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Operations research (OR) emerged during World War II as an important means of assisting civilian and military leaders in making scientifically sound improvements in the design and performance of weapons and equipment. OR techniques were soon extended to address questions of tactics and strategy during the war and, after the war, to matters of high-level political and economic policy. Until now, the story of why and how the U.S. Army used OR has remained relatively obscure, surviving only in a few scattered offi cial documents, in the memories of those who participated, and in a number of notes and articles that have been published about selected topics on military operations research. However, none of those materials amounts to a comprehensive, coherent history.

In this, the fi rst of three planned volumes, Dr. Charles R. Shrader has for the fi rst time drawn together the scattered threads and woven them into a well-focused historical narrative that describes the evolution of OR in the U.S. Army, from its origins in World

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History of Operations Research in the United States Army

Volume I: 1942–1962

Charles R. Shrader

History of Operations Research in the United States Army

VOLUME I: 1942–62

Charles R. Shrader

OFFICE OF THE DEPUTY UNDER SECRETARY OF THE ARMY FOR OPERATIONS RESEARCH
UNITED STATES ARMY
WASHINGTON, D.C., 2006

For those who served, 1942–1962

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Foreword

Operations research (OR) emerged during World War II as an important means of assisting civilian and military leaders in making scientifically sound improvements in the design and performance of weapons and equipment. OR techniques were soon extended to address questions of tactics and strategy during the war and, after the war, to matters of high-level political and economic policy. Until now, the story of why and how the U.S. Army used OR has remained relatively obscure, surviving only in a few scattered official documents, in the memories of those who participated, and in a number of notes and articles that have been published about selected topics on military operations research. However, none of those materials amounts to a comprehensive, coherent history.

In this, the first of three planned volumes, Dr. Charles R. Shrader has for the first time drawn together the scattered threads and woven them into a well-focused historical narrative that describes the evolution of OR in the U.S. Army, from its origins in World War II to the early 1960s. He has done an admirable job of ferreting out the surviving evidence, shaping it into an understandable narrative, and placing it within the context of the overall development of American military institutions. Often working with only sparse and incomplete materials, he has managed to provide a comprehensive history of OR in the U.S. Army that offers important insights into the natural tension between military leaders and civilian scientists, the establishment and growth of Army OR organizations, the use (and abuse) of OR techniques, and, of course, the many important contributions that OR managers and analysts have made to the growth and improvement of the Army since 1942.

In this volume, Dr. Shrader carries the story up to 1962, the beginning of the McNamara era and of America's long involvement in Vietnam. The subsequent volumes will cover Army OR during the McNamara era; its application in support of military operations in Vietnam; and its significant contributions to the Army's post–Vietnam recovery and reorganization, ultimately leading to a victory (after only 100 hours of combat) in the first Gulf War in 1991 and the emergence of the U.S. Army as second to none in modern weaponry, tactical prowess, and strategic vision.

These volumes should be of interest not only to those of us in the Army's analysis community but also to civilian leaders and military commanders and staff officers at all levels. The story of OR in the U.S. Army offers many insights into our past, our present, and our future. Its careful study will more than repay the time and effort that is invested.

WALTER W. HOLLIS
Deputy Under Secretary of the Army
for Operations Research

Preface

A topic as complex as the history of operations research (OR) in the U.S. Army from 1942 to 1962 requires a definition of terms. For the purposes of the study that follows in this volume, what is meant by the "U.S. Army" and by the dates 1942 to 1962 is quite clear. "U.S. Army" takes in the whole of the Army structure, both military and civilian, including the higher-level headquarters and staff of the War Department/Department of the Army and the technical and administrative services as well as the combat arms in times of both war and peace. It also includes the Army Air Forces up to the creation of a separate U.S. Air Force in 1947. The starting date for this study, 1942, was determined by the first efforts to create an OR capability in the U.S. Army; the ending date, 1962, was determined by the beginning of the major changes in Army organization and procedures instituted by Secretary of Defense Robert S. McNamara, notably the initiation of efforts to reorganize the Army along functional lines and to consolidate related activities under major functional commands, such as the U.S. Army Combat Developments Command and the U.S. Army Materiel Command.

The definition of "operations research" is much more difficult because the term is one that has as many definitions as it has practitioners and commentators.[1] Dozens, if not hundreds, of definitions have been offered over the years, each correct and useful in its own way. There is little to be gained by recapitulating all of those definitions here. It may be best simply to state the definition that has been used to limit operations research in this volume, the official U.S. Department of Defense definition:

> The analytical study of military problems undertaken to provide responsible commanders and staff agencies with a scientific basis for decision on action to improve military operations.[2]

It should be noted immediately that the official definition does not stipulate the use of mathematical techniques as an essential element of OR, although most other definitions do and the popular conception of OR is almost entirely that of an activity immersed in complex mathematics. Despite the fact that almost from its beginnings OR has been closely identified with the use of sophisticated mathematical calculations and models, the reality is that many of the best military OR studies have relied only peripherally on mathematical methods. Indeed, although the use of such methods is often helpful, and in some cases essential, it is possible to produce perfectly satisfactory OR studies without them.

What elements are essential to OR? For the purposes of this study, OR may be considered to have five essential elements, or steps:

1. the *definition of the problem* and the determination of the means of measuring its critical elements[3];
2. the *collection of data* (either by direct observation, the use of historical data, or the use of computer-generated data);
3. the *analysis of the collected data* (using both mathematical and nonmathematical methods);
4. the *determination of conclusions* based on the analysis of the collected data; and
5. the *recommendation* to the military decision maker of a course of action designed to correct or improve weapons and equipment, organization, doctrine, strategy, or policy.

To further define OR in this study, the focus has been on four principal applications of operations research to Army decision making:

1. the development, testing, and performance evaluation of weapons and other equipment;
2. the design and evaluation of military organizations, tactics, strategy, methods, and policy;
3. the evaluation of human performance and behavior; and
4. the design and evaluation of effective management structures and procedures.

This study deals primarily with the first two applications and to only a limited degree with the third. The examination of the fourth application of OR to Army management has been deferred to a subsequent volume because the major use of OR for that purpose falls after 1962. Between 1942 and 1962, the main thrust of OR work in the U.S. Army was in

fact the improvement of weapons and equipment, organization, tactical doctrine, and, to a lesser degree, the formulation of higher-level strategy and policy pertaining to the political, economic, and social issues facing the Army.

The focus on the five essential elements and the four applications of OR serves to limit the scope of this study and thus to give it greater coherence. It does mean, however, that certain elements of the story must be omitted or given only cursory treatment. Moreover, the present work is not a study of the evolution of OR techniques, and thus there is relatively little discussion of the nature and development of new techniques and methods in OR, of which there were many from 1942 to 1962. Rather, the focus here is on the development of Army OR organizations and the uses to which the Army applied OR in the period under consideration. It is in fact the story of when, how, and why the Army gathered, arranged, and managed the resources needed to create an effective and efficient OR program to aid Army leaders and staff officers in making key decisions during the two decades after 1942.

It is, of course, impossible to address all of the issues considered significant by all of the readers of this study. I have tried to highlight the major events and controversies and to present them as thoroughly and as accurately as possible, given the limited documentary evidence available. Each and every person connected with Army OR since 1942 has his or her own version of what happened and why. However, finding written documentation for the history of OR in the Army from 1942 to 1962 has proven surprisingly difficult. The materials on Army OR preserved in the National Archives are generally quite adequate for the World War II period and the postwar period up to approximately 1950. The document trail then thins, and it appears that very little useful material covering Army OR in the 1950s and early 1960s has made its way into the official archives. This is particularly true of the OR groups in the technical services. Similarly, the office files, planning documents, organizational memoranda, periodic reports, and similar materials for the Operations Research Office and its successor, the Research Analysis Corporation, seem to have "gone missing," thus leaving a large gap in our knowledge of what actually happened.

Acknowledgments

Given the complexity of the story and the gaps in the available documentation, it should not be surprising to the reader that some omissions and imperfections appear in this study. The responsibility for those is mine alone, and I am grateful for the assistance I have received from many sources. I wish to acknowledge specifically the contribution of Eugene P. Visco and Brian R. McEnany. Their fund of lore, penetrating comments, and useful suggestions have made this a much better study than it would otherwise have been. I am also much indebted to Randy Jones and Jim Hooper of SAIC for their support, and to Christine Cotting for her excellent editing. As always, my wife Carole has patiently endured my preoccupation with the task at hand and thus deserves a special acknowledgment.

CHARLES R. SHRADER
Carlisle, Pennsylvania
October 2005

PREFACE NOTES

[1]"Operations research" is also known as "operational research," "operations analysis," "management science," "industrial engineering," "decision science," and, in its more expansive manifestation, "systems analysis."

[2]JCS, *Joint Publication 1–02: Department of Defense Dictionary of Military and Associated Terms* (Washington: Office of the Chairman, JCS, 23 Mar 94), p. 277.

[3]In fact, the problem is continually reassessed and redefined throughout the course of any OR study, and steps 1 through 4 often run concurrently.

Contents

	page
Foreword	iii
Preface	v
Prologue	3
Classical and Early Modern Antecedents of Operations Research	3
"Scientific" Analysis of the Wars of Napoleon	4
The Emergence of Military Operations Research in World War I	5
Conclusion	6
Chapter one / *Operations Research in World War II*	9
Radar and the Origins of Operational Research	9
OR in the British Armed Forces, 1939–45	11
OR Crosses the Atlantic	14
The Role of NDRC and OSRD in the Development of OR in the United States	15
OR in the United States Navy, 1941–45	18
Mine Warfare Operations Research Group	18
Anti-Submarine Warfare Operations Research Group	21
Emergence of the Operations Research Group	22
OR in the United States Army Air Forces, 1942–45	23
The Origins of OR in the AAF	24
The Leach-Davidson Report, August 1942	24
Formation of the Operations Analysis Division on the Air Staff	25
Operations Analysis Sections with Major Commands	26
Personnel Issues	27
Relations with OSRD	29
OA Section, U.S. Eighth Air Force	30
Accomplishments of AAF Operations Analysis Sections	31
OR in the United States Army Service Forces, 1942–45	32
Operational Research Branch, Office of the Chief Signal Officer	33
Operational Analysis Branch, Signal Section, HQ European Theater of Operations	34
The Army Ordnance Department	34
Other Army Service Forces Elements	35
OR in the United States Army Ground Forces, 1942–45	36
Research Section, General Headquarters, Southwest Pacific Area	37
"The Balanced Team"—Operational Research Section, HQ Pacific Ocean Area	38
Historians and Op Annies	40
Conclusion	41

page

CHAPTER TWO / *Operations Research in the Postwar Era, 1945–50* 55

The Demobilization of OSRD and OFS 56
Operations Research in the United States Navy, 1945–50 56
Operations Research in the United States Air Force, 1945–50 58
Reconstitution of the Air Force OA Program 58
Project RAND and the RAND Corporation 59
Operations Research in the Department of Defense 60
International Cooperation 62
Army Operations Research Developments, 1945–50 62
Embedded Operations Research in the Technical Services and Army Field Forces, 1945–50 . . 63
The Operations Research Office, 1948–50 64
Negotiations with The Johns Hopkins University 64
Establishment of the General Research Office 66
Staff Recruitment 66
Organization of the GRO/ORO 67
ORO Fiscal Arrangements 68
The ORO Research Program, August 1948–June 1950 70
The Influence of Ellis A. Johnson 73
ORO—An Early Assessment 75
Conclusion 77

CHAPTER THREE / *The Expansion of Army Operations Research, 1950–62* 85

The Operations Research Office, 1950–61 86
ORO in Korea, 1950–53 86
ORO at Home, 1950–61 87
Organization 88
ORO's Relationship with The Johns Hopkins University 92
Army Oversight of ORO 94
Personnel 94
Physical Facilities 97
Budget 98
ORO Work Program, 1950–61 98
Other ORO Activities, 1950–61 105
Internal Programs 105
ORO Relationships with Other DOD OR Agencies 105
International Relationships 105
Industry and Academia 106
Operations Research Societies 107
New Organizations Using Operations Research, 1950–62 108
Human Resources Research Office 108
Special Operations Research Office 110
Computers and Wargaming 111
The Development of High-Speed Electronic Digital Computers 111
Early History of Wargames 113
Computers and Wargaming at ORO, 1950–61 114
The Strategy and Tactics Analysis Group 116
Recruitment and Training of Army OR Personnel 119
The Demise of ORO, 1961 120
Conclusion 122

page

Chapter four / *Operations Research and Combat Developments, 1950–62* 133
The Emergence of Combat Developments 133
The Need for an Integrated Combat Developments System 134
Project VISTA 134
Establishment of a Combat Developments Element in OCAFF 135
The Haworth Report 136
HQ CONARC and Responsibility for Combat Developments 137
Combat Developments in the Army Schools 138
The Combat Operations Research Group 139
Establishment of the United States Army Combat Developments Experimentation Command 142
Creation of the United States Army Combat Developments Command 145
Operations Research in the Technical Services, 1950–62 146
Ordnance Corps 147
The Army Research Office 147
The Chemical Corps 149
The Signal Corps 150
The Army Medical Service 151
Operations Research in the Other Technical Services 151
Conclusion 152

Chapter five / *The State of Army Operations Research, March 1963* 157

Epilogue 161

Appendix A / *Biographical Sketches* 163
Walter Barton Leach (1900–71) 163
Ellis Adolph Johnson (1906–73) 164

Appendix B / *Army Air Forces Operations Analysis Elements in World War II* 167

Appendix C / *The Army Research and Development Program, 1924–62* 169
Army Research and Development, 1924–45 169
Army Research and Development, 1945–50 170
Army Research and Development, 1950–62 173
Army R&D Funding, 1950–62 173
The Reorganization of Army R&D 174

Glossary 181

Selected Bibliography of Works Cited 185

List of Figures

Figure 1–1—U.S. Navy Operations Research Elements: 7 October 1944 23
Figure 2–1—Proposed ORO Organization: March 1949 68
Figure 2–2—Proposed ORO Organization: June 1949 68
Figure 3–1—ORO Organization: 1957 89
Figure 3–2—ORO Management Systems Division: 1958 89
Figure 3–3—ORO Tactics Division: 1958 90
Figure 3–4—ORO Strategic Division: 1958 91
Figure 3–5—ORO Operations Division: 1958 91
Figure 3–6—ORO Organization: 1960 93

Figure 3–7—ORO Relationship to JHU: After 1 July 1951 93
Figure 3–8—STAG Organization: End of First Quarter, FY 1963 117
Figure 4–1—Combat Developments Section, HQ CONARC 137
Figure 4–2—Organization of CORG: July 1956 141
Figure 4–3—Organization of CORG: 1 May 1957 141
Figure 4–4—United States Army Combat Developments Experimentation Center: 1958. 143
Figure 4–5—Organization of ROEC: 1958 144
Figure 4–6—Organization of CORG: 1 January 1963. 146
Figure 4–7—Organization of the Chemical Corps: June 1956 149
Figure C–1—R&D Division, General Staff, U.S. Army: 23 October 1947 172
Figure C–2—Office, Chief of Research and Development, Office of the Deputy Chief of Staff for Plans and Research, Headquarters, Department of the Army: circa March 1955 176

List of Tables

Table 2–1—ORO Budgets: FY 1949 and FY 1950 (Projected) 69
Table 3–1—Army Staff Responsibility for ORO Research Programs: July 1948–August 1961. 95
Table 3–2—Department of the Army ORO Senior Military Advisors: 1948–61. 95
Table 3–3—ORO Analysts and Research Aides: 1955–60. 95
Table 3–4—Distribution of ORO/RAC Personnel, by Discipline: 1953 and 1963 97
Table 3–5—ORO Appropriations and Expenditures: FY 1956–FY 1960. 99
Table 3–6—Distribution of ORO Projects, by Division or Topic Area: FY 1956–FY 1960 100
Table 3–7—Distribution of ORO Studies, by Topic: July 1948–June 1961. 100
Table 3–8—HumRRO Personnel Strength: FY 1952–FY 1961. 110
Table 3–9—STAG Personnel Status: FY 1961–FY 1963 118

Illustrations

(The illustrations appear after page 132; all are from Department of Defense files, unless otherwise noted.)

W. Barton Leach
Vannevar Bush
National Defense Research Committee
The main building of the Operations Research Office complex
Brig. Gen. Lester D. Flory
Maj. Gen. John P. Daley greets Dr. Ellis A. Johnson
Thornton L. Page (Courtesy, Digital Library and Archives, University Libraries, Virginia Polytechnic Institute and State University)
Analysts from the Combat Operations Research Group
A war game in progress
Col. Alfred W. DeQuoy

History of Operations Research in the United States Army

Prologue

Can the intensely human endeavor of war be accurately and thoroughly described in mathematical terms? At "Mathematics and War," a conference held in Karlskrona, Sweden, in August 2002, two Danish scholars—Lt. Col. (ret.) Svend Bergstein and Svend Clausen of the Danish Defense Research Establishment—presented papers titled, respectively, "War Cannot Be Calculated" and "War Can Be Calculated."[1] Citing the Austrian philosopher Karl Popper and the Prussian military theorist Carl von Clausewitz, Bergstein argued that war is a human activity that cannot be reduced to mathematical formulae. Clausen, citing the work of Frederick W. Lanchester and the Danish combat model, *Defense Dynamics*, argued that war can indeed be accurately described by mathematical models. Although the issue was not definitively decided at Karlskrona, it is certain that science, and mathematical analysis in particular, has played an important, if often *sub rosa*, role in warfare from the earliest times. The Stone Age tribal leader who first discovered that twelve men were better than six in a fight and that a light stone could be thrown farther than a heavy one was the first to apply mathematical analysis, and what today we call *operations research* (OR). In the millennia that followed, the sophistication of mathematical knowledge increased steadily, and military and political leaders increasingly relied on the use of scientific techniques to aid them in making decisions that improved their chances of victory.

Classical and Early Modern Antecedents of Operations Research

Archimedes—the ancient Greek mathematician, physicist, and mechanical engineer—has become the patron saint of military operations researchers, and most modern writers on OR have been obliged to make at least a brief reference to him.[2] Born around 287 B.C.E. in Syracuse, the largest of the Greek city-states in Sicily, Archimedes studied mathematics in Alexandria with disciples of Euclid and was for many years the scientific advisor to King Hieron II of Syracuse.[3] When a Roman army commanded by Marcus Claudius Marcellus laid siege to Syracuse in 213 B.C.E., Archimedes invented a number of military devices and techniques for countering the attacks of the Roman siege methods. His best-known military inventions were his new types of catapults, a device known as Archimedes' Claw for overturning ships, and a (perhaps apocryphal) system of curved mirrors to focus sunlight on the attacking Roman ships and set them on fire. When the Romans finally took the city in 212 B.C.E., Marcellus ordered that its citizens be spared, but Archimedes was killed by an impatient Roman soldier who failed to recognize him. Archimedes was perhaps the first operations analyst. In his role as scientific advisor to King Hieron, he used what can be considered a very early form of OR techniques. He collected empirical data, analyzed those data using mathematics, and used the results to design equipment and formulate methods for countering the Roman siege.

A century and a half before Archimedes applied his understanding of mathematics and physics to the design of weapons to defend his native Syracuse, King Philip II of Macedon (382–336 B.C.E.) set about creating an army and a tactical doctrine based on what can only be described as scientific observation and mathematical calculation.[4] Philip studied the military art in Thebes under Epaminondas, the victor over the Spartans at the Battle of Leuctra in 371 B.C.E. Epaminondas (circa 418–362 B.C.E.) was perhaps the greatest military innovator of ancient Greece and is credited with developing the so-called oblique order in which a commander weakens one portion of his battle line to provide massive numerical superiority at another portion to overwhelm the enemy line by concentrating mass at a critical point. Philip was an apt student and, having observed the oblique order tactic in action, applied basic mathematics to the reform of the phalanx, the principal infantry formation. He increased the depth and reduced the width of the traditional phalanx and equipped his soldiers with the *sarissa*, a pike about twice as long as the traditional infantry weapon. Philip also devised a new method of employing his supporting cavalry (by forming them in mobile wings on either flank of the main phalanx formation) and developed the stone-throwing catapult into a true field artillery weapon. Philip's innovations, based on empirical observation and scientific analysis, produced an offensive force with greatly increased

power and speed on the battlefield. His son, Alexander the Great (356–323 B.C.E.), subsequently used Philip's tactical improvements to conquer much of the known world.

For almost a millennium following the death of Alexander the Great, the Romans militarily dominated the western world. Best known for the development of the science of *poliorcetics*, or siegecraft, and for their skill in military engineering, the Romans, like Philip II of Macedon, used field observations and mathematical analysis to constantly improve the weapons and tactics of their armies. The Roman *castra*, or field camp, was a model of geometric precision, and the method of its construction was likewise a model of efficiency based on established calculations of the time, materials, and manpower required to construct it. Roman siegecraft included a variety of siege engines, the design and use of which were based on careful scientific observation and analysis.

With the decline of the Roman Empire in the West after the fifth century A.D., the science of military weapons design and tactical innovation were continued in the Eastern Empire (Byzantium), but in the West both science and the military art remained almost static until the onset of the Renaissance in the late fourteenth century. First in Italy and then in northern Europe, the knowledge of the ancients was revived by scholars, and innovation flourished in all of the arts and sciences. The application of science to military affairs was not neglected, and some of the most famous men of the Renaissance turned their hands to the design of weapons and improvements in tactics, and offered the results of their research to the military and political leaders of the day. Such famous Renaissance scientists as Leonardo da Vinci (1452–1519), Michelangelo Buonarotti (1475–1564), and Galileo Galilei (1564–1642) applied the re-emerging sciences of physics and mathematics to the solution of military problems, and the tactical doctrines of such writers as Niccolò Machiavelli (1469–1527) also owed a great deal to an understanding of the application of mathematical principles to military organization and tactical formations.[5] As the historian Henry Guerlac has noted:

> Science and warfare have always been intimately connected. In antiquity this alliance became strikingly evident in the Hellenistic and Roman periods. . . . The cultural and economic rebirth of western Europe after the twelfth century shows that this association was not fortuitous, for the revival of the ancient art of war was closely linked with the recovery and development of ancient scientific and technical knowledge.[6]

The scientific revolution of the late seventeenth century and the Enlightenment of the eighteenth century saw a quantum improvement in the sophistication of mathematics, physics, and the other sciences, as well as a growing conviction among educated people that it was possible to discover and state precisely the natural laws that governed not only the physical universe but all human activities, including the conduct of war. Perhaps the most concrete examples of the successful application of the rapidly improving sciences of mathematics and physics to military affairs were the advances in the science of fortification made by the French engineer Sébastien Le Prestre de Vauban (1633–1707), an advisor to King Louis XIV.[7] Steeped in the mathematics and physics of both gunpowder weapons and the design of fortifications, Vauban developed new methods for the construction of fortifications to resist the ever-improving cannon of the age. At the same time, he devised mathematically based methods for the conduct of effective siege operations.

