effort spent on research" seems entirely appropriate (Goodeve 1948, 228). The Battle of Britain was, of course, won, albeit by a small margin—in the absence of radar, it would almost certainly have been lost.

Following Blackett's work for CSSAD, he was appointed, in 1939, principal scientific officer in the instrument section of the Royal Aircraft Establishment (RAE). There, among other work, he embarked upon a study of bombsights that served as the catalyst for the development of the Mk-14 bombsight. This eliminated the need for a level bombing run at the time of bomb release, a requirement of previous equipment, which exposed aircraft to greater danger from defensive fire. It remained in service with the RAF until 1965.

Blackett and OR in World War II

The decisive moment in Blackett's wartime career took place on August 9, 1940 when A.V. Hill introduced him to General Sir Frederick Pile, commander-in-chief of Anti-Aircraft (Ack-Ack) Command. (Ack-Ack was the conventional abbreviation for anti-aircraft.) With an acute awareness of the Command's problematic gunnery performance, and having heard of the ongoing radar-related OR work at Fighter Command, he offered Blackett the position of scientific adviser at Ack-Ack Command Headquarters, Stanmore.

> PILE ON BLACKETT
>
> " . . . he [Blackett] came one morning, deep in thought, into the G (technical) Office at Stanmore. It was a bitterly cold day, and the staff were shivering in a garret warmed over only with an oil-stove. Without a word of greeting, Blackett stepped silently up on to the table and stood there pondering with his feet among the plans. After ten minutes somebody coughed uneasily and said, diffidently: 'Wouldn't you like a chair, sir . . . or something?' 'No, thank you,' said Professor Blackett, 'it is necessary to apply scientific methods. Hot air rises. The warmest spot in this room, therefore, will be near the ceiling.' At this, Colonel Krohn, my technical G.S.O., stepped up on the table beside the Professor, and for the next half-hour, the two stayed there in silence. At the end of this period Professor Blackett stepped down from the table saying: 'Well! That's *that* problem solved.' And so it was" (Pile 1949, 161).

Pile recognized that Blackett possessed "the quick intuition of a freshman" (Lovell 1975, 56). He remained with Pile for only 7 months, but during that short period he made an enduring impression. From a starting point when Ack-Ack gunners could engage in little more than a gesture of fist shaking at enemy aircraft, Blackett succeeded in reducing the number of rounds per bird (the average number of rounds used to shoot down one aircraft) from 20,000 at the onset of the London Blitz to only 4,000 by the summer of 1941.

There were two elements to this success—the personnel that Blackett recruited to assist him, and the application of OR. He acquired the services of an eclectic group of scientists, several of them with knowledge of radar. The multi-disciplinary group included three physiologists, a physicist, an astrophysicist, two mathematical physicists, two mathematicians, a surveyor, and an army officer. Collectively they became known as Blackett's Circus in recognition of this bizarre diversity of talent. In applying the scientific method to anti-aircraft fire, the Circus focused attention on the efficiency of radar sets used for gun laying. As Blackett recalled:

> . . . the first task was to work out the best method of plotting the [radar] data and of predicting the future enemy position for the use of the guns on the basis only of pencil and paper, range and fuse tables. The second task was to assist in the design of simple forms of plotting machines which would be manufactured in a few weeks. The third stage was to find means of bringing the existing [mechanical] predictors into use in connection with radar sets. . . . A special school was set up by AA Command to work out the methods of doing this and to give the necessary training. The fourth stage was to attempt to modify the predictors to make them handle the rough [radar] data more effectively (Blackett 1962, 208).

This proved to be a highly successful program of work in enhancing the effectiveness of Ack-Ack Command, a fact acknowledged by General Pile when, on the occasion of Blackett's departure to RAF Coastal Command in March 1941, he complained to A.V. Hill that "They have stolen my magician" (Lovell 1975, 58).

The OR group at AA Command became the nucleus of the Army Operational Research Group (AORG). Covering many aspects of Army operations, it became easily the largest wartime OR group. Hundreds of scientists worked in AORG during the course of the war.