The application of scientific thought to warfare did not go unpracticed in America. The American scientist and statesman Benjamin Franklin wrote to his British colleague Joseph Priestley on 3 October 1775:

> Britain, at the expense of three millions, has killed 150 Yankees this campaign which is £20,000 a head. And at Bunker's Hill, she gained a mile of ground half of which she lost by our taking post on Ploughed Hill. During the same time 60,000 children have been born in America. From these data any mathematical head will easily calculate the time and expense necessary to kill us all, and conquer our whole territory.[8]

"Scientific" Analysis of the Wars of Napoleon

The quarter-century after 1789 was one of continuous revolution and war in Europe, and culminated in the defeat of Napoleon at Waterloo in 1815. The length, breadth, and complexity of the military campaigns of the French Revolutionary and Napoleonic period, and the innovations in the military art that accompanied them, provided substantial grist for the mills of military commentators and theorists. The three greatest of these were the Austrian Archduke Charles, the Prussian Carl von Clausewitz, and the Swiss Baron Antoine-Henri Jomini.[9] The work of the Archduke Charles is little known in the English-speaking world, but the works of both Clausewitz (1780–1831) and Jomini (1779–1869) have had a profound influence on military theory in Great Britain and the United States. Both Clausewitz and Jomini were veterans of the Napoleonic wars, and both sought to construct a comprehensive description of the principles and laws governing war based on historical data and personal observation. Having analyzed their material, both men arrived at their conclusions and wrote them up for the edification of their patrons.[10] In this, both were engaged in massive works of operational analysis as we understand it today, albeit Clausewitz's analysis was based not so much on mathematics as on the idealist philosophy of Immanuel Kant. Jomini, who expressed skepticism regarding the value of mathematical calculations and explicitly denied that his work was based on mathematics, nevertheless clearly used

the language and laws of geometry to illustrate the points he wished to make about such matters as the principles of concentration and of interior lines.[11]

Since the early 1980s, the work of Clausewitz has been in vogue in the United States and has significantly influenced the development of American military thought and doctrine. However, the influence of Jomini has been no less profound and has been of much longer duration. Soon after the publication of Jomini's *Summary* in 1838, his work became the foundation for the study of tactics and strategy in the U.S. Army. Adopted as a text at West Point and taught to generations of American officers by the great military educator Dennis Hart Mahan, the work of Jomini colored every aspect of American military thought and practice well into the twentieth century. American military commanders from Grant and Lee to Pershing, MacArthur, and Eisenhower were steeped in the Jominian geometry of war and sought to adhere to the principles laid down by him for the conduct of campaigns.

The Emergence of Military Operations Research in World War I

Science, including mathematics, advanced steadily in the hundred years between Waterloo and World War I. During the same period, military technology also developed by leaps and bounds. By 1914, the belligerent powers had at their disposal many new weapons unknown to—even unimagined by—Clausewitz and Jomini. The dreadnought battleship, the airplane, the submarine, the tank, the radio, rapid-fire artillery used in the indirect fire mode, poison gas, and a variety of other new military technologies dominated the battlefields of Europe. Scientists were called upon directly to aid the war effort by studying the new weapons and suggesting improvements in their design and use.

The war had scarcely begun when Frederick William Lanchester (1868–1946), a pioneer in the British automobile industry and an early student of aeronautics, wrote his seminal work titled *Aircraft in Warfare: The Dawn of the Fourth Arm*.[12] While admitting that the use of military aircraft up to that time provided insufficient evidence from which to draw lasting conclusions about the airplane's long-term importance as a weapon of war, Lanchester nevertheless sought to provide "something in the nature of a lead in the direction in which it appears development [of military aircraft] may be logically anticipated."[13] In considering the role of military aircraft in combat, Lanchester discussed at length the importance of concentration as a factor in military victory from ancient times to his own era, and noted that "one of the great questions at the root of all strategy is that of concentration; the concentration of the whole resources of a belligerent on a single purpose or object, and concurrently the concentration of the main strength of his forces, whether naval or military, at one point in the field of operations."[14]

Having laid down the principle of concentration, Lanchester allowed that direct comparisons of numerical strength of combatant forces are common but not sufficiently mathematically sophisticated. He thus proceeded to construct a more useful mathematical formula for determining which side in a conflict might possess the greater strength. This was his famous "N^2 Law," which postulated that "the fighting strength of a force may be broadly defined as proportional to the square of its numerical strength multiplied by the fighting value of its individual units," or, expressed in mathematical notation, $FS = n^2 \times FV$, where FV ("fighting value") is a variable influenced by the armament, training, morale, and so forth of the force in question.[15] Lanchester's mathematical representations of such concepts as relative strength of opposing forces, concentration, weapons characteristics, and their effects on casualty rates and the outcome of battles are said to represent "possibly the first mathematical analysis of forces in combat" and have provided the basis for subsequent work on combat models and battle simulation to the present day.[16]

World War I also saw the involvement of other scientists in studying the weapons and methods of modern war. The British scientist Lord Rutherford was called upon to consult with the Admiralty on the campaign against the German U-boats.[17] In 1915, Lord Tiverton (the Earl of Halsbury from 1921) initiated a study of strategic bombing, and in his report to the Air Board in September 1917 (titled "Lord Tiverton's System of Bombing") he touched on a number of topics such as target selection, the value of large-scale bombing raids, and the concept of "circular error probable", all of which would be studied in detail by operations analysts in World War II.[18] An even more direct link between scientific study of military operations in World War I and the OR activities of World War II was provided by A. V. Hill, the head of the Anti-Aircraft Experimental Section of the British Army's Munitions Inventions Department in World War I and a prominent science advisor to the British government in World War II.[19] Brevet Major Hill and his associates, nicknamed "Hill's Brigands," studied antiaircraft problems and developed tactics and procedures to enhance the effectiveness of antiaircraft fire in the 1914–18 war.

Although the United States did not enter World War I until April 1917, American scientists were fully engaged in designing, testing, and improving the weapons and tactics of the U.S. armed forces before 1917. In response to the sinking of the *Lusitania* by a German U-boat on 7 May 1915, Secretary of the Navy Josephus Daniels established the Naval Consulting Board to mobilize American scientists for the study of naval problems. In early July 1915, Secre-

tary Daniels asked America's greatest scientist, Thomas Alva Edison (1847–1931), to serve as an advisor to the board.[20] Edison agreed, and the Naval Consulting Board became an important means of managing American scientific skills for the war effort. The board remained an unofficial entity until 29 August 1916, when Congress recognized its status in the FY17 naval appropriations bill. Edison played an important part in organizing the efforts of the board and personally undertook a wide variety of scientific studies, often spending long periods at sea collecting data.[21] His most notable contributions dealt with the submarine threat and included a plan for coastal shipping that minimized the U-boat threat, a study of the tactic of zigzagging (which found the tactic useless for merchant ships moving at less than 10 knots), and the preparation of a tactical board game designed to illustrate methods by which merchant vessels might avoid being sighted by enemy submarines.[22]

Edison's studies for the Naval Consulting Board were characterized by the collection of empirical data from actual operations, effective application of scientific method and statistical techniques to the analysis of that operational data, and the formulation of recommendations to Navy leaders on how to solve complex operational problems. Edison was particularly adept at defining measures of effectiveness, a skill that gave his studies substantial weight and brought him very close to the type of OR that would flourish in World War II.[23]

Like many of the operations analysts who followed him, Edison learned that a civilian scientist could expect serving officers to ignore or even actively discredit the results of his studies, particularly because he was not in continuous direct contact with the operational commanders in the field.[24] Consequently, his work had no effect on the Navy, and the suggestions he made to the British Admiralty in late 1917 were either already being put into effect or were judged "impractical."[25]

Conclusion

What links Archimedes, Epaminondas, Philip II of Macedon, the Renaissance military innovators, Vauban, Jomini, Lanchester, Tiverton, Hill, and Edison? All of them sought to define and find solutions to the problems of weapons design, military organization, and tactical methods by collecting operational data and subjecting it to more or less rigorous scientific, often mathematical, analysis. They then presented their conclusions to the military leaders of their time for implementation and consequent improvements that enhanced the prospects of victory. As both science—particularly the science of mathematics—and military technology became more sophisticated over the centuries, so too did the quantitative and qualitative analysis of warfare and the solutions derived therefrom. Although their methods may today be considered primitive, Archimedes and the others were indeed the forefathers of those operations analysts who have attempted, with some success, to describe many aspects of war in concrete terms.

PROLOGUE NOTES

[1]Draft conference program, Dept of Mathematics and Physics, Roskilde University, 27 Aug 02 (http://mmf. ruc.dk/~booss/mathwar/, accessed 1 Feb 03). The conference included several other papers of interest to operations researchers.

[2]See, for example, Keith R. Tidman, *The Operations Evaluation Group: A History of Naval Operations Analysis* (Annapolis, Md.: Naval Institute Press, 1984), pp. 3–4; U.K. Air Ministry, *Origins and Development of Operational Research in the Royal Air Force*, Air Publication 3368 (London: Her Majesty's Stationery Office, 1963), p. xvii (hereafter cited as *OR in RAF*).

[3]N. G. L. Hammond and H. H. Scullard, eds., *The Oxford Classical Dictionary*, 2d ed. (Oxford, U.K.: Clarendon Press, 1970), pp. 98–99.

[4]Ibid., p. 815; Lynn Montross, *War Through the Ages* (New York: Harper & Brothers, 1964), pp. 18–21; John F. C. Fuller, *Armament and History* (New York: Charles Scribner's Sons, 1945), pp. 28–29.

[5]For the contributions of Leonardo, Michelangelo, and Galileo, see Henry Guerlac, "Vauban: The Impact of Science on War," in Edward Mead Earle, ed. *Makers of Modern Strategy: Military Thought from Machiavelli to Hitler*, college ed. (New York: Atheneum, 1969), pp. 29–42. For Machiavelli, see Felix Gilbert, "Machiavelli: The Renaissance of the Art of War," in the same volume, pp. 3–25.

[6]Ibid., pp. 29–30.

[7]On the life and work of Vauban, see Guerlac, "Vauban," pp. 26–48.

[8]Quoted in R. V. Jones, "The Blackett Memorial Lecture 1982: A Concurrence in Learning and Arms," *Journal of the Operational Research Society* 33 (1982): 779–80.

[9]For a discussion of the influence of all three theorists and a comparison of Clausewitz and Jomini, see the excellent paper by Christopher Bassford titled "Jomini and Clausewitz: Their Interaction," presented at the 23d Meeting of the Consortium on Revolutionary Europe at Georgia State University, 26 Feb 93, http://www.clausewitz.com/CWZHOME/Jomini/JOMINIX.html, accessed 3 Feb 03. For Clausewitz, see Hans Rothfels, "Clausewitz," in Earle, *Makers of Modern Strategy*, pp. 93–113; and the introductory material in Carl von Clausewitz, *On War*, Michael Howard and Peter Paret, eds. (Princeton, N.J.: Princeton University Press, 1976). For Jomini, see the essay by Crane Brinton, Gordon A. Craig, and Felix Gilbert, "Jomini," in Earle, *Makers of Modern Strategy*, pp. 77–92; and the introductory material in Antoine-Henri Jomini, *Jomini*

and His Summary of the Art of War: A Condensed Version, J. D. Hittle, ed. (Harrisburg, Penn.: Stackpole Books, 1947). Bassford ("Jomini and Clausewitz," p. 16, n. 11) listed a few of the many English translations of Jomini's work and those American texts derived from Jomini.

[10]Clausewitz' first work, *The Principles of War*, was written in 1812 for the Prussian crown prince. His famous *On War* was published posthumously in full in 1832. Jomini's best-known work, *Précis de l'art de la guerre (The Summary of the Art of War)*, published in 1838, was written for the Russian czar Alexander I.

[11]Bassford, "Jomini and Clausewitz," p. 13.

[12]Frederick W. Lanchester, *Aircraft in Warfare: The Dawn of the Fourth Arm* (London: Constable and Company, 1916). Although Lanchester's work was not published until 1916, much of it was written as early as October 1914.

[13]Ibid., p. 4.

[14]Ibid., p. 39. In focusing on the importance of concentration, Lanchester echoed the conclusions that underlay Epaminondas' oblique order more than two thousand years earlier.

[15]Ibid., p. 48.

[16]Joseph H. Engel, "Lanchester's Equations," in Saul I. Gass and Carl M. Harris, eds., *Encyclopedia of Operations Research and Management Science*, 2d (centennial) ed. (Boston: Kluwer Academic Publishers, 2001), pp. 437–40.

[17]U.K. Air Ministry, *OR in the RAF*, p. 1.

[18]Joseph F. McCloskey, "The Beginnings of Operations Research: 1934–1941," *Operations Research* 35, 1 (1987): 143. The concept of "circular error probable" describes the mathematical probability of the distribution of bomb or artillery strikes around the putative aiming point.

[19]Ibid. A physiologist, Archibald Vivian Hill (1886–1977), shared the Nobel Prize for Physiology or Medicine in 1922 for his work on the heat generated by muscle activity.

[20]Edison's work as president of the Naval Consulting Board is summarized in Lloyd N. Scott, *Naval Consulting Board of the United States* (Washington: USGPO, 1920). See also William F. Whitmore, "Edison and Operations Research," *Journal of the Operations Research Society of America* 1, 2 (1953): 83–85; and Tidman, *Operations Evaluation Group*, pp. 6–8. The Naval Consulting Board, which met formally for the first time on 7 October 1915, comprised Edison as president, Dr. Miller Reese Hutchinson, and two members from each of the eleven largest U.S. engineering societies. Rear Admiral William Strother Smith served as the Navy's liaison officer to the board.

[21]Scott (*Naval Consulting Board*, pp. 160–92) enumerated Edison's many and varied contributions.

[22]Ibid., pp. 165–70, 180; Whitmore, "Edison and Operations Research," pp. 83–84. Edison's board game was very similar to the popular game "Battleship" that is available in toy stores today.

[23]Whitmore, "Edison and Operations Research," p. 83; McCloskey, "Beginnings," pp. 143–44.

[24]Whitmore, "Edison and Operations Research," p. 85; William F. Whitmore, "Military Operations Research—A Personal Retrospect," *Operations Research* 9, 2 (1961): 261.

[25]Whitmore, "Edison and Operations Research," pp. 84–85.

CHAPTER ONE

Operations Research in World War II

The story of the development of operations research (OR) in World War II encompasses the mobilization of scientists in Britain and the United States and the cooperation of the two great transatlantic allies as well as the design of new weapons and their constant improvement, the study of the human factors involved in their use, and the constant search for better methods of their employment.[1] It is also the story of the steady development of a new "science" and the bureaucratic battles to ensure that it was used fully in the fight against the Axis powers. On an even more finite level, it is the story of how managers and analysts were recruited, trained, administered, and employed in OR work and of the specific contributions they made to winning the war.

The story begins shortly before the war in Great Britain with the development of "radio detection and ranging," better known by its acronym (radar), and the efforts of British scientists to find effective ways of using the new technology to solve Britain's most pressing military problem: the defense of the homeland against attack by enemy aircraft. The science of OR emerged from the search for effective techniques for the use of radar, and, once the war began, OR methods quickly spread as the British armed forces at home and overseas created OR units to find the solutions to urgent technical and operational problems.

British OR practitioners eagerly shared their discoveries with their American colleagues, and, after Pearl Harbor, the U.S. armed forces began to establish OR units. Although administrative problems and the resistance of some commanders slowed the growth of OR in the U.S. forces, particularly in the Army ground forces, the value of OR for improving combat operations was gradually recognized, and OR in the U.S. armed forces took on a character of its own that was somewhat different from its British model.

The new science of OR gave the Allies a significant advantage over the Axis powers in World War II. The methods of OR steadily increased in sophistication over the course of the war and were applied to an increasing variety of military activities. By 1945, planning for postwar military organization in both Britain and the United States included provision for the continued use of OR in developing new weapons, organization, tactics, and strategy.

Radar and the Origins of Operational Research

In March 1934, the Nazi government of Germany, led by Adolf Hitler, denounced the disarmament clauses of the Treaty of Versailles, restored compulsory universal military service, and openly began the process of rearmament and aggression that led to World War II. Great Britain, its defenses debilitated by a decade and a half of neglect, at last began to recognize the challenge posed by a resurgent Germany. An aerial bombing attack on Britain appeared to be the most dangerous threat, and, at the end of July 1934, the British government acted to increase the size of its air defense forces. The effort was accelerated in the spring of 1935 after Hitler bragged that the Luftwaffe had achieved parity with the Royal Air Force (RAF) and would soon reach equality with France.[2]

In the spring of 1934, A. P. Rowe, then the assistant for armaments to H. E. Wimperis, the director of scientific research in the Air Ministry, attended a demonstration of an acoustic early warning system comprising a number of enormous concrete sound reflectors installed on the Channel coast. Convinced that the acoustic system would not work, Rowe studied all the Air Ministry files on air defense, and, in June 1934, he wrote a memorandum for Wimperis identifying the urgent need for an effective early warning system against enemy aircraft.[3] Five months later, in November 1934, Wimperis recommended to the secretary of state for air, Lord Londonderry, the formation of a committee to study the problem of air defense. Lord Londonderry quickly approved Wimperis' suggestion and named the

distinguished chemist and rector of the Imperial College of Science and Technology, Henry E. Tizard, to head a "Committee for the Scientific Study of Air Defence." Other members appointed to the committee included A. V. Hill, P. M. S. Blackett, Wimperis, and Rowe as secretary.[4] Officially charged with considering "how far recent advances in scientific and technical knowledge can be used to strengthen the present methods of defence against hostile aircraft," the Tizard Committee met for the first time in January 1935.[5] Shortly before the first meeting, Professor Hill suggested that the superintendent of the Radio Department of the National Physical Laboratory, Robert Watson-Watt, be consulted about the feasibility of a "death ray" to be used against enemy bomber crews.[6] Watson-Watt concluded that the "death ray" concept was impractical but did suggest that reflected radio waves might be used to locate aircraft in flight. On 26 February 1935, Watson-Watt conducted a demonstration of his concept of radio detection and ranging, and Rowe reported favorably about it to the Tizard Committee, upon whose recommendation the Air Ministry named Watson-Watt to lead a small group of scientists in a series of experiments on the detection of aircraft by radio waves.[7] The technical obstacles were quickly overcome, and by July 1935 Watson-Watt's team had demonstrated that radar was capable of detecting unknown aircraft up to a range of 33 miles as well as guiding interceptor aircraft at long range and directing searchlights and antiaircraft guns at short range.[8]

It soon became obvious that the utility of radar as a means of defense against enemy bombers depended on its integration with the existing system of ground observers, interceptor aircraft, and antiaircraft artillery positions. Accordingly, the Air Ministry established the Bawdsey Research Station under Watson-Watt in early 1936 to serve as the focal point for radar experimentation as well as headquarters for the chain of radar stations planned for the English coast.[9] That same year, the RAF Fighter Command was established and charged with the air defense of Britain, and a small team of RAF officers led by Dr. B. G. Dickins, an engineer from the Royal Aircraft Establishment at Farnborough, was established at Biggin Hill in Kent to study how the radar chain might be used for aircraft interception. The Biggin Hill group, working closely with the scientists at Bawdsey, conducted a series of experiments between 1936 and 1938 that aimed at integrating radar with other early warning, fighter direction and control, and antiaircraft artillery systems. As P. M. S. Blackett later wrote, "the Biggin Hill experiments were the first step towards the fully fledged operational research sections (ORS) eventually attached to all the major commands of all three Services."[10] The official historian of OR in the RAF also observed that

> the Biggin Hill experiments are important historically for two reasons. Firstly, they developed the technique that won the Battle of Britain and, secondly, they marked the beginning of an era of close collaboration between the serving officer and the scientist in the study of operational problems which achieved such great success during the war and has remained with us to this day.[11]

From 1937 to the outbreak of war in 1939, the scientists at Bawdsey and Biggin Hill took part in the annual air defense exercises conducted by Headquarters, RAF Fighter Command. The first of these exercises was held in the summer of 1937, and an attempt was made to integrate the information generated by the Bawdsey radar station with the general air defense warning and control system, but the results achieved were unsatisfactory.[12]

In July 1938, Watson-Watt became director of communications development in the Air Ministry, and A. P. Rowe took over as superintendent of Bawdsey Research Station for the rest of the war. During the 1938 air defense exercises, Rowe assigned two teams to evaluate the developing air defense system. The team led by Eric C. Williams studied the problems associated with the process of plotting and filtering the data received from the chain of five radar stations then in operation.[13] Although the technical aspects of using radar for aircraft detection were validated, new problems arose from the need to handle data from more than one station. The second team, led by G. A. Roberts, went to the operations rooms of the fighter groups to observe the controllers handling the information generated by the chain of radar stations. Roberts focused on the overall system while his colleagues, I. H. Cole and J. Woodforde, concentrated on fighter control techniques and improvement of the equipment used in the operations rooms.

Plans called for the relocation of the Bawdsey Research Station to Dundee in Scotland in the event of war.[14] Shortly before the outbreak of war in September 1939, A. P. Rowe and the RAF officer-in-charge of radar development, Squadron Leader Raymund G. Hart, made an informal arrangement for a small group of scientists from Bawdsey to remain behind to form a research section at Headquarters, Fighter Command, at Stanmore.[15] The teams from Bawdsey led by Williams and Roberts went to Stanmore again during the 1939 air defense exercises, and their work so impressed Air Chief Marshal Sir Hugh Dowding that he asked for a section to be permanently stationed at Stanmore. Both teams were subsequently attached to Fighter Command headquarters in accordance with the Rowe-Hart agreement and Air Chief Marshal Dowding's request. A Canadian on the staff at Bawdsey, Harold Larnder, was assigned to lead the combined team on 3 September 1939.[16] The team, which was designated the Stanmore Research Section in February

1940, remained part of the Bawdsey establishment (that is, the Telecommunications Research Establishment under the newly formed Ministry of Aircraft Production) until June 1941 when it was officially incorporated into the RAF as Operational Research Section (ORS) Fighter Command.

OR in the British Armed Forces, 1939–45

By the summer of 1941, the Air Ministry had recognized the value of the work being done at RAF Fighter Command, and it was decided to establish OR sections throughout RAF on the pattern of the Stanmore group. OR sections were soon established in the other RAF commands at home and overseas as well as in the Army, the Admiralty, and the Ministry of Home Defense.[17] Eventually a limited number of OR sections were also formed for service with British ground forces. Each of the services also established a number of high-level committees and other agencies to coordinate the work of their various OR sections and to provide liaison with similar units in the other services.

The number of people engaged in OR work in Britain grew steadily throughout the war but was constrained by the availability of skilled scientific talent; by mid-1942, the British were already struggling to find enough qualified personnel for OR work.[18] Even so, just before V-E Day, RAF had some two hundred scientific officers engaged in OR at home and overseas, and the British Army had another 365 scientists so occupied.[19] By the end of the war, the overall total had risen to more than one thousand.[20]

Most of the analysts and supervisors in the British OR programs were scientists (mainly physicists), engineers, or mathematicians.[21] This was only natural because new OR workers were normally recruited by those already involved in OR. Leading scientists such as Tizard, Watson-Watt, Rowe, and Blackett were particularly active recruiters. Despite a preference for men from the "hard sciences," a number of life scientists (particularly biologists and geneticists), geologists, statisticians, and a few businessmen and liberal arts graduates were recruited as well. Although the British OR analysts were mostly men, several women university graduates were also active in OR work, notably K. M. M. Goggin at ORS RAF Bomber Command and Hilary Lang-Brown who worked at both ORS RAF Fighter and Bomber commands.[22]

The British soon discovered that what was really required was not so much formal scientific training as it was a "scientific mind" attuned to questioning assumptions, devising and testing hypotheses by means of logic and experimentation, collecting and analyzing large quantities of diverse data, and formulating effective solutions. Maj. W. Barton Leach and Dr. Ward F. Davidson concluded that only approximately 20 percent of the OR work undertaken by the British up to mid-1942 required "specialized scientific knowledge or advanced mathematical training," and that such knowledge and training were less necessary when the project involved the analysis of operational systems ("true operational analysis") rather than the more technical study of specific weapons.[23] In point of fact, the men and women engaged in OR work frequently found themselves dealing with matters far from their field of specialization. Dr. Cecil Gordon, the geneticist who developed "planned flying" and "planned maintenance" for RAF Coastal Command, wrote:

> The complete disregard for frontiers between the different subjects, and the readiness to accept any problems as within their terms of reference, has been a refreshing contrast to the rigid specialization that has developed in all other branches of science. The Operational Research Sections have recaptured the atmosphere of the period of the foundation of the Royal Society.[24]

Like Gordon, many of the British and Commonwealth scientists who entered OR work during the war were distinguished men in their field. ORS Coastal Command alone boasted five fellows of the Royal Society (P. M. S. Blackett, John C. Kendrew, Evan J. Williams, Conrad H. Waddington, and John M. Robertson) and one fellow of the Australian National Academy (James M. Rendel) as well as two future Nobel laureates (Blackett and Kendrew). One reason that so many eminent British scientists were eager to participate in OR activities was perhaps their view that it offered an excellent way to influence government policy and decision making.[25]

By and large, the scientists engaged in OR work in Britain remained in civilian status, but a few were commissioned in the British armed forces before they were recruited for OR work, and members of the overseas OR sections were frequently given "honorary" commissions to clarify their status in the event of capture by the enemy.[26] In addition, some military officers with the requisite skills were seconded to OR units in each of the services. Blackett and other prominent OR experts frequently voiced their preference for civilian analysts, noting that men of the highest intellectual capacity were required and that civilians were better able to deal comfortably with all ranks and were not distracted by routine staff duties or the imperatives of a military career.[27]

A good deal of the credit for defining OR and codifying its scientific rules as well as determining the organizational and administrative structure of the British OR sections should go to P. M. S. Blackett.[28] In December 1941, shortly before he left Coastal Command for the Admiralty, Blackett prepared a paper, titled "Scientists at the Operational Level," in which he outlined his opinions regarding the organization and utilization of scientists in OR units working with the services.[29] This paper, which is considered by some to be "the cornerstone of modern operations research,"[30] provides the

rationale for assigning civilian analysts to operational military units, drives home the value of scientific methods to the study of operations, and addresses the proper organization and administration of OR units.

One of the principles evolved by the British was that OR groups should be formed on the request of the commander to assist him in solving his problems, functioning as integral parts of his command and working closely with his military staff and subordinate commanders. Projects were initiated either on request from the commander or, more commonly, by the OR section itself. The OR section chiefs reported directly and only to the commander and normally sat in on staff meetings and conferences.[31] By working in close proximity to the uniformed elements of the command, the OR units gained access to all types of operational information and shared in the informal communications networks.

The acceptance of this arrangement by both civilian analysts and military officers helped offset the natural suspicion in which civilians were held by many officers. When the war began in 1939, the "very idea that scientists should interfere in matters of tactics and strategy was anathema to senior officers in Britain."[32] However, as scientists and military personnel worked together much of the old mutual antipathy evaporated, and the two groups were usually able to work out a reasonable modus vivendi, particularly after the military learned that the scientists were genuinely interested in improving operations rather than "showing up" the military.[33] In those cases in which the OR analysts gained the complete trust and confidence of the commander, they enjoyed "the one supreme privilege of the court jester of old, namely that of saying things which would [be] lèse-majesté from anyone else. The privilege is a very great one—it should be used on occasions, but never abused."[34]

The British OR sections made significant contributions to winning the war as well as to developing the methodology of operations research. Leach and Davidson characterized the results achieved by the British operational groups up to 1942 as "uniformly successful, in some cases dramatically so," and Wing Commander A. C. Menzies, the head of the British Air Ministry Center of Operational Research, told them that "experimental research (except where some entirely new device like Radar is produced) is likely to yield an improvement of the order of 5 or 10%; but the yield of operational research is likely to be 100% or more."[35] In a postwar essay titled "Recollections of Problems Studied, 1940–45," P. M. S. Blackett was less precise but cited a number of areas in which the accomplishments of the OR sections contributed to winning the war.[36]

The Stanmore Research Section and its successor, ORS Fighter Command, initiated the new science of operational research and designed the integrated radar-based air defense system that ensured the victory of RAF in the Battle of Britain. Charles F. Goodeve later noted that radar increased the probability of intercepting an enemy aircraft by a factor of 10, and the work of ORS Fighter Command increased it by another factor of 2.[37] The operational analysts at Stanmore also investigated a number of related problems. including enemy bomber and escort tactics; procedures for night operations, including the development of ground control intercept equipment and methods; the most profitable use of weapons under various conditions; and the effects of weather and other factors on defensive air operations.[38] During the battle in France in May 1940, they were called upon to extend their analytical efforts into the field of high-level strategic policy making. On 14 May, the French requested additional RAF fighter support. The commander of RAF Fighter Command, Sir Dowding, intuitively opposed the transfer of additional aircraft and pilots to France and tasked the Stanmore group to make an assessment of British and French aircraft losses. In a matter of hours, Eric C. Williams, the deputy section chief, made a study of the problem and concluded that "additional transfers would involve attrition that could not be made good and that Fighter Command would be weakened beyond recovery in the face of the likelihood of a German attempt to invade Britain."[39] The section chief, Hugh Larnder, prepared the results of Williams' study in easily understandable graphic form and delivered the graphs to Dowding, who presented them to the War Cabinet on 15 May. Prime Minister Winston Churchill was inclined to accede to the French request but was convinced by Dowding's clear presentation of the risks and thus refused to send additional squadrons to France, thereby preserving critical aircraft and pilots for the coming Battle of Britain.[40] The involvement of the Stanmore analysts in questions of higher policy marked a significant change in the tasks that OR analysts were called to perform. Thereafter, OR would also be used to "predict the outcome of future operations with the objective of influencing policy."[41] Larnder himself concluded that "had Dowding not won his battle with Churchill in May, he would almost certainly have lost the Battle of Britain in September."[42]

ORS Coastal Command made major contributions to the defeat of the German U-boat threat in the crucial battle in the Atlantic. One of the most striking accomplishments of the OR analysts at Coastal Command was E. J. Williams' work on depth charge settings, which led immediately to a dramatic improvement of Coastal Command aerial attacks on German submarines—estimates of the increased efficiency ranged between 400 and 700 percent—and significantly diminished U-boat activity around the British Isles in the last half of 1941.[43] A second major contribution was made by Coastal Command analysts supervised by Cecil Gordon in studies that led to the important concepts of "planned fly-

ing" and "planned maintenance," which proposed that "the level of flying intensity be set first, and the maintenance organization be revamped accordingly," thereby allowing a reduction in the number of maintenance crews, more efficient use of ground crews, and more flying time.[44] Planned flying and planned maintenance were subsequently adopted throughout RAF and significantly increased the available flying hours for RAF aircraft.

ORS Bomber Command contributed important studies on bombing accuracy, the effect of given bomb loads on different types of targets, aerial gunnery, and the causes of bomber losses.[45] It was found that large-scale air raids over Germany produced proportionately fewer friendly losses than did smaller raids, a finding that led to the first thousand-plane RAF raid over Cologne, Germany, in May 1942.[46] ORS Bomber Command also contributed to the development of numerous technological innovations for the protection and guidance of bombers, including the use of "Window" (a cloud of small metallic strips dropped by bombers to confuse enemy radar) and the "Gee," "Oboe," and "H_2S" airborne radar navigation and bombing systems.[47]

At Anti-Aircraft Command, "Blackett's Circus" studied the best methods of conveying radar information to the antiaircraft artillery positions, the best deployment of the available guns and radar sets around London, and the claims of enemy aircraft destroyed by antiaircraft fire. Their work resulted in a reduction in the number of rounds fired to down one German aircraft from twenty thousand in the summer of 1941 to only four thousand in 1942.[48] One Army Operational Research Group (AORG) study, conducted with ORS Air Defence of Great Britain (ORS Fighter Command), resulted in methods that led to antiaircraft guns shooting down approximately 82 percent of the German V-1 buzzbombs fired at England, a rate double that before the study.[49] Another notable AORG study of artillery gun drills demonstrated that one crew member performed no function whatsoever during drills and could easily be eliminated because his task was to act as "horse holder" in a unit that had not had horses for two decades.[50]

The OR analysts at the Admiralty under the direction of P. M. S. Blackett also made substantial improvements in the organization and defense of convoys and antisubmarine warfare (ASW) operations in general, and in such fields as the use of radar and radio, aids to navigation, naval gunnery, and mine warfare as well as the continuation of RAF Coastal Command studies on the use of aircraft to attack submarines.[51] Studies of the January 1941–April 1943 Atlantic convoys by H. R. Hulme and J. H. C. Whitehead revealed that, with the number of escort vessels being held constant, the loss rate of merchant ships in convoy could be reduced by simply increasing the size of the convoys.[52] Larger convoys also reduced the overall number of crossings by one-third and the number of U-boat attacks by almost as much.[53] The OR efforts at the Admiralty played a major role in winning the crucial battle in the Atlantic.

In addition to solving many complex operational problems, the British OR sections provided a much better level of feedback from the operating units to which they were attached to the national scientific and engineering establishments that were charged with developing new weapons and equipment and improving existing materiel. By virtue of their scientific and engineering backgrounds, the civilian analysts in RAF, the Army, and the Royal Navy were able to understand and describe problems and opportunities that the military users of weapons and equipment were often not prepared to recognize.[54]

The British OR sections also made significant contributions to the development of OR methodology. In a paper prepared in May 1943, titled "A Note on Certain Aspects of the Methodology of Operational Research," Blackett summarized many of the OR techniques developed in Britain up to that time.[55] The Stanmore Research Section established the basic methods of operational research in the course of its studies on the integrated air defense system and other problems associated with the control of fighters in both defensive and offensive operations. E. J. Williams' 1941 study of optimum depth charge settings for RAF Coastal Command is often considered the "classic operations research study of World War II."[56] Blackett later noted that

> this work of Williams constitutes perhaps one of the most striking major achievements of the methods of operational analysis. This method is simply that of the scientific study of the actual operations of war, using all the statistical material that can be collected combined with a detailed knowledge of the physical properties of the weapons used and of the actual tactical situation. Such work can only be achieved by the closest collaboration between scientists of great analytical ability and the Service operational staffs.[57]

The density method, a basic OR tool, was first enunciated in the form of a series of equations in the reports prepared by E. J. Williams in March and October of 1942 regarding offensive ASW operations in the Bay of Biscay.[58] The basic theorem can be expressed as $u = A \times D$, where u is the total number of submarine sightings or detections, A is the area swept out, and D is the "surfaced density" obtained by dividing the number of surfaced U-boats in the total area by the size of the total area.[59] According to Joseph F. McCloskey (a professor at Cal State, Dominguez Hills, and an expert on OR in World War II), the density method was "the basic method of analysis used by ORS Coastal Command . . . and took into account the number of submarines known or believed to be in an area, the proportion likely to be on the

surface at any given time, and the characteristics and performance of the aircraft patrolling the area."[60]

OR units were also attached to some British ground forces. No. 2 ORS with Field Marshal Bernard Law Montgomery's 21. Army Group developed almost from scratch the process of "battle analysis," including techniques for assessing air and artillery support as well as the physical and morale effects of ground combat operations.[61]

In retrospect, the principal contribution of the British OR organizations to OR methodology was to bring together the two primary aspects of OR: (1) the evaluation of the performance of weapons and equipment and (2) the analysis of operations to determine how the weapons and equipment interacted with tactics, and to what degree tactics dictated the weapons selected.[62] Subsequently, two other important uses of OR emerged: "the prediction of the outcome of future operations either in the tactical or the strategical [sic] field with the object of influencing policy, and . . . the study of the efficiency of the organisations which wielded the equipment and weapons in battle."[63] All four aspects of OR would prove critical to Allied victory in World War II.

OR Crosses the Atlantic

The Atlantic Ocean has never been an obstacle to communication between British and American scientists or military men. Thus, it was only natural that word of the new techniques of "operational research" soon reached the United States. Individual British scientists, British scientific missions to the United States, U.S. military attachés and observers in Britain, and direct contact between British and American military commanders and staff officers ensured that the benefits being derived from OR by the British armed services were well known in America long before Pearl Harbor.[64]

The work on the development of radar and its integration in the British air defense system being done at Bawdsey, Biggin Hill, and Stanmore was undoubtedly known by American scientists and military personnel through private communications even before the war began in September 1939. However, the first official government-to-government discussions of radar and the new techniques of OR probably came with the Tizard scientific mission to the United States in September 1940. The idea of sending a scientific mission to the United States to share information on the development of new technology in Britain and to encourage American scientists and industrialists to aid in its production was the brainchild of Sir Henry Tizard and A. V. Hill, both members of the Tizard Committee on air defense.[65]

Following an unsuccessful visit by Hill to Washington, D.C., in May 1940, undertaken on the suggestion of Tizard for the purpose of encouraging greater exchange of scientific information and military experience between Britain and the United States, the two men developed a plan for a full-scale scientific mission to the United States in the hopes of encouraging the Americans to help produce some of the new war technology being developed in Britain. The concept was laid out by Tizard and approved by Prime Minister Winston Churchill. Meanwhile, the fall of France in May 1940 made Anglo-American scientific cooperation even more urgent, and, in July 1940, President Franklin D. Roosevelt agreed to receive the mission headed by Tizard.

The Tizard mission, which included both British and Canadian scientists and military personnel, arrived in Washington at the end of August 1940, prepared to hand over to the United States the results of their research and development in a wide range of fields.[66] The collection of scientific innovations that the British delivered to the United States has been called "the most valuable cargo ever brought to our shores."[67] The British gift would be paid for many times over by American improvements and mass production of technology first designed in Britain, such as radar, ASDIC (sonar), the sonobuoy, the variable time fuze, and the cavity magnetron.[68]

At first, U.S. Army and Navy officers were leery of disclosing their own secrets to the British, and it was not until mid-September that the necessary permissions were obtained for serious discussions with the Tizard mission to proceed. Once the hesitation of the American military was overcome, the Tizard mission proved extremely successful. Information on current developments was exchanged, and plans were made for future scientific cooperation. The decision made to pool scientific information and the later decision to divide up research responsibilities have been called "the starting point for Allied supremacy in new weapons, notably radar and subsurface warfare devices."[69]

On 27 June 1940, three months before the arrival of the Tizard mission, President Roosevelt established the National Defense Research Committee (NDRC) under the Council of National Defense and named as its chairman Dr. Vannevar Bush, an electrical engineer and then president of the Carnegie Institution in Washington, D.C., as well as chairman of the National Advisory Committee for Aeronautics. A year later, in June 1941, Bush was named to head the new Office of Scientific Research and Development (OSRD); and Dr. James B. Conant, a chemist and president of Harvard University, took over as chairman of NDRC, which was subsumed under OSRD. NDRC, and after its creation OSRD, greatly facilitated the exchange of scientific information with the British and provided a channel for disseminating information about OR and other British scientific developments throughout the American scientific community.

On 13 December 1940, Bush wrote to Sir Henry Tizard in hopes of arranging a reciprocal visit by American scientists

to Britain to discuss developments and the establishment of offices in London and Washington to facilitate the exchange of information. The details were worked out, the British issued an invitation, and on 1 February 1941 President Roosevelt asked Dr. Conant to lead the American delegation. Accompanied by Carroll Wilson and Frederick L. Hovde, Conant arrived in England on 1 March.[70] On 11 March, President Roosevelt signed the Lend-Lease Act, and British hesitations about providing the Americans with sensitive scientific data evaporated. Conant and his group were received cordially, and serious discussions about the exchange of information, the possible divvying up of fields of research, and the creation of permanent offices to facilitate contacts ensued. The British stressed the importance of using scientists to work closely with the military services and no doubt pushed the new concept of OR. Conant suggested that American scientists be sent to Britain for training in radar and other matters, and upon his return to the United States in April 1941 he urged the Army and Navy to form OR groups.[71]

Conant was successful in establishing a permanent American office for scientific cooperation in London, and a similar office, called the British Central Scientific Office, was established in Washington, D.C., in April 1941, headed by Dr. Charles G. Darwin, director of the National Physical Laboratory. In the first nine months after the establishment of the U.S. London liaison office, twenty-six American scientists visited Britain and studied a variety of scientific matters.[72] OR was closely connected with the development of radar in Britain, and representatives of NDRC Division 14 (Radar) were perhaps the first to recognize the importance of OR. Ralph Bowen, a member of Division 14 and research director at Bell Laboratories, made a comprehensive study of the British OR program by the end of 1941, and Division 14 and its principal contractor, the Radiation Laboratory at the Massachusetts Institute of Technology (MIT), kept a close eye on OR developments.

Among the American scientists who learned about OR work during visits to Britain before Pearl Harbor was John T. Tate, a physicist from the University of Minnesota and editor of *Physical Review*, who traveled to Britain in June 1941 and observed OR activities at Coastal Command and at the Admiralty. Thornton L. Page of the Naval Ordnance Laboratory (responsible for mine warfare activities in the U.S. Navy) was also among the visitors who had direct contact with British OR analysts. An American group that included Jacob Bronowski, LeRoy A. Brothers, and Charles J. Hitch also spent time studying the effects of bombing with the OR analysts at the civil defense establishment at Princes Risborough.[73]

A number of U.S. military officers also traveled to Britain before Pearl Harbor to study British air defense, strategic bombing, and antisubmarine warfare activities. They could scarcely have avoided learning something about the British development of OR. Army Air Forces Maj. Gordon P. Saville went to Britain in the summer of 1941 to observe the Battle of Britain. Then-Lt. Gen. Henry H. "Hap" Arnold, the commander of the Army Air Forces, subsequently recalled Maj. Saville from England to set up air defenses in the United States, and, by the end of January 1942, Saville was already contemplating the establishment of his own OR group.[74]

Two weeks before the Japanese attack on Pearl Harbor, the U.S. naval air attaché in London passed to the chief of naval operations, Admiral Harold Stark, a copy of P. M. S. Blackett's new paper on "Scientists at the Operational Level" and recommended establishment of an OR program in the U.S. Navy.[75] The Navy technical bureaus, especially the Bureau of Ordnance, were already acquainted with Blackett's work, and informal talks about establishing OR in the mine warfare field were in progress. Navy Capt. Wilder D. Baker, the officer-in-charge of ASW studies for the Atlantic Fleet, also read Blackett's paper and asked John T. Tate of NDRC Division 14 to provide some scientists to help with ASW studies.[76]

The Role of NDRC and OSRD in the Development of OR in the United States

In the months after the 7 December 1941 Japanese attack on Pearl Harbor, the U.S. armed forces gradually began to develop an OR capability. A major role in that development was played by civilian scientists from NDRC and OSRD.[77] Created by the Council of National Defense on 27 June 1940 to coordinate and support war-related research, NDRC became a component of OSRD when that office was established by Executive Order 8807 on 28 June 1941 to advise the president on the status of defense-related scientific and medical research, to coordinate federal government research related to national defense, and to marshal scientific personnel and resources for the war effort. Executive Order 8807 also created a second component of OSRD, the Committee on Medical Research (CMR) to support military medical research.[78] Two other federal agencies, the National Academy of Sciences and the National Advisory Committee for Aeronautics, both of which existed before the war, completed the group of government agencies that oversaw and supported scientific research in World War II.[79]

As noted previously, NDRC established a London liaison office following the visit of James B. Conant to Britain in March and April 1941. The liaison office became a component of OSRD per OSRD Administrative Order No. 1 of 20 August 1941. The first head of the office, Frederick L. Hovde, was replaced by Bennett Archambault in April

1942. The office had a small permanent staff and handled a large number of visiting American scientists (some 250 per quarter), generated some seven hundred cables per quarter, and processed more than fifty-nine thousand reports, letters, and samples over the course of the war.[80] The office was officially abolished in late July 1945, but some liaison activities continued to mid-November 1946.

Vannevar Bush is often credited with promoting OR in the United States in World War II, but the evidence strongly suggests that Bush in fact acted as a brake on the adoption of OR.[81] Although practical considerations such as the scarcity of scientific manpower colored Bush's views, his desire to keep OSRD out of the services' OR programs appears to have primarily sprung from his intent to preserve the "purity" of science as a search for truth unhampered by government controls. At least until mid-1943, Bush sought to avoid the involvement of OSRD and its subordinate agencies in OR activities, arguing that OR sections might constitute a drain on scientific talent, interfere with the organization of scientific research and development (R&D) work, and properly belonged to the services to manage directly. His principal concern was to establish and preserve the autonomy of American science from government control and interference, and the involvement of OSRD with OR in the services would bring scientists too much under the control of the government and the military. Moreover, he believed that OR benefited the military, not scientific research and development, and that, although scientists had much to offer the military, the military had nothing to give scientists.[82] By defining OR as outside the scope of OSRD's proper functions and by suggesting that OR did not require the scientific skills of OSRD research and development personnel, Bush hoped to avoid the loss of key research scientists and managers to the service OR programs.[83]

Bush's attitude was outlined in a letter he addressed on 29 May 1942 to Brig. Gen. Raymond G. Moses and Rear Adm. W. A. Lee, Jr., his colleagues on the Joint New Weapons and Equipment Committee (JNWEC) of the Joint Chiefs of Staff:

> A certain amount of operations research is being started in this country. . . . I judge that it has in some instances produced significant results [in Britain]. However, in regard to possible efforts along the same lines in this country, I have a few definite ideas already formulated. . . . Research of this sort should, I feel, be conducted by groups that are a part of the armed services themselves, on account of the intimate interconnection with operations. . . . It would be undesirable for NDRC to become closely identified with such matters. This is for the general reason that the NDRC is concerned with the development of equipment for military use, whereas these groups are concerned with the analysis of its performance.[84]

A few months later Bush wrote to Sir Henry Tizard:

> It has been my view from the outset that this kind of activity [OR] is one for which the Services themselves should take the main responsibility. I am sure that civilian agencies can be of real assistance in the selection of personnel who should remain in civilian status, but in view of the need for intimate relationship between the operational research group and their commanding officers, we consider that this mutual confidence can best be established and maintained if the activity is one which is clearly recognized as a Service activity.[85]

Bush continued to hope that OSRD could avoid direct involvement in the management and operations of OR sections in the U.S. armed forces. On 15 February 1943, he wrote to Karl T. Compton, then the president of MIT:

> This movement is certainly of great importance and I hope that it will go well. On the other hand, I hesitate to become too much involved with it, for I think it will prosper to best advantage if the Services go ahead with it themselves and do not feel that it is being forced upon them in any way by any outside scientists and engineers.[86]

Bush's effort to avoid deep involvement in OR was compromised by his subordinates in NDRC and OSRD, many of whom became enthusiastic supporters of OR. The chairman of NDRC, James B. Conant, had observed the British OR teams in action during his 1941 visit to Britain and argued forcefully for the adoption of a similar OR program in the United States.[87] Later, Conant wrote to Bush, "As our priority situation develops, I believe it may well prove that we could transfer a number of men from NDRC projects to operational research with an increased effectiveness in the total war effort."[88]

During the first months of 1943, scientists in NDRC divisions with an interest in OR, notably Howard P. Robertson, Alan T. Waterman (a professor of physics at Yale University), and Warren Weaver (head of NDRC Applied Mathematics Panel), began to exert pressure on Bush to allow greater OSRD involvement in OR.[89] On 26 July 1943, John H. Teeter wrote to Carroll Wilson arguing that "Operational Research fits into OSRD" because of the need to coordinate the distribution of scarce scientific manpower, the necessity for constant interchange of information between the laboratories and the operating units in the field, and the desirability of raising the morale of R&D personnel by providing an opportunity to "desert the bench and take up a gun."[90] Moreover, the heads of NDRC divisions with an operational rather than strictly technological orientation saw OR as a way to market their expertise directly to the military.[91] Some NDRC leaders even took positive action on their own. For example, John T. Tate of NDRC Division 14 offered the division's assistance to the Navy in the creation and operation of the Anti-Submarine Warfare Operations Research Group (ASWORG).[92]

In the end, Bush was forced to yield by the combined force of demands by the armed services for OR involvement

and the positive response to the concept of OR among his own subordinates. The final straw was probably a letter Bush received from Ward F. Davidson in which Davidson noted that the available scientific personnel in the United States might be better used in OR than in research and development.[93] In March 1943, Davidson directed another memorandum to Bush in which he noted:

> One of the serious weaknesses under the present very loose organization is that there is not ready means for training men in the broad principles of operations analysis nor for instructing them in essential matters of military organization. . . . Finally, it seems to me that OSRD might take the responsibility for (a) a central Operations Analysis organization [and] (b) employing civilian OA personnel for assignment to service commands.[94]

Bush's response was to simply rename the activity in question in hopes of avoiding the adoption of OR on the British model, which he believed gave the military too much control over scientific activity. He thus proposed a program of what he wished to be called operational analysis, managed by the services directly with some limited support provided by OSRD in recruitment, training, and liaison but without burdening OSRD program and staff.[95]

The rapidly growing need for the services of scientists with units in the field offered Bush an opportunity to reach a compromise on the matter of OSRD involvement in OR. By mid-1943, the development of new military technology by the Allies had progressed to the point that the focus for the use of scientific manpower ought to change from developing new weapons to assisting the services in the optimal use of those weapons already in production. At the same time, internal OSRD discussions on the desirability of creating an OSRD-managed OR program had convinced Bush that he could no longer hold out.[96] On 15 October 1943, Bush created the Office of Field Service (OFS) with Karl T. Compton as chief and Alan T. Waterman as deputy.[97] The mission of OFS was to act as the OSRD focal point for OR activities as well as to coordinate the fielding and use of new weapons systems by the armed forces. As Erik Peter Rau wrote in his 1999 doctoral dissertation at the University of Pennsylvania, "Bush's main objective in creating the OFS was to position the OSRD as the principle [sic] broker of all forms of civilian technical expertise needed by military commands in the field, particularly those in the Pacific."[98]

OFS undertook three main types of projects: operational analysis; the assignment of one or two scientists to assist combat units with the process of introducing new weapons and equipment; and the assignment of groups of scientists to the active theaters to conduct special studies, make reports, and devise recommendations for improvements in the design and use of weapons and equipment.[99] OFS also sponsored four large permanent field activities: Navy ASWORG, the ALSOS mission in Europe to survey German scientific developments, the Operational Research Section at Lt. Gen. Robert C. Richardson, Jr.'s Pacific Ocean Area headquarters in Hawaii, and the Research Section at General MacArthur's Southwest Pacific Area headquarters.[100] Navy ASWORG, which operated under a contract with Columbia University arranged by OSRD and later administered by OFS, was of course deeply involved in OR, but the two OFS-sponsored groups in the Pacific functioned more along the lines of a field service organization despite their names. In every case, the OR activities for which OFS did take responsibility remained under the operational control of the military organizations to which they were attached.[101]

By the end of the war nearly five hundred men and women had been involved in the work of OFS.[102] Of that total, more than a third (37 percent) were physicists, electrical engineers, or communications experts, and others were drawn from chemistry, civil and mechanical engineering, the earth sciences, the life sciences, medicine, and industrial engineering, with a handful from such diverse fields as economics, law, and library science.[103]

For the most part, OSRD agencies did not participate directly in OR work. However, NDRC and CMR, working closely with the armed services, did conduct some activities that can be characterized as OR.[104] For example, the Applied Mathematics Panel of NDRC, established in November 1942 under the direction of Warren Weaver, was involved in the application of mathematics and statistical methods in the analysis of bombing accuracy.[105] Working closely with Army, Army Air Forces, and Navy agencies at home and overseas, the panel also studied rocket accuracy and various gunnery problems of both naval and field artillery. NDRC Division 2 (Effects of Impact and Explosion), under MIT architect John E. Burchard, was also interested in OR work on bombing effects being conducted by the British Ministry of Home Security Research and Experiments Department at Princes Risborough.[106]

The civilian scientists of NDRC and OSRD also made important contributions to the definition of OR and the description of its functions. Writing to Frederick B. Jewett on 7 February 1942, Karl T. Compton described the difference between an OR section and a "field research group." He defined the former as "a civilian body attached to an operating arm of the Army or Navy, whose function is to analyze the effectiveness of various types and elements of field operations and advise the armed services on this subject" and the latter as "a group of civilians who have accompanied newly developed equipment into the field or on board [sic] ship to study its operation as a piece of equipment in order that the producer of the equipment may be informed regarding points of failure

or desirable redesign or adaptation which will make it perform its functions as an instrument in the hands of troops more satisfactory."[107] The distinction was an important one in view of the fact that the teams organized by OFS for service with Army ground forces in the Pacific late in the war were identified as OR sections but actually functioned more as field research groups. Civilian scientists also distinguished between "functional" OR groups and "structural" ones. "Functional" OR groups focused on a particular military problem (for example, antisubmarine warfare), whereas "structural" OR groups were assigned to specific military commands and focused on the problems of that command.[108]

Perhaps the most difficult challenge that OSRD faced was finding sufficient scientific manpower to meet America's needs. OSRD had to compete with American industry for the services of both research scientists and engineers. Accordingly, OSRD focused on recruiting scientists from academia to meet the needs of the government and the armed services.[109] At first, OSRD tried to decentralize research "on contract" and leave the scientists at their home universities, but eventually it became necessary to place scientists with the operating units in the field.[110]

Liaison with the armed services was another knotty problem faced by OSRD. To perform their functions adequately, civilian scientists of NDRC, CMR, and OFS required easy access to a wide variety of operational information that could be obtained only from the services.[111] In some cases, the services did not collect such data and had no effective way of doing so. Much of the data they did have was classified, and military officers were normally reluctant to provide classified information to civilians. Eventually, OSRD was able to reduce this problem and many other aspects of working effectively with the armed services. One method was that of seconding officers from the services to work with NDRC divisions and other scientific groups as project liaison officers, but these officers often lacked the necessary technical and military experience, rotated frequently, and often served the interests of their military service rather than those of the country as a whole.[112] Somewhat better results were obtained through the military members of the OSRD Advisory Council, the War Department liaison officer to NDRC, and the Navy coordinator of research and development.[113]

The other major forum for the coordination of OSRD with the services was the Joint New Weapons and Equipment Committee of the Joint Chiefs of Staff. In February 1942, Harvey H. Bundy, special assistant to Secretary of War Henry L. Stimson and the Army representative on the OSRD Advisory Council, called Secretary Stimson's attention to the need to ensure that the War Department General Staff, and particularly the planners in the War Plans Division, were kept up to date on the many new scientific developments influencing strategy and tactics.[114] To perform this function, Bundy recommended the formation of a three-man committee consisting of Vannevar Bush as chairman, an Army general, and a Navy admiral.[115] Bush made a similar proposal to President Roosevelt in March 1942, and apparently also discussed the matter with Secretary Stimson.[116] In April 1942, it was decided to form such a committee that would report to the newly formed Joint Chiefs of Staff. JNWEC met for the first time on 12 May 1942, with Bush as chairman, Brig. Gen. Raymond G. Moses as the Army representative, and Rear Adm. W. A. Lee, Jr., as the Navy representative. The committee was charged with coordinating the efforts of civilian research agencies and the armed services in the development and production of new weapons and equipment.[117]

JNWEC also played an extremely important role in the spread of OR in the U.S. armed forces. It was for JNWEC that Leach and Davidson compiled their comprehensive report on OR in Britain and the United States in the summer of 1942.[118] For a time, JNWEC was also the base for Maj. Leach's intense efforts to spread the word about OR and promote its adoption in the U.S. armed services. Although primarily involved in the development and fielding of new weapons and equipment, JNWEC continued to be concerned with the use of OR techniques by U.S. forces until the end of the war.

OR in the United States Navy, 1941–45

The United States Navy owns the distinction of having the first active OR group in the U.S. armed forces: the Mine Warfare Operations Research Group (MWORG), established informally in January 1942.[119] The Navy's early adoption of OR was partly the result of prewar contacts with British OR groups at RAF Coastal Command and the Admiralty working on problems of naval mining, antisubmarine warfare, and convoy organization. The work being done in Britain was directly applicable to the problems faced by the U.S. Navy immediately after the Pearl Harbor attack. Thus, it was only natural that the Navy should have been eager to create its own OR capability. Although not the largest program in terms of numbers of scientists employed, the World War II Navy OR program was arguably the best organized, and it was the only U.S. OR program to survive essentially unchanged into the postwar period.

Mine Warfare Operations Research Group

MWORG was officially established as part of the U.S. Navy Bureau of Ordnance's Research Division on 24 June 1942, but it had existed informally since late January 1942 and thus merits distinction as the first OR organization in the U.S. armed forces. MWORG grew out of work being

done on countermeasures for German magnetic mines from December 1939 at the Naval Ordnance Laboratory (NOL) in Washington, D.C.[120] The NOL Mine Research Unit, led from early 1940 by Ellis A. Johnson, a Carnegie Institution physicist, focused on techniques for sweeping for magnetic mines and degaussing (demagnetizing) U.S. naval and merchant vessels.[121] In July 1940, Ralph D. Bennett, a professor of electrical engineering at MIT, was called to active duty as a lieutenant commander, U.S. Naval Reserve (USNR) and was assigned the task of expanding NOL staff, which he did by bringing in accomplished scientists of his acquaintance, increasing the scientific staff at NOL from a dozen to nearly one thousand.[122] The scientists whom Lt. Cdr. Bennett recruited joined a group that at various times included Dr. Frances Bitter, William Shockley, John Bardeen, Shirley L. Quimby, Lynn Rumbaugh, Scott Forbush, David Katcher, and Dr. Thornton L. Page, all of whom would play important roles in OR in World War II and after.

On weekends, Johnson's Mine Research Unit met informally to discuss broader issues of mine and countermine warfare and developed wargaming methods to work out the interesting problems raised by naval mining operations. On Saturday, 6 December 1941, Johnson was at Pearl Harbor inspecting degaussing efforts, and the other members of the group were in Washington, D.C., playing a wargame involving an aerial mining attack on Pearl Harbor.[123] Following the Japanese attack on the very next day, 7 December, Johnson helped to ensure that Pearl Harbor and its approaches were clear of mines, and, on his return from Hawaii in January 1942, he set up an informal seminar at the NOL to discuss mine warfare operations. The group was authorized by NOL as a scientific study group in the Mine Research Unit and met regularly from 21 January to 17 June 1942.[124] Johnson reported the results of the meetings to Capt. J. B. Glennan, the head of NOL, suggesting that wargames could be used to develop mine countermeasures.[125]

Some naval officers opposed the involvement of civilians in sensitive operational matters such as those discussed in NOL seminars, but the vice chief of naval operations, Vice Adm. Frederick J. Horne, knew of Shirley Quimby's reports on British mining operations and the work of Johnson's NOL study group, and he urged NOL to continue the group's work, basing it on the British OR model.[126] In fact, the Johnson study group had close contacts with the British OR specialists working on naval problems and incorporated information on British mining operations and mine-sweeping procedures into their informal discussions.[127] The wargames that they developed also used OR concepts learned from the British. Quimby, a physicist from Columbia University, served as the NOL liaison officer in Britain and reported on British OR methods with regard to mining.[128] In the summer of 1942, Quimby was replaced by Dr. Thornton L. Page, an astronomer from the University of Chicago who had long been in contact with British OR scientists and had worked with Blackett's group in 1941.[129]

On 1 March 1942, the NOL study group was combined with a similar group in the Bureau of Ordnance (BuOrd) to form the Mine Warfare Operations Research Group.[130] Dr. Walter Michels was designated as head of the new group and had the assistance of Dr. Page and Dr. Laurence E. Hoisington in the task of studying all operational aspects of offensive mine warfare, particularly analytical approaches to minefield design and the development of basic equations for minefield theory.[131] On 24 June 1942, MWORG was officially incorporated into the BuOrd Research Division. However, MWORG inherited only part of the original NOL study group, and additional scientists had to be recruited. Dr. Francis Bitter, a physicist from MIT, was selected to head MWORG (vice Walter Michels).[132] Shirley Quimby was recalled from London, and in September 1942 Ellis Johnson transferred to MWORG, where he joined the famous mathematicians James Alexander and John von Neumann.[133]

By mid-1942, MWORG had grown to some nineteen scientists, most of whom were physicists or mathematicians and all of whom were employed by the Navy as civilian contract personnel on a per diem basis that varied from $9 to $25.[134] MWORG reported to Cdr. L. W. McKeehan, the director of underwater ordnance research in the BuOrd Research Division.[135] Its work involved two phases:

1. the gathering and analysis of information pertaining to all aspects of naval mine and countermine operations, including the distribution of shipping, mineable waters, degaussing facilities, and the characteristics of U.S. and foreign mines; and
2. the application of the information and analyses developed in the first phase to more-general problems and the formulation of a "theory of mining" that included the study of the selection of mines, optimum mine-laying patterns, countermeasures, and sweeping techniques.[136]

The combination of technical and operational knowledge represented in the "theory of mining" appealed to naval officers in BuOrd and the Office of the Chief of Naval Operations (OCNO) who felt mines were not sufficiently appreciated by officers in the fleets.[137]

One of the most difficult problems MWORG faced was merely obtaining information. MWORG contacts with British OR groups, particularly with Blackett's team at the Admiralty, were excellent, and reports on British development often reached MWORG in Washington, D.C., in less than

three weeks.[138] However, obtaining operational information from official Navy sources was much harder, mainly because of the reluctance of Navy officers to provide classified or otherwise sensitive information to civilians, even civilians who were official Navy employees.[139] This problem was partially resolved with the transfer of MWORG from BuOrd to OCNO on 31 October 1942.[140] The civilian scientists in MWORG and the naval officers in OCNO soon developed a close relationship. MWORG received necessary operational information and, in return, promoted mining operations in the Pacific. Otherwise, the relationships established by the civilians in MWORG with naval officers were excellent, and MWORG received its fair share of attention and resources from the Navy hierarchy.[141] With respect to the use of civilians instead of military personnel for OR tasks, Cdr. McKeehan even expressed the view that prior knowledge of military operations and doctrine was of secondary importance to the ability to "think without squeaking."[142]

Once the problems of the German magnetic mine, degaussing, and mine sweeping were under control, MWORG turned its attention to the offensive use of mines in the Pacific. Ellis Johnson had become convinced that the most effective OR work would be done in the active theaters of operation by commissioned officers with full access to operational data and plans.[143] In 1943, he accepted a commission as a lieutenant commander, USNR, and volunteered to return to Pearl Harbor as mining operations officer for the Pacific Fleet.[144] Accompanied by Lt.(jg) William F. Wallace, USNR, Johnson arrived at Pearl Harbor on 15 March 1943 for duty on the staff of the commander of Service Squadron Six, Pacific Fleet, where he and Wallace were joined by Lt. Cdr. Shirley L. Quimby, USNR, and Lt. Kenneth L. Veth, U.S. Navy (USN).[145] Quimby and Veth soon left for Australia to advise Gen. Douglas MacArthur on offensive mining operations, and Wallace was sent to Guadalcanal to serve as officer-in-charge of mining operations. Following a tour of the South Pacific with Capt. George D. Hull, the commander of Service Squadron Six, Johnson remained at Pearl Harbor working on torpedoes and aerial magnetic mines.[146] Johnson was joined at Pearl Harbor by Lt.(jg) Thornton Page who came out to work on plans for the central Pacific. One of the first problems Johnson tackled was that of malfunctioning torpedoes, a problem he solved with tests in a quarry, thereby earning for himself the confidence of the naval staff in general and Admiral Chester A. Nimitz, the commander in chief of the Pacific Fleet (CINCPAC), in particular.[147]

Efforts to assist Admiral Nimitz to initiate a program of mine laying by submarines were almost derailed in the early fall of 1943, when MWORG personnel identified the need for a "sterilizer" to disarm the submarine-laid mines after a certain time.[148] Against the advice of MWORG experts, a British "sterilizer," untested for compatibility with American equipment, was put into use and proved not to work, thereby putting at risk American submarines that had to traverse areas seeded with such mines. Admiral Nimitz, well known for permitting few outsiders to become involved in his theater, turned against submarine mine laying and against MWORG as well.

The first MWORG efforts to promote mine laying by aircraft in the Pacific also encountered problems when MWORG scientists began to infringe on the work of their former colleagues in the Bureau of Ordnance.[149] The conflict was resolved several months later when the BuOrd scientists needed MWORG and its OCNO patrons to help promote the use of the new aerial mines they had developed.[150]

Despite the false starts, by the end of 1943 Johnson obtained the concurrence of the CINCPAC staff to use aerial mines in the carrier strikes of the Fifth Fleet across the central Pacific as well as to use the minelayer U.S.S *Terror* to transport the mines, equipment, and personnel to the carriers.[151] Johnson, Page, and Wallace left Pearl Harbor on U.S.S. *Terror* on 5 March 1944 and oversaw the mining operations by aircraft from U.S.S. *Hornet* and naval patrol bombers from Eniwetok atoll.[152]

Johnson continued to pursue aggressively the development of offensive mining against the Japanese and began to achieve better results after the OCNO staff mounted an intense letter-writing campaign to inform commanders in the Pacific about the potential of aerial mining.[153] Even so, the reception in the field was only lukewarm. In the southwest Pacific, General MacArthur authorized a small trial of aerial mining but assigned the task to the Royal Australian Air Force, which laid 1,142 mines with generally good results.[154] A second trial was made in August 1944 using B–29s of the XX Bomber Command to lay mines in Palembang Harbor in Sumatra.

In late July 1944, the OCNO staff appointed Johnson as project manager for the aerial mining program, a position that gave him the authority to promote and coordinate mine-related activities throughout the Pacific on behalf of BuOrd and OCNO.[155] In late September 1944, he proposed to Lt. Gen. Henry Arnold a plan for aerial mining of the Shimonoseki Straits, but Gen. Arnold preferred not to interrupt the strategic bombing of Japanese cities and he stalled for time.[156] It was only after Johnson convinced Admiral Nimitz to issue a formal request to Gen. Arnold for Army Air Forces (AAF) support on 7 November 1944 that Arnold finally agreed that the aerial mining program should begin in the spring of 1945.[157] Arnold was good to his word, and the mining campaign, codenamed Operation STARVATION, was conducted by XXI Bomber Command between the end of March and 15 August 1945. It was a tremendous

success, isolating Japan and closing some 140 Japanese ports for long periods.[158] Although only approximately 5 percent of the overall AAF effort was involved, the results of the mining campaign were as important to the defeat of Japan as the much larger strategic bombing campaign against military and industrial sites on the Japanese mainland.[159] Operation STARVATION has also been called "the most complete single example of the successful application of military operations-research techniques during the war."[160]

Like the other two early OR groups in the U.S. armed services, the OR group in the AAF Directorate of Air Defense and the OR group in the Army Signal Corps, MWORG initially focused on technical and engineering matters. However, with the development of the concept of a "theory of mining" MWORG took the first steps toward the application of OR to more-general problems of tactics and strategy, which were matters well beyond the purely technical problems of mine warfare.[161] As McCloskey noted, the work of Ellis Johnson and his colleagues on the mining campaign in the Pacific was particularly important in that respect.

> Johnson and his associates went far beyond "classical" operations research as it was developing in Britain and as it was being applied in both the ASWORG and the Army Air Forces Operations Analysis sections. They started with technological concerns and had developmental roles; their analytical or advisory roles were subordinated. And Johnson and some of his colleagues went beyond recommending strategy and tactics to playing operational roles.[162]

Anti-Submarine Warfare Operations Research Group

ASWORG was the largest and most complex of the Navy's World War II OR elements.[163] On 16 March 1942, Capt. (later Rear Adm.) Wilder D. Baker, who was the antisubmarine warfare officer for the Atlantic Fleet and was stationed in Boston, Massachusetts, wrote to the Navy's coordinator of research and development, Rear Adm. Julius A. Furer, recommending the establishment of an OR element in the Atlantic Fleet ASW unit, similar to the OR sections in RAF Coastal Command and the Royal Navy.[164] Rear Adm. Furer approved the idea and made arrangements for the necessary scientific personnel through NDRC. Dr. John T. Tate, then chairman of NDRC Section 6 (Subsurface Warfare), selected Dr. Philip M. Morse, an MIT physicist, to head the project on a part-time basis.[165] Tate then placed an NDRC contract on the Navy's behalf with Columbia University for the administration and pay of the necessary scientists.[166] Morse selected the initial group of men for the project, including Dr. William B. Shockley, who was designated the group's executive head.[167] The Navy's ASW OR group, designated as Group M (for Morse), thus came into official existence on 1 April 1942.[168]

Most of the early Group M personnel were physicists, mathematicians, or statisticians (actuaries).[169] Their annual salaries ranged from $2,500 to $5,100 and were based on what they were earning previously plus an additional amount to cover the costs of living away from home.[170] Almost from the beginning, the naval officers overseeing ASWORG felt that additional staff was needed, and Morse spent considerable time trying to find men of suitable training and ability. The actual recruitment and administration of ASWORG scientists were handled by NDRC through the contract with Columbia University.[171] By the end of the war, ASWORG included a total of eighty-six scientists, many of them men of substantial reputation.[172]

In general, ASWORG operated as a single unit with its headquarters in Washington, D.C., and certain members detailed on a temporary basis to serve with various Navy ASW commands.[173] At any given time between one fourth and one third of the ASWORG staff was in the field.[174] The men in the field collected, evaluated, and analyzed data for the group in Washington and undertook the analysis of specific problems for the command to which they were attached.[175] The studies conducted by both the ASWORG field representatives and the main group in Washington were distributed widely throughout the Navy by the central office in Washington, D.C., which also played an important role in coordinating the activities of the field representatives and shifting personnel from one assignment to another to meet constantly changing requirements.[176]

ASWORG analysts also worked closely with the Army Air Forces.[177] Until the fall of 1943, the AAF I Bomber Command on Long Island, commanded by Brig. Gen. Westside T. Larson, was responsible exclusively for airborne ASW work in the Atlantic, and, in June 1942, the AAF established a Sea Search and Development Unit (SADU), led by Col. W. C. Dolan at Langley Field in Virginia, to investigate problems of airborne ASW equipment and tactics. In September 1942, Howard H. Hennington of ASWORG went to SADU at Langley Field, where he was later joined by Maurice Bell and Donald D. Cody.[178] In October 1942, I Bomber Command was redesignated as AAF Anti-Submarine Command (AAFAC), and ASWORG analysts Arthur A. Brown and Malcolm E. Ennis arrived at AAFAC headquarters where they were joined in December by Arthur W. Brown.[179] In December 1942, Brig. Gen. Harold M. McClelland, the AAF director of technology, was assigned as the AAF liaison officer to ASWORG.[180]

In November 1942, Morse and Shockley traveled to England to view British OR activities firsthand.[181] They visited E. J. Williams at Coastal Command, Blackett at the Admiralty, Brig. B. F. J. Schonland at Anti-Aircraft Command, the newly formed U.S. Eighth Air Force operations analysis

(OA) unit, and the AAF ASW squadrons stationed in Cornwall. Morse returned to the United States in late December, but Shockley remained until January 1943 helping the AAF 1st and 2d antisubmarine squadrons at St. Eval.[182] One result of their visit was the exchange of British and American OR analysts. ASWORG analysts Arthur A. Brown and Edward J. Lamar went to ORS Coastal Command and Blackett's team at the Admiralty, and J. P. T. Pearman of ORS Coastal Command, who had already been to the Caribbean in early 1942 to assist American ASW efforts, became the key British contact with ASWORG.[183]

Like their colleagues in MWORG, the civilian scientists in ASWORG encountered some difficulties in dealing with Navy traditions and biases.[184] Operational information was closely guarded, and, as Morse himself later wrote, "to let nonmilitary persons participate in even minor operational decisions was, of course, heretical to many officers, especially those in the Navy, with their tradition that the commander of the ship of the fleet was absolute master."[185] Such attitudes extended even to the top of the Navy hierarchy. When ASWORG was established in June 1942, Admiral Ernest J. King insisted that NDRC ensure that Morse's group work only for the Navy and disclose no information, even to NDRC, unless authorized by the Navy.[186] ASWORG analysts sometimes discovered that their Navy colleagues were holding out on them, and Morse noted, "some of the group were irritated by what they called the Navy's refusal to make us members of the family. They felt that withholding facts from us restricted us to the smaller, tactical problems and made it impossible for us to help in the bigger, strategic decisions."[187]

On 20 May 1943, responsibility for all ASW operations was consolidated in the newly activated Tenth Fleet with headquarters in Washington, D.C., and the following July, ASWORG was transferred from Atlantic Fleet to Tenth Fleet control.[188] Until about the time of its transfer to the Tenth Fleet, ASWORG focused almost exclusively on ASW matters. Afterward, ASWORG personnel began to investigate a number of pressing problems in other areas. Among the important OR studies conducted by ASWORG between April 1942 and September 1945 were those dealing with problems of searching for and attacking enemy submarines, convoy protection, the operating capabilities of U.S. and foreign equipment, and countermeasures for German submarine radar and acoustic torpedoes.[189] Perhaps ASWORG's most important contribution was the development of a general search theory, or what Morse called "a set of definitions of important quantities and equations relating these quantities so as to predict search efficiencies and patterns, as well as to specify a procedure to evaluate the quantities from the answers we hoped to find in the operational reports."[190] On the basis of search theory, the essence of which was worked out by George K. Kimball and Bernard O. Koopman, ASWORG analysts were able to develop the basic rules for visual and radar sightings and more-effective methods for locating and engaging enemy submarines by both aircraft and surface vessels.[191]

Emergence of the Operations Research Group

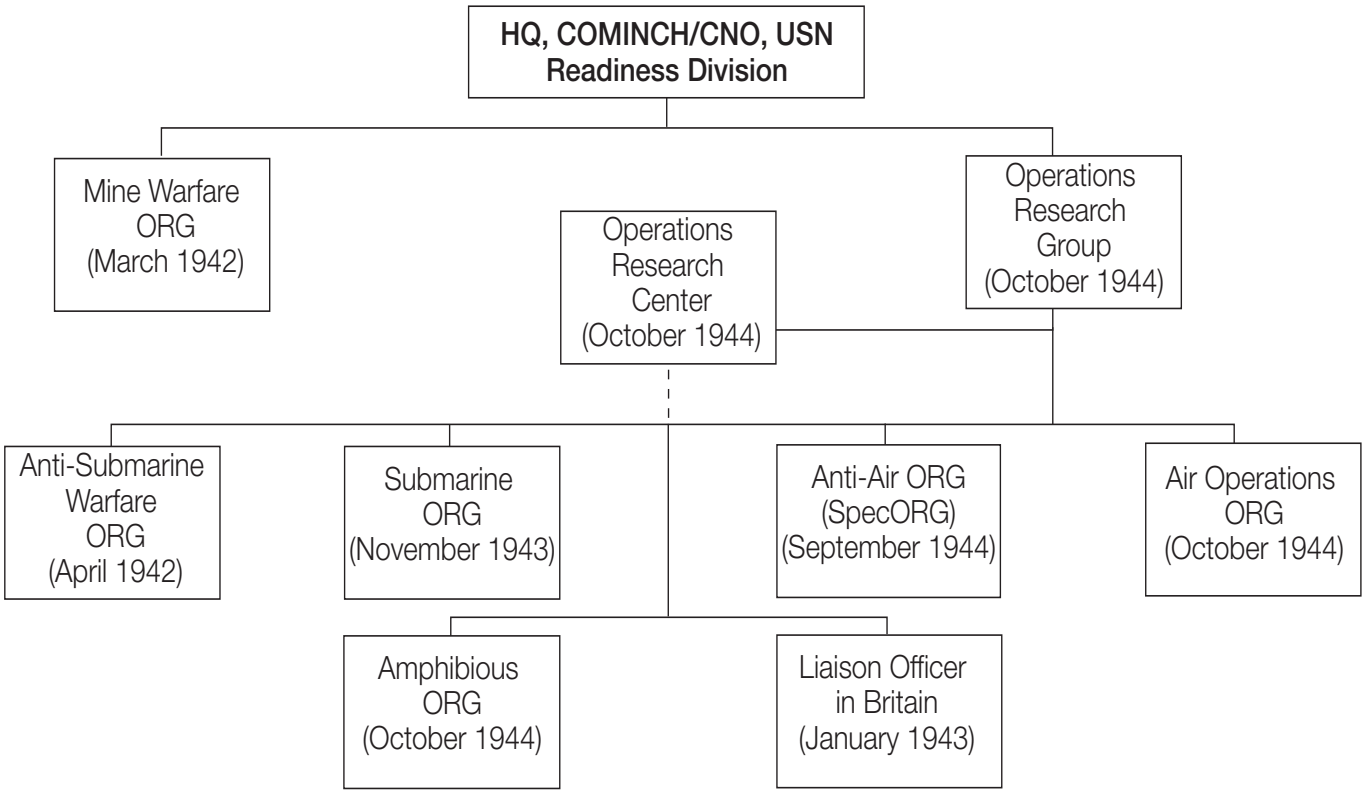
In September 1943, Secretary of the Navy Frank Knox wrote to Admiral King and other senior Navy officers about the Navy's use of OSRD scientists for OR work, noting that "the increased complexity of modern warfare demands prompt analysis of the performance of new weapons and equipment and of the operational procedures incident to their use."[192] Secretary Knox also noted that as the demand for OR had increased, the number of qualified naval personnel became inadequate and civilian scientists had to be obtained on loan from OSRD, a satisfactory method but one that should be considered temporary, with OSRD scientists being replaced by officers or civil service personnel if such services were required indefinitely.

By the late summer of 1943, the Allies had won the "Battle of the Atlantic," and ASWORG was able to turn to other problems of particular interest to the Navy. The group formed teams to deal with those problems. The situation was put on a regular basis on 7 October 1944, when Admiral Ernest J. King, the commander-in-chief, U.S. Fleet, and chief of naval operations (COMINCH/CNO), ordered the transfer of ASWORG from the Tenth Fleet to the Readiness Division of Headquarters, COMINCH, and reorganized it under the new title of Operations Research Group (ORG).[193]

The various ASWORG teams officially became subgroups of ORG, and the scientific personnel for ORG subgroups continued to be obtained on loan from the Office of Field Service, OSRD, and administered under the OSRD contract with Columbia University.[194] The various subgroups were loaned out to the various divisions of Headquarters, COMINCH/CNO, or to commanders of the various fleets, and a central office—the Operations Research Center (ORC)—was established and assigned to the Readiness Division of Headquarters, COMINCH/CNO.[195] The director of ORG served as both the head of ORC and the consulting supervisor of the subgroups. The resulting organization for OR in the Navy is shown in Figure 1–1.

The experience of the Navy Operations Research Group during World War II provided several important lessons for the future and for the other services.[196] The first lesson was that civilian scientists could best serve the military by remaining out of uniform and thus unrestrained in their con-

FIGURE 1–1—U.S. NAVY OPERATIONS RESEARCH ELEMENTS: 7 OCTOBER 1944



Note: The dates shown are those of formal organization.

Source: Details of the establishment, organization, operations, and achievements of the various ORG subgroups can be found in Keith R. Tidman, *The Operations Evaluation Group: A History of Naval Operations Analysis* (Annapolis, Md.: Naval Institute Press, 1984), pp. 81–89, and ORG, HQ, COMINCH/CNO, Summary Report to the OFS, OSRD, Washington, 1 Dec 45, pp. 24–36, in College Park, Md., National Archives II, RG 227, Entry 179, Box 301, Folder Summary Rpt to OFS, OSRD.

tacts with all ranks, staying free from routine staff duties and unbothered by restrictions on their intellectual freedom.[197] Second, the formal training of scientists and mathematicians made them especially well suited to collecting and analyzing the data needed to find solutions to the Navy's technical and tactical problems. Third, for the Navy to take best advantage of its OR personnel, they needed to have access to the highest levels of the naval hierarchy as well as to all available operational data. Fourth, the optimal organization for OR was one that had both OR units in the field and a core OR group at headquarters in Washington, D.C.[198] Fifth, mutual trust among the civilian scientists in ORG and the naval officers with whom they served was essential.

OR in the United States Army Air Forces, 1942–45

The development of operations research in the U.S. Army Air Forces began early in 1942 and eventually spread to AAF units around the world.[199] The AAF program drew inspiration from both the British and the Navy programs but differed from them in several respects. Unlike the Navy ORG, which maintained relatively tight central control with the principal OR unit located in Washington, D.C., and teams sent to the active theaters only for limited periods, the AAF system was decentralized, the operations analysis sections serving with the principal Air Force command headquarters at home and overseas being both more autonomous and more closely tied to the command that they served.[200] The central office at HQ USAAF in Washington, D.C.—the Operations Analysis Division (OAD)—served only to help set up the OA sections and provide them with necessary training and administrative support. In this they resembled the British ORS more closely than the Navy ORG. The relationship of the AAF OR program with NDRC and OSRD was also somewhat stormier than the Navy's relationship with those organizations.

The Origins of OR in the AAF

Given the early success of the ORS RAF Fighter Command in strengthening the air defenses of Britain, it was only natural that one of the first applications of OR in the United States was to the complex problems of air defense. After 7 December 1941, Anglo-American contacts regarding OR increased rapidly, and, in response to a request from the U.S. military mission in London, the British Air Ministry sent Robert Watson-Watt to the United States in January 1942 to evaluate radar and air defense systems in Hawaii, on the West Coast, and in Panama.[201] Watson-Watt did not spare the feelings of his hosts, and his report on his visit, which ended in April 1942, criticized U.S. radar and air defense warning systems as "insufficient organization applied to technically inadequate equipment used in exceptionally difficult conditions."[202] Watson-Watt recommended that the U.S. armed forces employ scientists to improve the air defense system in the same way the ORS RAF Fighter Command was doing, but neither the Navy nor the Army Air Forces took direct action.[203] Watson-Watt's visit did spur interest in OR at fairly high levels, however, and General Arnold ordered an independent review of U.S. air defenses.[204]

When the independent review confirmed the faults found by Watson-Watt, Arnold directed that the AAF air defense system be thoroughly reorganized. Maj. Gordon P. Saville, who had been in England observing RAF Fighter Command operations, was recalled to the United States, promoted to colonel, and appointed director of air defense on the Air Staff.[205] Col. Saville was familiar with the work of the ORS RAF Fighter Command and immediately acted to establish an equivalent capability in his directorate. He consulted with Vannevar Bush at OSRD who passed him on to Frank B. Jewett of the National Academy of Sciences. Jewett introduced Saville to Cyril M. Jansky, Jr., and, on 20 March 1942, Col. Saville obtained the appointment of Jansky as a special consultant.[206] Jansky established a small OR section to support AAF air defense planning and operations at the staff level.

Jansky familiarized himself with air defense problems, made a trip to Britain to investigate OR activities, and then immediately set about acting as a staff-level OR analyst for Col. Saville, setting up OA units for the various fighter commands, coordinating their activities, and providing liaison for them with other AAF agencies.[207] Jansky obtained the personnel for the fighter command OA teams, most of whom were highly qualified experts on radar and radio engineering. Both Jansky and the men he recruited were hired by AAF on a per diem basis as consultants, thereby circumventing the restrictive civil service regulations.[208]

Saville and Jansky may have had ambitions for organizing a large OA organization for the entire War Department.[209] Soon after appointing Jansky as special consultant, Col. Saville directed him to study the application of OR throughout the War Department, and, in late April or early May 1942, Jansky produced "Memorandum on Operational Analysis in the War Department."[210] Defining operational analysis as "the objective scientific study of data accumulated during the normal operation of a system already functioning [the objective of which] is the formulation of recommendations looking towards improvement in the system and increased over-all efficiency," Jansky recommended that operations analysts be civilians without military authority and responsible, after the British model, to the commander to whom they were attached.[211] In brief, Jansky envisioned a vast OR system spread throughout the War Department including Army ground forces units.[212] Operations analysts would act as the regulators of the system, conducting the "objective scientific study of the data which are being accumulated continuously, together with such limited experimental work as can be performed without in any way impairing or disturbing the normal functioning of the system" for the purpose of advising military commanders on ways to improve the efficiency and effectiveness of their organization and operations.[213] As Rau has noted, Jansky saw military activities "as integrated systems reliant upon dependable information. The job of the operations analyst . . . was to perfect the system."[214]

About the time Col. Saville and Jansky were starting up OA activities in the AAF Directorate of Air Defense in the early spring of 1942, Secretary of War Henry L. Stimson and his special assistant, Harvey H. Bundy, visited Panama to inspect the defenses of the Canal Zone.[215] They discussed defense issues with the commander of the Caribbean Defense Command, Lt. Gen. Frank M. Andrews, who suggested that a team of civilian analysts might be useful for integrating the available radar equipment with the other defenses in Panama.[216] The immediate requirement was satisfied in August 1942 by the dispatch of two experienced communications systems engineers, Charles A. Parker and Graham L. Tevis, under the aegis of Jansky's newly established office, to work with Lt. Gen. Andrews' Caribbean Defense Command.[217] They soon proved their worth, and Gen. Andrews expressed the opinion that "if all the operational analysts selected are of the caliber of these two men there will be no question as to their value to the government."[218]

The Leach-Davidson Report, August 1942

On his return to Washington, D.C., from Panama in the spring of 1942, Bundy conferred with Vannevar Bush and learned about ongoing OR activities in Britain.[219] Their conversation led Bush to arrange the establishment of a commit-

tee in the Joint New Weapons and Equipment Committee of the Joint Chiefs of Staff (of which he was the chairman) to prepare a report "on the desirability and method of extending and coordinating operations research and analysis in the Army and Navy."[220] On 7 July 1942, the task of preparing the report was assigned to Maj. Walter Barton Leach, a Harvard Law School professor recently called to active duty; a few days later, Dr. Ward F. Davidson, the director of research for Consolidated Edison, was added to the team. A Navy representative was to be included, but the Navy never supplied anyone to fill the slot.[221]

Leach and Davidson made a comprehensive survey of OR activities in Britain and the U.S. armed forces and submitted their report on 17 August 1942. At the end of their report, Leach and Davidson made five recommendations concerning the future development of OR in the Army and Navy. They argued forcefully for the use of well-qualified civilian analysts assigned to field units and responsible directly to the field commander but supported and coordinated by a central office in Washington; effective means of administering the corps of civilian analysts with regard to recruitment, training, assignment, pay and benefits, and travel arrangements; effective coordination of the Army and Navy OR programs; effective liaison between the U.S. and the British OR communities; and the extension of OR techniques to all aspects of Army and Navy operations.[222] They also warned of the dangers of uncontrolled growth in OR activities and laid down the principle, subsequently followed by AAF, that OA sections should be formed only on specific request of the commanders of the units that they were to serve. Leach and Davidson also noted:

> Our investigation has convinced us that in many commands at various levels a civilian or group of civilians, operating as an adjunct to the commander, can perform important services of an analytical nature which cannot as a practical matter be performed by Army or Navy personnel in war time. We have been impressed by the record of success of analysts in England and (for a brief period) in this country, by the uniform satisfaction of service officers with analysts attached to their commands, by the insistent demands of these officers for more analysts, and by the desire for this type of help evinced by officers who have become familiar with the experience of other commands.[223]

Two weeks after submitting the report to JNWEC, Maj. Leach wrote to Harvey Bundy to clarify several aspects.[224] In the accompanying memorandum, Leach noted that the OA sections should be led by a non-scientist, preferably a lawyer, with an outstanding scientist to head the section's scientific personnel. He recommended that the OA section personnel be equally divided between scientists and non-scientists, experienced older men and brilliant younger men. He also restated the recommendation that the administration of the OA sections be provided by a personnel corporation operating under a nonprofit contract with the secretary of war and the secretary of the Navy and that the Army and the Navy each create a small unit to inform service officers of the benefits of OA, to coordinate existing OA groups and recruit new ones, to relieve the OA groups of administrative burdens, and to provide liaison with the British and Canadians. Leach noted that the organization of such a coordinating office should include an OA officer, a civilian scientific consultant, a junior officer to perform security and personnel functions, and a clerical staff, and that it be "attached at Staff level to a general officer convinced of the worth of the enterprise, having broad knowledge of service organizations and having operational authority adequate to assure OA of a fair hearing."[225]

Formation of the Operations Analysis Division on the Air Staff

For the most part, the Leach-Davidson report was largely ignored in the Navy and Army hierarchy. However, General Arnold, already receiving requests for OR support from his subordinate commanders and with several AAF OA units already in operation, turned the Leach-Davidson report over to his Advisory Council for its recommendation.[226]

Not long after submitting his report to JNWEC, Maj. Leach accompanied the AAF director of technology, Brig. Gen. Harold M. McClelland, and others to England to help set up the OA sections for the U.S. Eighth Air Force.[227] While Maj. Leach was in England, Col. Saville, Brig. Gen. McClelland, and Brig. Gen. Muir Fairchild, the AAF director of bombardment, pressed General Arnold to establish an OA coordinating office similar to the one outlined in the Leach-Davidson report.[228] On 24 October 1942, Arnold sent a letter to his subordinate Air Force commanders and the chiefs of the Air Staff divisions noting the "dramatic" successes already achieved by the British civilian OR analysts and the fact that many American military leaders who had become familiar with the British experience had already acted to establish OR units of their own.[229] In conclusion he stated, "This method of using officers and civilians for purely analytical work has proven fruitful in many fields, and the Army Air Forces should make use of it where appropriate."[230] General Arnold also directed that an Operations Analysis Division be created in Maj. Gen. Byron E. Gates' Management Control Division of the Air Staff. The necessary directive was issued, and OAD was established on 31 December 1942, with Leach, newly returned from England and promoted to lieutenant colonel, as its chief.[231]

According to Rau, the original plan was to assign OAD to Brig. Gen. McClelland's Directorate of Technical Services, but Col. Byron E. Gates, the assistant chief of the Air Staff

for management control, made a successful grab to add OAD to Management Control, which already supervised the Statistical Control Division.[232] The choice of the Management Control Division as the "home" for OAD was probably well reasoned inasmuch as the Management Control Division was the principal Air Staff element engaged in applying "scientific management" and statistical methods to the management of AAF. Leach's own take on the matter was given in his two-year report:

> There was never any theoretical justification for placing Operations Analysis under Management Control. But the Chief, Management Control had the vision to see the possibilities in an innovation which ran counter to basic military thinking. His willingness to give this organization a free hand and to put his full weight behind it when support was needed is the single most important factor in any contribution it has made to the Air Force.[233]

Lt. Col. Leach set up shop in Room 3D982 of the Pentagon and began to build OAD and a system of OA sections throughout AAF in accordance with the blueprint provided in the August 1942 report. OAD itself remained relatively small, but the number of OA sections formed and deployed to satisfy the requests of AAF commanders grew rapidly. The number of commissioned officers in OAD never exceeded three, although four were authorized.[234] The principal functions of OAD were recruiting and orienting analysts; establishing, equipping, and supporting the OA sections; maintaining liaison between AAF OA program and other OR activities; and publishing and distributing OA reports.[235] OAD also served as a temporary home for AAF analysts between field assignments.[236] Over time, some functions, such as overseeing the training of terminal ballistics experts and gunnery analysts, were delegated to other agencies.[237]

The AAF OA program was decentralized, and OAD exercised no operational control of the OA sections once they had been established. Under the circumstances, a large headquarters operation was not required, but Col. Leach expressed some misgivings, writing, "Some of this decentralization is healthy, but there has been too much of it. Moreover, the limited staff has prevented performance of some functions which ought to have been undertaken."[238] He conceded, however, that "at this stage of the war it is not believed that the basic set-up should be changed," but he did propose a larger organization in the event of "any subsequent war."[239]

Leach also experienced some disappointment in that two of his main recommendations relating to the coordination of Army and Navy OR efforts and liaison with OR elements in the British and Canadian forces were never implemented. In their report, Leach and Davidson had recommended the creation of a Joint Operations Analysis Committee under the Joint Chiefs of Staff, the purpose of which would be to ensure that OR activities in the two services were properly coordinated.[240] The proposed committee was to consist of one OR officer and one civilian OR consultant from each of the services. No such committee was ever formed, probably because of disinterest on the part of the Navy. Based on their discussion with Wing Commander A. C. Menzies, the head of the British Air Ministry Center of Operational Research, Leach and Davidson recommended the establishment of a liaison office in London to be called the American Operations Analysis Center to provide a focal point for contact between British and American operations analysis personnel.[241] The center also never emerged.

Operations Analysis Sections with Major Commands

The first six AAF "Op Annies" (civilian operations analysts) reported to the VIII Bomber Command in London on 15 October 1942.[242] Within a year after the formation of OAD, there were nine OA sections (employing some sixty-eight personnel) either in existence or requested by commanders in the field.[243] By V-J Day, there were more than twenty-five OA sections with more than four hundred officers, enlisted men, civilian analysts, and clerical personnel, many of whom had served in more than one theater of war.[244] Jansky's OA program in the Directorate of Air Defense continued to exist separately, but almost all other operations analysis units in the AAF came under the aegis of Leach's OAD.[245]

Most of the OA sections were assigned to AAF operational or training commands, but late in the war OAD-sponsored analysts were also attached to several other Air Force organizations. In mid-1945, General Arnold established five Air Evaluation Boards to conduct appraisals of AAF operations in the various theaters.[246] Each board consisted of a small group of officers and one Op Annie who was to assist the board in defining its scope, organizing its efforts, and writing its report. Leach recruited five lawyers to fill the Op Annie positions, and they were given a brief indoctrination and sent overseas. The five lawyers were George W. Ball (Europe), Stephen P. Duggan, Jr. (southwest Pacific), Ronald J. Foulis (Mediterranean), Norman Newmark (central Pacific), and Joseph E. Nolan (China, Burma, India).[247] Some of the boards made little use of their analyst, and Col. Leach expressed some chagrin for not ensuring that the analysts were wanted and that the presidents of the boards were fully aware of their usefulness in advance of their assignment.[248] Some of the boards employed civilian scientists to assist in their work. For example, William W. Whitmore, an instructor in physics from MIT, served with a group of seven other civilians from December 1944 to June 1945, preparing a report on the tactical bombing of the French railway system during the Normandy campaign.[249]

The United States Strategic Bombing Survey (USSBS) was established in 1944 to determine the effect of the Allied strategic bombing campaign on the Axis powers. The USSBS worked closely with the Air Evaluation Boards, and a few OAD-sponsored operations analysts were placed on loan to USSBS to help organize its work.[250] Only one analyst, Theodore Tannewald, Jr., was actually assigned to USSBS before the Japanese surrender, but several others joined the survey in Japan after V-J Day.[251]

In addition to his duties as chief, OAD, Col. Leach also served as a member of the committee of operations analysts, established by General Arnold on 8 December 1942 as the Advisory Committee on Bombardment.[252] Other members of the committee included a number of officers from the Air Staff, such as Leach's boss, Col. Byron E. Gates; Gates' deputy, Col. Guido R. Perera; and several distinguished civilians, including Elihu Root, Jr., and Dr. Edward M. Earle of the Institute for Advanced Study at Princeton.[253] The purpose of COA was to prepare a report on the progressive effect the Allied strategic bombing campaign was having on the German war effort, but COA "was really a steering committee for a small army of analysts."[254] The work of COA had an important influence in shaping the evolving strategic bombing campaign against Germany and Japan. As Secretary of War Stimson wrote to Army Chief of Staff Gen. George C. Marshall in December 1943, "the work of this Committee indicates that certain planning matters for specific operations can be effectively handled by this method although the usual operations analysis section deals primarily with tactical matters."[255]

No OA section was established except on request of the local commander whom it was to serve, and OAD functioned as an administrative support and coordination center without interfering in the day-to-day operations of the OA units.[256] Each OA section was tailored to the needs of its command, and each had a slightly different relationship with its commander, his staff, and subordinate elements of the command. In ideal situations, the chief of the OA section reported directly to the commander or to his chief of staff and the OA section enjoyed unrestricted access to all elements of the command without having to "go through channels."

Leach's principal difficulty was spreading the word about the benefits of OR to AAF commanders in the field. Once they learned of what OR might do for them, most AAF officers became wholehearted supporters of the concept.[257] AAF operations analysts encountered few of the problems of Navy OR workers regarding access to classified operational data.[258] Even so, as Leach noted:

> Quite naturally service officers somewhat hesitate to let civilians into the inner sanctum. . . . We emphasize that operations analysis groups can only be valuable if the commander to whom they are attached gives them a whole hearted cooperation which can come only from an informed enthusiasm for this type of help.[259]

Although each OA section was tailored to its command, in October 1943 AAF attempted to standardize the organization of the OA sections by issuing a Table of Organization and Equipment (TOE) prescribing the personnel and equipment authorized for OA sections assigned to Air Force headquarters and to bomber, fighter, air support, and air service commands.[260] This TOE provided for 6 officers (1 colonel, 2 lieutenant colonels, 2 majors, and 1 captain) and 10 enlisted men (1 master sergeant, 1 staff sergeant, 2 sergeants, 3 corporals, 2 privates first class, and 1 private). The authorized equipment included the usual array of small arms, entrenching tools, chemical protection gear, and office furniture and equipment, including a dictionary, a computing machine (mechanical adding machine), a paper-fastening machine (stapler), and one typewriter.

In recognition of the growing number of operations analysts in the field, the War Department published *Field Manual 30–27: Regulations for Civilian Operations Analysts, Scientific Consultants, and Technical Observers Accompanying U.S. Army Forces in the Field*.[261] The August 1944 edition of *FM 30–27* replaced the edition of 3 September 1942, which did not mention operations analysts. *FM 30–27* defined operations analysts, scientific consultants, and technical observers and prescribed their official status, privileges, discipline, uniform, indoctrination, travel, reports, and credentials. In general, operations analysts received the privileges of commissioned officers, and *FM 30–27* included a table of equivalent ranks to clarify the status of operations analysts in the event of their capture by the enemy.

The OA sections performed functions similar to those of the Navy OR groups. The principal function of each OA section was to analyze problems and advise the commander. The OA section had no operational or administrative duties or powers. Among the types of problems studied were bombing accuracy and techniques, bomb selection and fuzing, combat losses and damage, communications (including radar and radar countermeasures), aerial gunnery, aircraft operating ranges and fuel consumption, personnel matters, and training activities. The choice of topics for study was directed by the commander or generated by the OA section members themselves.

Personnel Issues

In December 1944, Col. Leach noted that "obtaining the able personnel is the secret of O.A. success and constitutes the most difficult problem."[262] Leach later defined the able person he was looking for as "a genius who hasn't forgotten that the answers to hard questions come by hard work and not by looking into a crystal ball. In picking men that's the

standard we shoot at. Sometimes we hit it."[263] The task was a daunting one; in all, OAD recruited, trained, deployed, and managed some four hundred professional and clerical personnel during World War II.[264]

OAD recruited personnel for the OA sections after consulting with the local commander to determine his needs and desires. In general, Col. Leach and most commanders preferred civilian analysts to those commissioned in AAF, although some commanders insisted that all of their analysts be commissioned officers.[265] As Leach and Davidson noted in their report:

> The need for civilian analysts is a war-time military and naval need of a country which undermans and underfinances its armed services in time of peace. When war comes every officer of superior ability is needed for important operational and administrative posts, and the supply is inevitably less than the demand. In any post or command the operational needs of the moment and the problems of administration, personnel and supply absorb the time and energy of the commander and his staff. Therefore no time left to analyze new weapons or the many intelligence and operations reports coming in.[266]

Responding to the questions of a journalist near the end of the war, Col. Leach repeated his main argument for civilian rather than uniformed operations analysts:

> The great difficulty is that these officers are so inevitably absorbed with carrying out today's mission and planning tomorrow's they simply don't have the time and uninterrupted attention which most of these matters require. And that's where the Operations Analysis Sections come in.[267]

The reasons for keeping the Op Annies in civilian status were that civilians could deal more effectively with all ranks, did not compete with staff officers, could not be diverted to other military duties, could be more easily dismissed if unequal to the tasks at hand, did not need to meet the rigid physical standards required of commissioned officers, could not be commissioned easily under existing officer procurement regulations, and normally refused to accept a commission anyway.[268]

Of course, Leach conceded that under certain circumstances it might be necessary to put operations analysts in uniform, particularly when they were assigned to the overseas theaters where they ran some risk of capture by the enemy. In any event, Op Annies in the theaters were required by theater regulations to wear uniforms without insignia. Consequently, they were often mistaken for war correspondents or USO entertainers. One OA section chief was approached by a sergeant who asked, "What instrument do you play, bub?"[269]

Leach and other leaders in the AAF OA program did not share the bias of the British and the U.S. Navy for scientists as analysts.[270] In fact, as a practicing lawyer, Leach had a positive preference for lawyers to lead the various OA sections.[271] In any event, by coming late into the field, AAF program managers found it difficult to find qualified scientists who were not already employed in the Navy OR program or other essential war work. As Capt. Hall opined:

> The fact that the abilities of certain civilians are not presently being utilized in the war effort would be merely a regrettable circumstance were it not for the fact that there appears to be more than a fair chance that they could be of real help to the Army in the conduct of the war.[272]

Leach therefore looked elsewhere.[273] Of the 180 analysts employed by AAF on 1 December 1944, 14 (including some scientists) were university presidents or heads of university departments or research labs, 71 were scientists or engineers, 37 were mathematicians or statisticians, 23 were educational administrators, 17 were lawyers, 11 were university faculty members (other than scientists), 3 were economists, and 5 were drawn from various branches of industry.[274]

In their August 1942 report Leach and Davidson noted that there should be an organization to assume the administrative details of personnel management and pay for operations analysts but that "there is no existing organization or method of employment that fits the prescription even approximately."[275] Among the alternatives they considered and rejected were employment through the civil service, per diem contracts, an OSRD contract with a university or other research organization, commissioning of analysts in the Army Specialist Corps or in AAF, and the President's Emergency Fund.[276] All of the alternatives seemed to pose substantial problems, and Leach and Davidson recommended the creation of a personnel management corporation that would operate under a contract with the secretary of war.

Early on, Leach had hoped that recruitment and personnel management for the OA sections could be handled under a contract between the secretary of war and a private nonprofit corporation, preferably the National Research Council.[277] When negotiations with the council fell through, Dr. Frank Aydelotte of the Institute for Advanced Study at Princeton University expressed interest in providing the necessary corporate entity, but Leach rejected the offer after considering the physical difficulties of conducting business between Washington, D.C., and Princeton, New Jersey.[278] Instead, he discussed the matter with Harold N. Marsh, a Washington lawyer who agreed to set up a corporation in the District of Columbia to be known as Special Services, Inc., that would undertake the task of managing AAF OA personnel, and Leach himself bankrolled the establishment of the corporation.[279] That arrangement apparently failed to get the approval of the secretary of war. Vannevar Bush at OSRD also declined to help Leach by arranging a contract with a university or research center along the lines of the contract between ASWORG and Columbia University.[280]

By September 1942, Leach's attempts to set up a corporation to handle OA personnel management assumed some degree of urgency inasmuch as the analysts sent to the Eighth Air Force were working on per diem consultant appointments limited to 180 days by Secretary of War Administrative Order No. 50, dated 29 August 1942.[281] Having failed to arrange for a contract for management of AAF operations analysts, either through OSRD or on an ad hoc basis, Leach was compelled to hire all AAF analysts as special consultants on a per diem basis limited by law to no more than $25.[282] The actual per diem rate (up to the $25 maximum) was determined by considering an analyst's previous civilian salary and an additional allowance for uniforms, equipment, and the extra cost of insurance plus a subsistence allowance for living away from home. Special measures had to be taken to ensure that the overtime pay of $628.32 to which analysts were entitled as civilian employees of the AAF did not result in a net gain in compensation to the analyst. As Col. Leach noted, "Adherence to the salary policy . . . has been extremely difficult in view of the competition of laboratories, industrial companies and the Office of Field Service of OSRD."[283] In fact, competitors of the AAF, including OSRD, professed the "no-gain, no-loss" policy but found creative ways to provide "fringe" increases that gave them a recruiting advantage. Even so, the salaries of civilian analysts working for the AAF exceeded the direct salary and allowances of commissioned personnel and thus sometimes caused problems in working relationships at the unit level. Leach called the resolution of this problem "one of the major headaches of administration of Operations Analysis."[284]

The overall costs of the AAF OA program were substantial. As of 1 December 1944, the annual cost of OAD alone was $36,114.80 ($22,460 in officer's pay and allowances and $13,654.80 in clerical salaries).[285] The cost of the OA sections in the United States and overseas was $1,162,241.44, including $932,955.70 in civilian analyst salaries, $91,961.74 in officer pay and allowances, $127,324.00 in enlisted personnel pay and allowances, and approximately $10,000 in salaries for civilian clerical personnel.[286] Travel expenses amounted to roughly $400,000, making the total annual cost of the program approximately $1.75 million.

Relations with OSRD

The Navy got on well with Vannevar Bush and OSRD, in large part because the Navy OR program was fairly limited, was organized on the traditional scientific "functional" basis, relied on scientists for analytical work, and had a relatively troublefree contractual arrangement with Columbia University. Leach and OSRD, however, had a much rockier relationship.[287] In the first instance, Leach was an enthusiastic promoter of OR, envisioning a rather expansive OA program for AAF, and thus clashed with Bush's desire to minimize the effect of OR on the relationship between science and government. Moreover, the AAF program was organized along command lines, and AAF operations analysts were more closely controlled by commanders in field. The AAF program also represented a potentially significant drain on scarce scientific talent already employed by NDRC and OSRD. As a well-known scientist, Morse at ASWORG was able to do a lot of his own recruiting by virtue of knowing the potential recruits either personally or by reputation; OSRD had only to administer them, and Bush's own "stable" was not seriously affected. Leach, however, was late on the field and sought to impose significant recruiting burdens on NDRC/OSRD. Then, too, Leach had no convenient contractual arrangement for the management of AAF analysts and thus represented another potential drain on OSRD time and effort. Significantly, Leach and his AAF OA colleagues did not share the Navy and OSRD preference for scientists for OR work. As a lawyer, Leach was not a member of the scientist "club" and thus raised hackles at OSRD, particularly those of Vannevar Bush. When Leach saw to it that the distinguished New York lawyer John M. Harlan was named to head the Eighth Air Force OA section in October 1942, Bush moaned to Karl T. Compton, the president of MIT:

> Now it appears that Leach has probably gone too far. I fear that after my conversations he has fallen into the fallacy that so many attorneys have of trying to establish a dependent relationship between legal and scientific personnel rather than a partnership. . . . I hope that I can aid him . . . to avoid this pitfall along with some others.[288]

Many of Bush's colleagues at OSRD did not share his disdain for OR and worked actively to involve OSRD in the Navy and AAF programs, perhaps even to bring them under the wing of OSRD. For example, Dr. Alan T. Waterman pushed for an OSRD-sponsored OR program that would take over many of the administrative and training functions that plagued Col. Leach.[289] Shortly before the creation of the OSRD Office of Field Service in October 1943, Col. Leach let it be known that, unlike ASWORG, the AAF OA program would not be placed under OFS control.[290] Leach did not want to reorganize the AAF program along functional lines, and he emphatically disagreed with the OFS policy of rotating analysts between field assignments and laboratory work. Leach's opposition, in the words of Erik Peter Rau, "summarily crippled most of Waterman's ambitions for operations research. Leach restricted the OFS role in Air Force OR to recruitment and training, precisely the limitation many OSRD staff members had wished to avoid."[291]

Despite his opposition, when OFS was created under Karl T. Compton in October 1943, Leach tried again to work through OSRD to meet AAF OA personnel needs,

but the issue of temporary versus permanent assignment of OFS analysts to AAF field commands remained a sticking point, and Leach subsequently returned to per diem contracts arranged by his office.[292] After two years of experience, in December 1944, he addressed the problem at some length (and with obvious frustration):

> It was to be expected that the Office of Scientific Research and Development would be most helpful in securing able scientific personnel. This proved not to be the case. This Division insisted upon the following as basic personnel policies:
>
> (a) That analysts would be employed and paid by the Air Forces.
> (b) That analysts should undertake a term of service which was indefinite in duration and would end only when, in the judgment of the [commanding general] to whom an analyst was assigned, the job was completed. Ordinarily this would mean employment for the duration.
> (c) The analyst must have but one loyalty—to the Air Force to which he is attached; he may communicate with his previous employer, OSRD or scientific laboratories only as permitted by his Commanding Officer and then only through channels.
> (d) He must be prepared to accept a commission in the Army of the United States if requested to do so.
>
> The Office of Scientific Research and Development declined to furnish personnel to the Operations Analysis effort in the Air Forces to be employed in accordance with the above-stated policies. Instead, OSRD set up an "Office of Field Service" (OFS) which offered to employ scientists and loan them to the Air Forces for three- to six-month periods. The use of personnel thus employed was tried on a sufficient scale to constitute a fair experiment; the experiment proved that this method of handling personnel was not satisfactory. This attitude of OSRD has been a serious handicap to the Operations Analysis program. There is much more to be said on this subject, and at some future day it should be said in such a way as to promote a more effective handling of scientific and technical personnel in the next war and between wars.[293]

The relations between the AAF OA sections and OSRD were not entirely negative. Technical training for AAF operations analysts was provided through arrangements with NDRC/OSRD at the Radiation Lab at MIT, the Radio Research Lab at Harvard, and the NDRC Division 2 and Applied Mathematics Panel. The Princeton University Station under John E. Burchard's Division 2 of NDRC offered courses of six to eight weeks on a variety of mathematical, physics, and photographic interpretation/bomb damage assessment subjects to small groups of four to six analysts.[294] Burchard and Division 2 also helped OAD recruit and train specialists in terminal ballistics to serve in the overseas OA sections.[295] The NDRC Applied Mathematics Panel chaired by Warren Weaver assisted OAD with the recruitment of more than twenty mathematicians and the organization of their training in aerial gunnery prior to their deployment to overseas OA sections.[296] The panel also helped the OA sections in the field directly with the analysis of certain bombing operations.[297]

OA Section, U.S. Eighth Air Force

It is simply impossible to discuss individually here the organization, personnel, operations, and accomplishments of each of the OA sections established by the AAF in World War II, but the OA section, Eighth Air Force, merits attention as both the earliest and the largest of the AAF OA sections.[298] In many ways, the problems faced by the OAS Eighth Air Force—and the solutions it found—were representative of those of the other AAF operations analysis sections.

During a visit to England in June 1942, Cyril M. Jansky, Jr., of the AAF Directorate of Air Defense, was approached by Brig. Gen. Ira C. Eaker, the commander of the VIII Bomber Command, who had observed OR in action in RAF Bomber Command. Brig. Gen. Eaker expressed to Jansky his desire for operations analysts.[299] This raised the question of whether the Eighth Air Force should have a separate OR team or whether American analysts ought to be seconded to ORS RAF Bomber Command, which would then serve both Eighth Air Force and RAF Bomber Command.[300] Ultimately, the decision was to form an American OA unit. In August 1942, Maj. Gen. Carl Spaatz, the commander of the Eighth Air Force, acting on the advice of Brig. Gen. Eaker, wrote to AAF commander General Arnold and to Vannevar Bush asking for their help in forming an OR unit within the Eighth Air Force.[301] The request was approved, and the task of assembling the group fell to Maj. W. B. Leach, who was aided by Dr. Ward F. Davidson. Maj. Gen. Spaatz had asked for fifteen analysts, but that was considered too many to start with, and the group assembled by Leach and Davidson, with some reluctant help from OSRD, consisted of six men led by the distinguished New York lawyer John M. Harlan.[302]

The six newly minted Op Annies arrived in England on 15 October 1942, accompanied by Brig. Gen. McClelland, the AAF director of technology, and Maj. Leach. On 22 October, they reported to by then Maj. Gen. Eaker at Headquarters, VIII Bomber Command, at Wycombe Abbey near London. Dr. B. G. Dickins and ORS RAF Bomber Command helped the new OA section settle in, and the two groups subsequently maintained close personal and professional contacts.[303]

On 23 October 1942, Maj. Gen. Eaker issued a directive concerning the organization and mission of the OA section, stating that it would work directly under his chief of staff and would have access to all information and elements of the command.[304] Eaker also gave Harlan a list of the projects to be undertaken and personally set the new OA section its first task when he asked the simple question, "How can I

put twice as many bombs on my targets?"[305] Answering this question and its correlatives became the primary mission of the OA section for the rest of the war.

Although seemingly simple, Maj. Gen. Eaker's question involved the investigation of many diverse interrelated factors. The section immediately began analytical work and was soon deeply involved in studies on bombing accuracy, bombing tactics, flight procedures, weapons selection, aircraft battle damage, radar, fuel consumption, and other topics.[306] To organize the work efficiently, the OAS VIII Bomber Command was divided into seven subsections: Bombing Accuracy, Bombs and Fuzes, Loss and Battle Damage, Radar and Radio Countermeasures, Gunnery, General Missions Analysis, and Tactical Mission Reporting.[307] The Bombing Accuracy subsection gathered data, established standards, and developed more-effective bombing tactics. The Bombs and Fuzes subsection studied the effects of various bomb and fuze combinations on various targets and recommended more-effective selection of weapons. The Loss and Battle Damage subsection collected data, studied the effects of enemy weapons on Eighth Air Force bombers, and recommended tactical and technical methods of reducing the number of aircraft damaged or lost to enemy flak and fighters or to accidents. The Radar and Radio Countermeasures subsection investigated radar bombing methods and equipment as well as means of foiling enemy radar and enemy jamming. The Gunnery subsection studied aerial gunnery techniques and ways to improve the effectiveness of Eighth Air Force gunners. The General Mission Analysis subsection was established to handle nonrecurring problems and undertook two major projects: producing the day raid reports and conducting a study of fuel consumption that resulted in significant reduction in the number of aircraft lost because they ran out of fuel. The Tactical Mission Reporting subsection rationalized debriefing forms and mission after-action reports.

Inasmuch as the work of the OA section pertained to the Eighth Air Force generally, it was transferred from VIII Bomber Command to Eighth Air Force control when Maj. Gen. Eaker replaced Lt. Gen. Spaatz as Eighth Air Force commander in December 1942.[308] In June 1943, an OA section headed by Lauriston S. Taylor was formed in the VIII Fighter Command, the mission of which was to protect the Eighth Air Force bombers and to provide training for the elements of Ninth Air Force then forming up in England.[309] In May 1944, small OA teams were authorized for each of the three subordinate air divisions of VIII Bomber Command, and, once formed, the Air Division OA section cooperated actively with OAS Eighth Air Force.[310]

The OA section grew quickly, and by 1 January 1944 it employed thirty-five operations analysts with another seven assigned to the three subordinate air divisions. In addition to the thirty-five Op Annies, the section also had fifty-six other personnel, including clerks, draftsmen, and stenographers, as well as a detachment of female soldiers (WACs), for a total strength of ninety-one.[311] By the end of the war, some forty-eight uniformed and civilian operations analysts had served with OAS Eighth Air Force.[312]

Accomplishments of AAF Operations Analysis Sections

Although the AAF operations analysis program in World War II produced no Nobel Prize winners, the Op Annies contributed substantially to winning the war and made important advances in the new science of operations research. As Col. Leach noted after the war, "the accomplishment of the OA Sections is almost impossible to evaluate. OAS was a part of the team in its Air Force. Who can say whether a touchdown is attributable to the half back, the tackle or the coach?"[313] Indeed, each of the AAF OA sections was part of a larger team that included the staff, the air and ground crews, and the administrative and support personnel of the command to which it was assigned. The improvements suggested by the OA sections in bombing accuracy, more-effective tactics, better aerial gunnery, fuel conservation, and the like had an enormous effect on AAF mission performance, and, as one journalist noted toward the end of the war, the analysts'"practical, precise studies . . . have not only been instrumental in making the AAF a more effective fighting machine but have saved countless lives in the process."[314] The problems studied and the solutions found by AAF operations analysts during the war were many and varied, and the list of specific accomplishments is long.[315]

One historian has noted that"the most distinct contribution of the Eighth Air Force OA section was its work in measuring the accuracy of visual formation bombing."[316] When the first OA section arrived at the VIII Bomber Command in October 1942, fewer than 15 percent of the command's bombs were falling within 1,000 feet of the aiming point; by October 1944, the command's performance had improved to greater than 60 percent, a fourfold increase in accuracy that "meant that in 1944 250 bombers were doing the work which in 1942 would have required more than 1000."[317] OAS VIII Bomber Command analysts also recommended putting the best bombardier in the lead plane and having everyone else "bomb on the leader," a method that resulted in a substantial improvement in accuracy, the length of bomb patterns being reduced from 4,600 feet to 3,200 feet and the width being reduced from 2,600 feet to 2,500 feet.[318] In all, the improvements in bombing accuracy inspired by OAS Eighth Air Force more than satisfied Maj. Gen. Eaker's initial request to find out how to get twice as many bombs on the target; the overall increase was probably far greater than 1,000 per-

cent.[319] The work of W. John Youden, Lt. Col. Philip Scott, and James A. Clarkson of OAS Eighth Air Force on bombing accuracy led to the development of bombing tactics and procedures that subsequently became the standard doctrine for AAF in World War II.[320] The analysts at OAS Eighth Air Force also were active in work on radar countermeasures, a topic of interest to the British and to Division 15 of NDRC as well. One estimate is that more-effective Allied radar countermeasures saved U.S. strategic air forces based in England alone some 450 aircraft and 4,500 casualties.[321]

OAS Ninth Air Force also conducted a number of bombing accuracy studies that led to a threefold increase in accuracy.[322] Target analysis studies by Derald M. West and Leonard H. Reinke at OAS Ninth Air Force led to more-efficient selection of weapons and tactics as well as more-accurate estimates of force requirements.[323] Clifford H. Dowker and Roger Hayward at OAS IX Bomber Command, together with George W. Taylor, the chief of OAS Fourteenth Air Force, developed "position firing" and prepared the basic AAF aerial gunnery manual, *Get That Fighter*, which was subsequently adopted by the Navy, the Marine Corps, and the Chinese Air Force.[324] OAS IX Bomber Command analysts in Libya also discovered a magnesium brine in the salt lagoons near Benghazi that could be used to stabilize the dust on airfields in Libya with consequent reduction of engine wear, saving perhaps the equivalent of fifty B–24 engines.[325] At OAS Fifteenth Air Force, George W. Housner made an analysis of underground oil storage tanks in the Vienna–Lobau area and concluded the tanks did not have bombproof covers—thereby facilitating a successful attack against them—and Robert N. Davis flew over the Ploesti oil fields and took the first radar pictures ever taken in combat.[326]

In the Pacific, Alexander Green of OAS XX Bomber Command invented a sliderule-type device for estimating the size of sighted ships and used it on its initial test flight to identify the battleship *Yamato* and the main Japanese fleet in the Inland Sea, thereby precipitating the battle that finished the Japanese Imperial Navy.[327] Roger I. Wilkinson at OAS Thirteenth Air Force also developed effective methods for attacking moving ships from low altitudes using radar.[328] At home, William J. Crozier and Charles L. Foley of OAS Second Air Force discovered that the carbon dioxide fire extinguishers used on most AAF aircraft actually fed rather than extinguished fires in the magnesium engines of the B–29, a discovery that led to changes that saved a number of B–29s and their crews.[329]

The contributions of AAF operations analysts to the development of OR theory and procedures are little mentioned in the sources, but they too were no doubt substantial.[330] The analytical problems presented to AAF analysts were in their own way as new and complex as any faced by the British ORS or the Navy ORG, and the Op Annies were equally successful in finding innovative methods for dealing with them.

Two AAF operations analysts made the ultimate contribution. Widnell D. Knott of OAS Second Air Force was killed in the line of duty on 3 September 1944, and Robert W. Arneson, the only Op Annie combat casualty, was killed in action in the Pacific on 5 May 1945.[331]

The success of AAF OA sections can be measured in part by the awards they received and the tributes paid to them by the AAF commanders they served.[332] On 2 November 1943, the commander of the IX Bomber Command informed General Arnold that

> the Operations Analysis Section has made important contributions to the effectiveness of operations in this command. These people attack problems by rational methods with a detached viewpoint which apparently makes it possible for them to discover solutions which tactical personnel have overlooked or have not had the necessary uninterrupted time to develop.[333]

In a memorandum to Col. Leach written less than a year later, General Arnold acknowledged that

> Operations Analysts, comprising some of the ablest analytical minds of the country, have served in all Air Forces at the request of the respective commanding generals. They have made a significant contribution to the impact of American air power upon the enemy and the excellence of their work has been commended in official communications.[334]

On 29 May 1945, Maj. Gen. W. E. Kepner, the former commander of the VIII Fighter Command and the Second Air Division and then commander of the Eighth Air Force, wrote to Maj. Gen. Eaker:

> We feel that our OAS contributed heavily to the success our mission. As a group of scientifically trained civilian specialists, they brought capable and enquiring minds to bear on a host of operational problems. The freedom which they enjoyed from military regimentation enabled them to deal directly with all ranks and echelons in the Air Force with no lost motion. They tackled with avidity any and all problems thrown at them and, in the majority of cases, came up with the right answer.[335]

OR in the United States Army Service Forces, 1942–45

The Marshall Reorganization of March 1942 placed the Army's technical services in the newly created Army Service Forces. The Army's "scientific" branches—the Ordnance Department, Medical Department, Signal Corps, and Chemical Warfare Service—had long been accustomed to conducting scientific research and analysis as part of their responsibility for the design and testing of weapons and equipment. Such work often involved techniques of mathematical and statistical analysis that today we would consider

part of the "weapons design" branch of operations research. Until World War II, it did not, however, extend to the collection and analysis of operational data for the purpose of making recommendations as to improvements in weapons, tactics, or strategy. And, during World War II, only the Signal Corps tried to establish anything called an OR section, and even then the work done was primarily of the engineering analysis variety.

Operational Research Branch, Office of the Chief Signal Officer

Sir Robert Watson-Watt's survey of U.S. air defenses and his April 1942 report attracted the attention of AAF commander General Arnold and led to the formation of operations analysis sections in AAF. The Army Signal Corps bore primary responsibility for radar development, the most prominent area in which British OR analysts had achieved success. Watson-Watt's report thus also caught the eye of the Army's chief signal officer, Maj. Gen. Dawson Olmstead, who directed his planning director, Col. Frank C. Meade, to set up an OR group.[336] On the recommendation of Dr. Frank B. Jewett of the National Academy of Sciences and Dr. Karl T. Compton of MIT, Col. Meade selected Dr. William L. Everitt to head the Signal Corps program, and Everitt was duly appointed in March 1942 as a civil service employee, grade P–8.[337] Everitt's official title was "senior consultant in air communications," but he also held the titles of "special consultant to the secretary of war" and "scientific advisor to the chief signal officer." In contrast to his several exalted titles, Everitt's civil service pay amounted to only $8,000 per year, about one half of his previous annual income.[338]

Soon after his appointment, Everitt toured the country examining radar sites, factories, and research facilities before accompanying Cyril Jansky on a one-month trip to England where they studied British OR programs firsthand. He then returned to the United States to organize what came to be called the Operational Research Branch, Office of the Chief Signal Officer (ORB OCSigO).

The functions of ORB OCSigO included the analysis of various problems having to do with radar equipment and its use as well as the training and selection of radar personnel. As such, the branch more closely resembled an engineering consulting firm than a true OR section.[339] Another important task undertaken by Everitt's group was the preparation and publication of manuals, equipment handbooks, and other training materials in the radar, radio, and wire communications field.[340] Everitt himself noted that ORB "studies the operations and operational procedures from a detached engineering viewpoint and suggests to the operating groups new and better improved methods aimed at a better overall Signal Service."[341]

Everitt drew up a rather rigid, detailed organizational plan for the group based on its assigned functions and detailed job descriptions for the personnel he planned to hire. The organizational scheme foresaw Everitt as the director aided by an associate director in overseeing six subordinate units each headed by an assistant director and employing one to five engineers or scientists and a team of clerks, stenographers, and draftsmen. Overall, Everitt's plan called for the employment of twenty-five professional and nine clerical personnel, all of whom he intended to hire through the civil service. It was here that he ran into serious problems. The civil service rules and procedures were restrictive, cumbersome, time consuming, and totally unsuited to the type of organization required.[342] The hiring of the necessary professional personnel through the civil service was also hampered by the fact that the civil service regulations set salary levels based on the number of subordinates one supervised rather than on the technical qualifications required, and many well-qualified prospects declined the offer of a job under such conditions. Nevertheless, Everitt persevered and hired six experienced radio engineers at various civil service grades from P–5 to P–7.[343] By October 1943, Everitt's group had grown to twenty-eight people.[344]

Once organization and hiring were under way, Everitt drew up a list of six potential projects, all of which were essentially engineering studies concerned with radar operation, performance, maintenance, and the training and performance of radar operators. Only Project ORG–E–1 (which dealt with the operation of air-surface vessel detection equipment and the planning of flights so as to get adequate coverage) even bordered on real OR.[345]

Several Army agencies were concerned with the development and use of radar, and the work of Everitt's group inevitably intersected with other radar-oriented activities. He maintained close contact with other Signal Corps offices, notably the Radar Division headed by Maj. Charles F. Fell (also in the Directorate of Planning) and Col. Tom C. Rives' Radar Division in the Signal Supply Service. Inasmuch as AAF was a prime user of radar and the AAF air defense system was based on it, Everitt's ORB OCSigO also had extensive contacts with Jansky's OA section in the AAF Directorate of Air Defense. To avoid duplication and working at cross purposes, Everitt and Jansky worked out a memorandum of agreement as to the division of responsibilities between their two groups. The memorandum, signed on 9 May 1942, defined the function of Everitt's group as "to provide a consulting engineering service which can assign a group of technical specialists to analyze the technical operating problems involved in the proper functioning of the Radar and Air Communications Systems," and to use field experience to advise the research and manufacturing establishments on

changes to present and future equipment, to advise training centers and schools on the selection of personnel and curricula to obtain the maximum technical performance from the available equipment, and to serve as general consultant to the chief signal officer on engineering problems.[346] Provisions were also included for ORB OCSigO to provide consulting engineering services when Jansky's personnel in the field were unable to deal with special problems. Everitt and the ORB also worked closely with Col. Leach and OAD. The two groups assisted each other with the procurement and training of OR personnel, liaison, and the coordination of a wide variety of OR matters.[347]

The ORB OCSigO also had a working relationship with NDRC and OSRD, primarily in the area of training for radar operators.[348] Despite Everitt's apparent belief that the average American lacked the ability to be trained for radar work in a few weeks, John Teeter of OSRD developed a two-month program for Signal Corps radar specialists headed for OA assignments. The students received "basic training" with Everitt and his deputy, Lynne C. Smeby, in Washington, D.C., and then went to the AAF School of Applied Tactics in Orlando, Florida; the Radar Operators and Maintenance School at Boca Raton, Florida; and, with stops at Langley Field and Fort Monroe in Virginia and one day in New York City, on to the Radiation Lab at MIT and the Radio Research Lab at Harvard.[349]

ORB OCSigO made many important contributions to the effective use of radar by the U.S. Army and Army Air Forces, not the least of which was the publication of a multitude of technical and training manuals. Inasmuch as their work was almost entirely technical, it remained, as previously noted, more on the order of an engineering consulting firm than a real OR organization, and the branch's contributions to the development of OR theory and procedures were negligible.

Operational Analysis Branch, Signal Section, HQ European Theater of Operations

In the spring of 1944, Col. (later Maj. Gen.) William S. Rumbough, the chief signal officer of the European Theater of Operations, requested the assignment of an operational analysis section to his office.[350] The purpose of the group was "to prepare staff studies and surveys on the technical feasibility of new operational uses of Signal Corps equipment, submit recommendations for the improvement of existing systems based on theoretical analysis of operational results, and furnish an engineering consultant service on problems concerning radiation propagation and electronics."[351]

The request was approved, and Dr. Everitt of ORB OCSigO selected the personnel for the team and then placed them under contract with the Office of Field Service, OSRD. The initial group consisting of Karl R. Spangenberg, O. M. Covington, and the section chief Royal V. Howard reported to Headquarters, European Theater of Operations, United States Army (ETOUSA) on 23 July 1944, and by the end of September they were joined by Lucien L. Farkas, Robert A. Fox, Eugene O. Pack, and Carl C. Bath.[352]

During the period 23 July 1944 through 20 May 1945, the branch, led by Howard and then Farkas and billeted in Paris, completed some thirty-one separate assignments, including work for the Twelfth Army Group, the First, Third, and Ninth U.S. Armies, and the Combined Intelligence Office Survey. Most of their work dealt with radar, but they also studied identification friend or foe systems, captured German signal equipment, guided missiles, and radio production facilities in France. Their duties occasionally brought them under enemy fire.

The degree to which the activities of the ETOUSA Signal Operational Analysis Branch constituted engineering work rather than OR is testified to by Karl R. Spangenberg, one of the original team members who later noted that the group did useful work, although the nature of that work was not as originally contemplated (that is, not to act in part as an OA group) and that, although difficult, it would have been both possible and desirable for it to act as an OA group.[353] In fact, Spangenberg terminated his assignment to the group and departed for the United States on 3 October 1944, writing in his after-action report to OSRD, "Inasmuch as I am not a service specialist, as there was not prospect of doing any operations analysis, and as there is not immediate prospect of further investigational work, I terminated my activity."[354]

The Army Ordnance Department

The World War II–era Army Ordnance Department was responsible for the design, testing, and maintenance of weapons, ammunition, and tank and automotive equipment. Its activities were conducted in a number of laboratories and testing sites throughout the United States and they involved a good deal of mathematically based scientific research on design and performance characteristics. Many analysts who have served in the Army's OR program since World War II assert that the Ordnance Department, and in particular the Ballistic Research Laboratories (BRL) at Aberdeen Proving Ground in Maryland, was deeply involved in OR during World War II. Unfortunately, the documentary evidence does not support such an assertion.[355] Even so, scientists at BRL undoubtedly used a variety of mathematical and statistical techniques in their work on the design and testing of the weapons systems, ammunition, and tank and automotive equipment for which they were responsible, and some of their activities certainly bordered on OR even as it was defined in World War II.

Aberdeen Proving Ground was established in August 1917 as an ordnance test facility, and, in December 1938, its Research Division was redesignated as BRL. In 1940, the BRL was fully organized with 65 personnel and an annual appropriation of $120,000; by V-E Day, BRL staff had increased to 729 people and the annual appropriation to $1.6 million.[356] The BRL was under the direction of an Ordnance Corps officer. From 1938 to 1941, the director was Col. H. H. Zornig, and, from 1941 to 1949, Lt. Col. L. E. Simon served in that position.[357] The mission of BRL was to conduct basic and technical research in ballistics and the related fields of physics, chemistry, mathematics, and engineering. Among the tasks undertaken were weapons systems development; quality control; the development of computing techniques; the preparation of ballistic tables for guns, bombs, and rockets; and provision of information regarding the effects of various weapons when used in combat. To organize the work more efficiently, BRL formed sections to deal with interior, exterior, and terminal ballistics and the like. An internal advisory council assisted the director, and a scientific advisory council of twelve eminent American scientists was formed in 1940 to provide advice and help with the recruiting of scientists. One of the principal functions of BRL was the preparation of ballistics firing tables for various weapons and ammunition as well as aerial bombs. The BRL workload in this area increased greatly during World War II, and a substantial portion of the BRL effort was directed to testing weapons, ammunition, and bombs and computing firing and bombing tables. Another major BRL function was the surveillance of ammunition, and during the war BRL scientists developed reliable sampling techniques that significantly improved the quality control of stockpiled ammunition.

BRL also provided other technical information and assistance to troops in the field. For example, BRL trained and deployed technical service teams to calibrate guns in the field. This work, too, expanded exponentially between 1941 and 1945, and BRL research work was set aside to solve more-pressing practical problems. The technical analysis assistance provided by BRL to the Army and Army Air Forces in the field included studies to determine the optimum bomb pattern to ensure a high probability of destroying a target on a single bombing run, the development for the Army in the Pacific of a special artillery fuze that would not explode when hitting jungle treetops, the vulnerability of the German 88-mm. gun to fragmenting shells, the reduction of sight errors and dispersion of aerial gunnery, and computation for the Army and Navy of new ballistics tables that would help ensure the destruction of concrete pillboxes.[358] Toward the end of the war, BRL also conducted a series of experiments on the vulnerability of U.S. aircraft. All of these activities involved the collection of test and operational data, analysis of the data using mathematical and statistical methods, and the production of recommendations for new weapons, ammunition, and fuzes, or the improvement of existing materiel and corresponding means of improving techniques. As such, they probably qualify as operations research under the definitions now accepted.

The testimony of several scientists who worked at BRL during the war also lend credibility to the claim that BRL was involved in OR. In an oral history interview conducted in April 1992, Arthur Stein, who first began work at BRL in October 1941, stated that in the early days of the war BRL adopted a multidisciplinary approach to problems, many of which were varieties of optimization problems.[359] Stein related that some of his assignments at BRL "were very interesting and might have been called operations research if that discipline existed."[360] On the other hand, he also stated that, to his knowledge, "there had been no work on the kinds of operations research that dealt with large forces."[361]

Another BRL employee during the World War II period and after was Frank Grubbs, who served as an Ordnance Corps officer during the war and was first assigned to BRL in 1941. He remained there, with a short break, until the end of 1946.[362] In an oral history interview, Grubbs recalled that "military operations research got started with a group in the BRL called [the] Advisory Council. It consisted of a director of the BRL and the laboratory chiefs, and associate technical directors." Grubbs went on to state that OR began in the Advisory Council's investigations regarding the infantry rifle and expanded to the study of artillery and other items, eventually resulting in the introduction of the weapons systems analysis function at the lab.[363] Grubbs' testimony is somewhat problematic in that the activity he describes as OR and the Weapons Systems Laboratory were postwar additions to BRL. In his interview, the distinction between wartime events and those that occurred in the immediate postwar period is sometimes unclear.

The available evidence thus seems to lead to the conclusion that, although BRL was involved in a number of what might be termed proto-operations research activities, there was no sustained and distinct OR activity in the Ordnance Department in World War II. Of course, the successful application of OR to other military activities during the war led to its widespread adoption throughout the Army, including the Ordnance Department, in the postwar period.

Other Army Service Forces Elements

The World War II–era Chemical Warfare Service (later renamed the Chemical Corps) was responsible for the development and use of chemical (gas) and flame weapons and defenses against such weapons. Of course, there were no ac-

tive chemical operations by U.S. forces during World War II, and, as is the case with the Ordnance Department, there is no documentary evidence to support the conclusion that the Army's Chemical Warfare Service conducted any sustained or distinct OR activities during World War II. However, the Chemical Warfare Service apparently did ask the NDRC Applied Mathematics Panel for assistance in calculating the number of gas bombs of a given type required to produce a minimum gas concentration over a specified area in a certain time, a task that no doubt required the application of OR-like methods.[364]

The Army Medical Department was responsible for evacuating and treating casualties and for providing medical equipment and supplies. As part of its responsibilities, the department conducted extensive medical research, including research that today might be included under the general heading of OR of the "human performance" variety. Although few details are available, a twenty-man group composed primarily of Medical Corps officers, went to Fort Knox, Kentucky, in early 1942 to conduct studies on the performance of armored crewmen.[365]

OR in the United States Army Ground Forces, 1942–45

The application of operations research techniques to the improvement of the equipment and tactics of Army ground forces lagged behind their application to air and naval operations. This was true in Britain as well as in the United States, although by the end of the war the British had several OR sections assigned to its ground forces and doing important OR work. No. 2 ORS was assigned to Field Marshal Bernard Law Montgomery's 21. Army Group, and the chief of No. 2 ORS noted in his after-action report that the application of scientific methods to the development of weapons was well established by World War II, but

> the complexities of military tactics proved for a long time intractable, since even the smallest battle is a bewildering compound of variables, and new methods had therefore to be worked out before there could be any hope of results. . . . For the superficial details of battle may be altered in a moment by the introduction of a new weapon, while the underlying principles of warfare scarcely change from one century to the next.[366]

From early 1942, U.S. Army OR leaders advocated the extension of OR to Army ground forces. In April–May 1942, Cyril Jansky, the special consultant on operations analysis in the AAF Directorate of Air Defense, suggested that operations analysis be applied not only to AAF commands but also to the Army's armored, antiaircraft artillery, and tank destroyer commands.[367] In July 1942, the subject was broached in NDRC when Robert W. King, the executive assistant to the chairman of NDRC, wrote to Vannevar Bush suggesting that there was a need for the analysis of battle data that might merit the creation of a group of analysts to study land warfare activities.[368] In their August 1942 report, Leach and Davidson echoed Jansky's opinion, noting that there was no reason that operations analysis should not apply to such areas as tank warfare or training programs.[369]

No action was taken in 1942 or most of 1943 to form OR groups for the Army ground forces on the pattern of the British, Navy, or AAF OR groups, but in November 1943, Lt. Col. Leach brought the matter to the fore in a memorandum prepared for Harvey Bundy, who passed it on to Maj. Gen. Stephen G. Henry, the director of the New Developments Division of the War Department General Staff, with the comment, "This development [OR] has been adopted with conspicuous success by the Air Forces but the Ground Forces have really not been aware of its advantages nor do I believe they have studied the matter intensively."[370] In his cover letter to Bundy, Lt. Col. Leach raised a number of issues growing out of his sixteen months of experience as chief of OAD, noting that he was providing the memo to Bundy for his use at such time as "someone in the Ground Forces tentatively concludes that Operations Analysis should be established there and requests you for suggestions as to what steps ought to be taken."[371] In his 2 November memo, Leach recounted the success of AAF OA sections and the advantages of using civilian operations analysts before pointing out that Army commanders in the field would continue to ignore the value of OA unless it was brought to their attention by top authority, as had been done by General Arnold in his 24 October 1942 letter to key AAF commanders and Air Staff officers.[372] Leach went on to set two prerequisites for the establishment of OA in the ground forces: OA sections must be desired and requested by commanders in the field, and an administrative organization must be established in Washington to recruit and administer the OA sections. He further recommended that the proposed Washington OA coordinating office consist of a colonel as chief and one to three lieutenant colonels, all under the supervision of a general officer connected to operations, perhaps the chief of the theater group in the Operations Division of the War Department General Staff. On 25 November 1943, Lt. Col. Leach reiterated his arguments for the extension of OA to the Army ground forces and the need for the personal backing of the Army chief of staff in a memorandum to Secretary of War Henry L. Stimson.[373]

As a result of Leach's prodding, a draft letter was prepared for the signature of Army Chief of Staff Gen. George C. Marshall, addressed to all major Army ground force commanders, in which the drafter (probably Leach) stated that "serious consideration should be given to the extension of the use of operations analysis teams to ground and amphibious operations in all theaters."[374] On 6 December 1943, Secretary Stimson sent

a memorandum to General Marshall enclosing the draft and several papers dealing with the development of OA in AAF and noting that Lt. Gen. Willard F. Harmon, the commander of Army forces in the South Pacific, had requested an analysis section to study jungle warfare, and that Lt. Gen. Jacob D. Devers in Europe had expressed interest in having OA help. Secretary Stimson suggested to General Marshall that "it may be that this would be an appropriate time to consider a general extension of the operations analysis program."[375]

On 17 November 1943, Lt. Gen. Harmon had indeed requested, "a well-rounded Operations Analysis Section for jungle warfare comprising five or six men."[376] Lt. Col. R. E. Elwell from OAD, HQ AAF, was sent out to Lt. Gen. Harmon's headquarters to assess requirements and reported that Harmon planned to use the proposed OA section for improving troop morale, photographic interpretation, adapting arms and equipment for jungle fighting, studying the use of limited facilities for the movement of personnel and supplies, and solving problems of communications and the adaptation of communications equipment for use in jungle warfare.[377]

There is no evidence that Lt. Gen. Harmon ever received the requested OA team.[378] General Marshall apparently did, however, charge two War Department General Staff officers in the current section of the Operations Division with overseeing the establishment of OA sections in the Army ground forces, causing Vannevar Bush to opine, "It seems to me that the matter of operations [analysis] sections in the Ground Forces is well launched and apparently in very good hands."[379]

Research Section, General Headquarters, Southwest Pacific Area

Although no OA section was assigned to Headquarters, South Pacific Area, two OA sections were formed under the auspices of the Office of Field Service, OSRD, in early 1944 for service in the Southwest Pacific Area and in the Pacific Ocean (Mid-Pacific) Area. The first to be formed was the Research Section, Headquarters, Southwest Pacific Area.[380]

By late 1943, the attention of OSRD was turning from the production of new weapons to the effective introduction to and use by the troops in the field of those weapons already in production. The creation of the OSRD Office of Field Service under Dr. Karl T. Compton, on 15 October 1943, provided a means by which OSRD could help the armed forces meet the needs of field commanders for both "field services" and operations research. Accordingly, in December 1943, Dr. Compton traveled to the southwest Pacific to discuss with Gen. Douglas MacArthur his needs and desires for scientific help and he returned with a list of twenty-five problems on which scientific advice was needed. In February 1944, General MacArthur formally requested the establishment of a research section in his headquarters at Brisbane, Australia, staffed by representatives of OSRD, to handle the visits of field service consultants and to provide OFS-sponsored scientists and technicians to solve new problems as they arose. The Research Section, General Headquarters, Southwest Pacific Area (GHQ SWPA), began operations in April 1944 with the arrival of Dr. George R. Harrison as section chief and E. B. Hubbard as scientific aide.[381] Contrary to the long-standing admonitions of Col. Leach, the research section was buried deep in the headquarters structure by being assigned to the office of Maj. Gen. Spencer B. Akin, the GHQ SWPA chief signal officer.[382] Consequently, the scientists in the section did not have ready access to the key decision makers.[383] The Research Section reported through the Signal Office and MacArthur's adjutant general to the War Department General Staff New Developments Division.

Dr. H. Kirk Stephenson arrived in June 1944 to take over as scientific aide, and in July 1944 Dr. Harrison returned to the United States and was replaced as section chief by Dr. Paul E. Klopsteg. In mid-September, the section moved with MacArthur's GHQ to Hollandia. Klopsteg preceded the main group and, when Hubbard, Stephenson, and the three WACs assigned to the section arrived in Hollandia in late September, they found that the Research Section, GHQ SWPA, consisted of "Klopsteg, a small table, and a chair at one end of a Quonset hut."[384] The following month, both Klopsteg and Hubbard returned home, and Stephenson became chief, a position he retained until the end of the war.

In general, relations of the civilian scientists in the Research Section with their uniformed colleagues was satisfactory, but Stephenson related:

> we also had a little trouble with the military men now and then. Some of it resulted from stupidity, some from jealousy, and some from pure cussedness. One officer tried to steal my office and my three WAC's while I was away on a trip, but the WAC's had connections.[385]

In early 1942, long before Dr. Compton's visit to GHQ SWPA, Maj. Gen. W. H. Marquat, the commander of the 14th Anti-Aircraft Command, had tried to get analysts to work with his command but was unsuccessful.[386] He repeated his request to Compton in December 1943, and Dr. Sidney Darlington was sent out under OFS auspices in August 1944.[387] Darlington worked until April 1945 with Maj. Gen. Marquat's staff and operating units to study the performance of U.S. antiaircraft artillery and the performance and tactics of Japanese aircraft. Darlington studied the effects of meteorological conditions on 90-mm. antiaircraft artillery fire and wrote several training circulars on the subject. In cooperation with Henry Abajian of the Radiation Lab at MIT, he invent-

ed an attachment to the M–9 antiaircraft predictor to correct the problem of lagging bursts, a frequent problem because of the Japanese pilots' tactic of accelerating when they first came under antiaircraft fire. Darlington moved to the Philippines in November 1944 to conduct studies (using movie cameras) on Japanese tactics for evading antiaircraft fire.

During his visit to GHQ SWPA in December 1943, Karl Compton was approached by the SWPA chief signal officer Maj. Gen. Akin with a request for experts in time and motion studies to investigate the command's signal communications centers with a view to improving their operating efficiency.[388] Two OFS contract experts, Herbert F. Goodwin and A. H. Mogensen, studied the problem from April to June 1944, and their work was continued by D. F. Copell from June to September 1944. The OFS experts provided training in work simplification, and several hundred trainees were taught to apply the principles to various message center functions.

During Compton's visit to GHQ SWPA he also discussed engineering problems with Maj. Gen. Hugh J. Casey, chief engineer, GHQ SWPA, who asked for the help of several engineering experts to advise on construction problems, especially the construction of airfields, and the performance of engineer equipment in jungle environments.[389] Subsequently, two engineers attached to the Research Section, GHQ SWPA—J. A. Russell and J. P. Becich—worked with the engineers in New Guinea from April to September 1944, advising on the siting and construction of airfields. They also worked in the office of the chief engineer, GHQ SWPA, in Brisbane, assisting with planning and writing engineer training and instruction manuals. Russell and Becich were later replaced by J. W. Farwell who served in New Guinea and Leyte providing advice on construction problems.

By December 1944, the Research Section had personnel scattered all over the southwest Pacific from Sydney to the Philippines, and, in January 1945, the section moved with GHQ, SWPA, to Tacloban on Leyte. There it was transferred from the control of Maj. Gen. Akin to the United States Army Forces Far East (USAFFE) Board headed by Col. William Alexander.[390] In early March 1945, the Research Section moved with the USAFFE Board and GHQ SWPA to Manila. Almost immediately, Dr. Stephenson returned to the United States for consultations with Compton and Bush, orientations on new equipment, and other matters. By the time he returned in late June, the war in Europe had ended and Alan T. Waterman had traveled to the Pacific to explore the possibilities of establishing a Pacific branch of OSRD with lab and shop facilities in Manila.

The period from late June 1945 until the end of the war on 2 September 1945 was one of great activity for the Research Section. When Karl Compton arrived in Manila in August 1945 to set up the Pacific Branch-OSRD, the Research Section was overseeing some thirty-five men on assignment in the theater and more than forty on call for various projects.[391] Plans called for expansion to more than two hundred scientists and technicians, but the war ended before that could come to pass, and the section shrank quickly. The last task handled by the section before being officially inactivated, on 13 September 1945, was the dispatch to Japan of a mission of nine scientists led by Dr. E. L. Moreland to study the state of Japanese science and to exploit Japanese scientists.[392]

In all, the Research Section, SWPA, managed some one hundred scientists and technical personnel; the usual duration of assignment was from three to six months.[393] For the most part, the projects they undertook fell into the category of "field service" or engineering consultation rather than operations research, but some limited OR work was performed by men assigned to the Research Section, GHQ SWPA.[394] Among the topics studied were radar employment, radio propagation, and radar countermeasures; LORAN (LOng-RAnge Navigation, a terrestrial navigation system using low-frequency radio transmissions from fixed land-based stations); marine borers and insect infestation of Army food stores; tropical deterioration; transportation bottlenecks and equipment failures; DUKW (amphibious truck) operations; immunizations, treatment of malaria, and fungus infections of the skin; the use of DDT (dichlorodiphenyltrichloroethane) and other insecticides; the use of smoke munitions in combat; antiaircraft artillery; rockets; silent weapons; chemical warfare; mortars and tank-mounted flame-throwers; engineering operations; Japanese weapons and equipment; scientific intelligence; communications systems planning; and time-motion studies to simplify communications centers operations.[395]

"The Balanced Team"—Operational Research Section, HQ Pacific Ocean Area

On his way to the southwest Pacific in December 1943, Karl Compton stopped in Hawaii to discuss the need for scientific support with Admiral Chester Nimitz. Nimitz, who shared General MacArthur's distaste for interlopers in his command, declined Compton's offers of assistance, but Compton enjoyed a warmer reception when he called on Lt. Gen. Robert C. Richardson, Jr., the commander of Army forces in the Pacific Ocean Area.[396] Richardson had already inquired of the War Department in the fall of 1943 about the possibilities of establishing an OR section, and he responded positively to Compton's proposals.[397] Compton stopped to see Richardson again on his way back from MacArthur's headquarters in late January 1944, and Richardson expressed interest in a "balanced team" of civilian scientists sponsored

by OSRD. The "balanced team" concept, which envisioned a team composed of both OR and field service representatives, was promoted by OSRD officials who were somewhat miffed when Lt. Gen. Richardson dubbed his group the "operational research section."[398]

In late February 1944, the ubiquitous Lt. Col. Leach stopped in Hawaii on his way back from a visit to GHQ SWPA and Headquarters, U.S. Army Forces in the South Pacific. He called on Lt. Gen. Richardson and, following some detailed legwork with Richardson's staff and subordinate commanders, made a number of useful recommendations regarding the organization and initial tasks of the proposed ORS Pacific Ocean Area (POA).[399] As to the organization of the team, Leach recommended that it consist of a mature man with leadership and administrative abilities as chief, to be stationed at Fort Shafter, Hawaii; a mature man, preferably a physicist or mathematician or at least someone accustomed to working with scientists, to be deputy chief stationed at Schofield Barracks and to spend much time in forward areas; two men for the study of loading and supply problems; two men with construction engineering backgrounds and training in terminal ballistics; two mathematical physicists able to adapt to the study of tactical problems and the effective use of technical devices; a communications engineer with radio experience; two or three physically fit and enthusiastic younger men, not necessarily scientists, to serve as a flexible reserve; and two enlisted stenographers and one enlisted draftsman to provide administrative support. Leach also noted that the two senior men should be selected first and that they should help select the remaining team members. He also reminded Lt. Gen. Richardson that the success of any OA section depended on the quality of its personnel, and told him of the meeting with officers of the 7th and 27th divisions where he had collected information on "the types of problems with which an analysis section would deal."[400] Leach's long list of "principal problems suggested for initial study" included the efficient use of labor; the effectiveness of depot operations; the reduction of paperwork; supply and transportation problems associated with amphibious operations; the tactics of amphibious operations, including the effectiveness of various types of pre-landing attacks, the coordination of fire support, the detection and destruction of underwater obstacles, the use of smoke, and peculiar hydrographic conditions; and all types of problems associated with radar and radio communications in amphibious operations.

On 4 March 1944, Lt. Gen. Richardson submitted his formal request for the assignment of a "balanced team" and asked for a chief, deputy chief, and nine or ten men. Col. Leach and Lt. Gen. Richardson had agreed that an OSRD representative should be sent out to study requirements and draw up a list of recommendations. Accordingly, in March 1944, Dr. Paul E. Klopsteg, then chief of NDRC Division 17, was sent to Hawaii to consult with Richardson's staff regarding the type of work required. He returned to Washington in April with a long list of potential projects.[401]

Meanwhile, the search for men to compose the team went forward slowly. Many of the potential candidates, both for the job of section chief and to serve as analysts and field service men, were already gainfully employed and could not be convinced to change jobs.[402] John E. Burchard was proposed as chief of ORS POA but was obligated to the Navy, so Dr. Lauriston C. Marshall was selected, and Burchard agreed to go with Marshall to Hawaii to help him get started.[403] After some difficulties, Niels E. Edlefson, Roderick Stephens, Nathan Newmark, and Norman Dahl were selected for assignment to ORS POA, with Helge Holst as administrative assistant. Burchard, Marshall, Stephens, and Holst, accompanied by Lt. Col. Henderson of the New Developments Division of the War Department General Staff, arrived in Hawaii on 31 May 1944 and immediately set to work.

The mission of ORS POA was laid out in Section II, Circular No. 102, Headquarters, United States Army Forces in the Central Pacific Area, on 16 June 1944, and was subsequently revised and expanded in Circular No. 2, Headquarters, United States Army Forces Pacific Ocean Area (USAFPOA), dated 2 January 1945. In brief, the ORS POA mission was to inform military personnel of the command about new scientific developments and equipment; to assist in the use of existing equipment and techniques; to assist in determining requirements for new equipment or modifications to existing equipment and in the development of techniques for using that equipment; and to inform civilian and Army scientific and technical agencies in the United States of matters in the command having a bearing on the development of new equipment, modifications, or techniques.[404] By verbal authorization, the services of ORS POA were also made available to Army Air Forces, Navy, and Marine Corps units in the theater.[405]

Following the arrival in Hawaii of the initial contingent, ORS POA grew steadily until the end of the war. A table of organization was drawn up with the assistance of the USAFPOA G–3 section calling for a permanent establishment of twenty-three men. At the end of the war, ORS POA had a total of fifteen men organized in four main groups: weapons and analysis; radar, communications, and countermeasures; amphibious operations, transportation, and cargo handling; and work simplification.[406] Another nine people were in the theater working out of ORS POA and cooperating with ORS POA regulars, and two Army Signal Corps officers were detailed to ORS POA. By September 1945, nearly fifty men had been attached to ORS POA at one time or another for varying periods.[407]

Unlike General MacArthur, Lt. Gen. Richardson understood the importance of establishing the team directly under the top command leadership, and he wrote to Compton on 5 May 1944 to tell him that would be the case with ORS POA.[408] For administrative purposes ORS POA was assigned to work under the supervision of USAFPOA G–3 rather than as a separate Special Staff section, as had been originally envisioned. Some difficulties were encountered with restrictions imposed by lower-ranking officers in the G–3 section and having to do with ORS POA direct communications with OSRD, but Lauriston Marshall got them resolved with POA chief of staff Maj. Gen. Clark L. Ruffner.[409] Throughout the assignment of ORS POA to HQ USAFPOA, Lt. Gen. Richardson, Maj. Gen. Ruffner, USAFPOA staff, and subordinate commanders maintained a very positive attitude toward the civilians of the "balanced team," and Lt. Gen. Richardson even approved their informal work for the Navy and Army Air Forces.

Of necessity, ORS POA interacted almost daily with both the OSRD Office of Field Service and the War Department General Staff New Developments Division. Marshall, the chief of ORS POA, had held a high position with OSRD and had extensive experience in dealing with Vannevar Bush and the NDRC/OSRD bureaucracy. Nevertheless, he encountered a number of difficulties in dealing with OFS, mostly problems involving the terms of assignment of field personnel.[410] The OFS-sponsored personnel who came to the theater on specific, temporary assignments could be managed with little difficulty, but the frequent rotation, griping, and seeming lack of dedication and discipline of some of the "permanent" members of ORS POA posed substantial problems. In his final report, Marshall felt compelled to state:

> either there should be more control within the OSRD organization and willing discipline amongst its personnel or some other scheme should be adopted in case of another war. If in total war men are to be exempted from the operation of the Selective Service Laws because of their peculiar abilities, there is no apparent reason why they should not be subject to some of the controls placed on members of the armed services in the war service which their peculiar abilities make it possible for them to render. When a man does not choose to work where he can best contribute to the war effort because it will take or keep him away from his family for a year, the comparison with officers of the armed services who have been absent from their families for three or four years is unfavorable. The scientists and those qualified to work with them in this war have been a privileged class and some individuals involved have not always recognized the obligations which should have accompanied their privileges. The British method of handling their scientists should be studied.[411]

In contrast, ORS POA and the New Developments Division worked well together and maintained cordial and relatively stress-free relations. In his final report Marshall noted that the New Developments Division

> performed the unique function of bringing together on a common meeting ground the points of view of the military and the civilian scientists. The officers in this section were thus in a position to see all sides of the problem and help in synthesizing some of the points of view represented. Solutions to problems were found quickly in this manner, aiding materially it is believed in expediting satisfactory conclusion of the war.[412]

ORS POA also enjoyed good relationships with the Research Branch, GHQ SWPA, as well as AAF and Navy operations research groups stationed in Hawaii.[413] A clear division of responsibilities was worked out between ORS POA and AAF OAS Pacific Ocean Area (Seventh Air Force), and Marshall's team occasionally assisted the AAF section with the loan of expert personnel. The field service representatives and OR analysts at ORS POA also maintained a good working relationship with the members of the Navy Operations Research Group at Pearl Harbor, particularly those involved in submarine warfare and air operations.[414] Shortly before the end of the war, more than a third of the personnel assigned to ORS POA were in forward areas on temporary duty with AAF units.[415] Overall, ORS POA devoted about half of its total effort to projects of interest to the Navy or AAF.[416]

ORS POA undertook a number of studies and provided advice on a wide variety of topics, making particular contributions in the areas of radar defenses, communications, the use of port facilities, and cargo handling.[417] Lt. Gen. Richardson did not share General MacArthur's suspicions and biases and was quite willing to have "outsiders" examine and critique the operations of his command. Thus, although a good portion of the work done by ORS POA fell into the "field service" category, a fair number of analytical studies also used the methods of operations research. The constant interaction with Navy and AAF OR personnel no doubt kept the analysts at ORS POA inspired and up to date on the newest developments in OR and the successes being achieved by OR analysts elsewhere. In any case, what OR work was done by the members of ORS POA accounted for the largest part of all OR work done in the Army ground forces in World War II, and set the path for the sustained application of operations research techniques to land warfare for the U.S. Army in the postwar period.

Historians and Op Annies

One brief coda needs to be added to the history of operations research in the U.S. Army during World War II. The operations analysts sent out by Navy ORG, Army Air Forces OAD, or to the Pacific by the OSRD Office of Field Service were not the only men in the field gathering operational data, subjecting it to analysis, and writing up the results in a form

useful to military commanders and staff officers. The Historical Branch of the War Department General Staff formed a number of teams of historians who were assigned to the various theaters of war for the purpose of collecting historical data, analyzing those data, and producing reports and histories of the operations of Army Air Forces, Army service forces, and Army ground forces units around the world.[418]

The work done by the Army field historians was similar in form and purpose, if not in content, to the work done by operations analysts—the major difference was that historians relied on historical method whereas the operations analysts frequently used mathematical and statistical models to help them organize and understand the data. In fact, more than one of the Army's World War II field historians, notably Hugh M. Cole, later turned up in the Operations Research Office and other postwar Army operations research activities.

The degree to which the work of the historian and that of the operations analyst is related is shown by one World War II OSRD Office of Field Service team formed at the request of Maj. Gen. Stephen G. Henry, the director of the New Developments Division. From 24 April to 28 October 1944, Douglas Nettleton and, from 24 July to 6 October 1944, Margaret Piedem were put on OFS contracts to conduct a "scientific analysis of Battle Records in an attempt to determine the morale and physical effects of bombardment on individuals within the impact area."[419] Assisted by the project director from the New Developments Division, Nettleton and Piedem studied five landing operations on coral atolls in the central Pacific: Tarawa, Makin, Kwajalein, Roi Namur, and Eniwetok. After examining the available reports and other documentation, the team concluded that it "was not possible to find any precise method of measuring the direct effects of bombardment . . . [and] . . . that the information to be obtained from reports in their present form is wholly inadequate for the type of analysis called for in the basic directive."[420] The project director thus recommended that the study be discontinued until a standard form for reporting battle results was adopted. Moreover, he noted that such statistical reporting of battle results would place an undue burden on field commanders but suggested that the task might be undertaken by a civilian team.

Conclusion

The new "science" of operations research played a substantial role in winning World War II. Indeed, OR must be reckoned with the other major scientific discoveries of the World War II era—radar, sonar, modern fire control, rockets and guided missiles, the proximity fuze, the new incendiaries, and the atomic bomb—as one of the applications of science that helped the Allies win World War II.[421] The application of OR techniques to weapons systems design and integration; the improvement of operational procedures, tactics, and strategy; the countering of enemy weapons, tactics, and strategy; and the early identification of useless lines of scientific research gave the Allies in World War II a decisive advantage over the Axis powers, none of whom developed an effective OR capability.[422]

Beginning with their work on the integration of radar into the air defense system, British scientists created from scratch the new science of operational research and built the organizational and theoretical foundation on which the U.S. armed forces formed their own OR organizations. The U.S. Navy and the U.S. Army Air Forces—and to a much lesser extent the U.S. Army service forces and U.S. Army ground forces—absorbed the British experience and used OR to solve a wide variety of technical and operational problems. Although they looked to British models for organizational patterns and analytical techniques, the Army and Navy analysts devised their own unique solutions compatible with the traditions, procedures, and needs of the services for which they labored. In making their own contribution to the winning of the war, American OR managers and analysts worked as part of a team that included the commanders, staff, and operational forces as well as their supporting administrative and logistical personnel.

The path taken in the development of OR in the United States in World War II diverged somewhat from its British model. The differences between operational research in Britain and operations research/operations analysis in the United States can be explained mainly by the fact that the British effort was largely directed toward finding how to do the best they could with limited resources whereas the American effort, once the American war machine got rolling, was directed more toward how to effectively integrate new technology and new techniques into the fighting forces.

There were also other, somewhat superficial, differences. For example, the British had a preference for operations analysts trained in the hard sciences, a preference shared by the U.S. Office of Scientific Research and Development and the U.S. Navy but mitigated by the Army's use of lawyers, economists, and even librarians. The British were also more successful in introducing operational research into their ground forces. From 1941 to 1945, the U.S. Navy and U.S. Army Air Forces built on the British foundation large and complex OR organizations spread worldwide and conducting research on a variety of technical and operational problems. Navy and AAF analysts contributed to the development of OR as a distinct methodology as well as to the solution of many practical problems. On the other hand, the spread of operations research in U.S. Army service and ground forces was limited, both by the press of operations and the igno-

rance of field commanders regarding the benefits that might be derived from the use of civilian operations analysts. Nevertheless, Army OR personnel were part of many of the teams led by service and ground combat commanders, and they did contribute their bit to winning the war.

The pressures on wartime operations researchers to produce the solutions to practical problems in minimal time left little time or energy for developing the theoretical aspects of OR much beyond the basic formulae and rules worked out by the British early in the war. Most of the problems faced by World War II–era operations analysts were limited in scope and complexity and could be solved by relatively simple analytical methods.[423] In most cases, common sense backed by the existing mathematics, statistics, and probability theory sufficed. But there were some exceptions. The British work on density method and on planned flying and planned maintenance and American work on search theory and bombing accuracy constituted significant advances in the techniques of operations research.[424] Perhaps the development with the most significance for the future was the discovery that OR could be used not only to solve immediate problems of optimizing existing equipment and procedures but to predict "the results that may be expected from adopting proposed courses of action; these predictions can then be used as guides to the development of future strategies, tactics, and weapons."[425]

The complex and difficult task of organizing and managing World War II OR programs produced many practical lessons regarding leadership, recruitment, training, administration, pay, and other aspects of integrating civilian specialists into the structure of the armed forces on a comparatively large scale. The widespread use of civilian operations analysts created a number of challenges for Army civilian and military leaders. In trying to meet those challenges, Army leaders found many solutions, some effective and some ineffective. The failures as well as the successes provided important lessons for the future, and, although the problems remain much the same today, some of the World War II–era solutions were soon forgotten and had to be rediscovered repeatedly in the postwar years.

One of the most difficult challenges faced by the managers of Army OR in World War II was finding an effective mechanism for recruiting, training, administering, paying, and distributing civilian OR specialists. Various methods were tried, and none was entirely satisfactory. For a number of reasons, the induction of civilian analysts into the armed forces, even as commissioned officers, was found to be undesirable except in limited circumstances. Employing analysts in the civil service also had significant drawbacks, and hiring them as special consultants on a long-term basis proved clumsy and conflicted with existing laws and regulations. The best solution found was for the government to contract with a nonprofit entity for the full range of personnel recruitment and management services required. The model for this method was the contract between the Navy Operations Research Group and Columbia University, arranged through the Office of Scientific Research and Development. The ORG–Columbia University arrangement was relatively troublefree, and in the postwar period it would serve as the model adopted by all three services.

The limited methods for employing OR personnel by the U.S. armed forces was compounded by limitations on the compensation that could be paid. In most cases, working for the Army or Navy as an operations researcher involved significant financial loss for the civilian scientist, often amounting to half his previous salary. This obstacle was overcome only through the patriotism and sacrifice of the individual analyst willing to interrupt a civilian career, accept a substantial loss of income, and forgo personal comfort and freedom of action.

Another challenge encountered in the World War II–era OR programs of the U.S. armed forces was that of merging two distinct cultures espousing different values and ways of doing things. The integration of civilian scientists into the military structure of the Army or Navy was often difficult and never entirely without friction. Uniformed personnel naturally bore some negative feelings for civilians who were free of the usual military restrictions, much better paid, and often free to terminate their employment at will. Moreover, many military officers did not understand fully the purpose of the civilian analysts in their midst, in some cases considering them spies sent to inform or regulate the performance of the uniformed personnel. Higher-level commanders were usually sufficiently aware of the purpose and value of their civilian analysts, but lower-level commanders and staff officers frequently placed obstacles in the way of the OR teams assigned to their commands, blocking the analysts' access to crucial classified operational information and restricting their communications with their counterparts in other commands and in the broader scientific community. From the civilian perspective, the restrictions of military life and tradition could be annoying and apt to inhibit the work they were trying to do. The differences between the "military mind" and the "scientific mind" provided ample occasion for misunderstanding and even conflict. Fortunately, the friction between the two cultures tended to abate as time passed and the assignment of civilian specialists to operational units became more common. Military personnel learned to understand and even value the work of civilian analysts, and civilian analysts learned to understand and tolerate the military way of doing things. In the end, they were able to form an effective partnership, one that would endure far beyond World War II.

It must also be said that the civilian scientists who served in U.S. armed forces OR sections overseas bore a share of the risk faced by their uniformed colleagues. One OSRD civilian scientist was killed in action, one died in the line of duty, and one was wounded in action, but not one was court-martialed or given punitive discipline by a theater commander. In fact, many of them received decorations and special letters of commendation from commanders who observed their work and felt the services had obtained some benefit from it.

A third challenge encountered by the civilian and military managers of operations researchers in World War II was identifying exactly what characteristics defined the ideal Op Annie." The British and the U.S. Navy as well as the "science Mafia" at NDRC and OSRD strongly preferred to recruit analysts from the ranks of those trained in the hard sciences, such as physics and mathematics. But, as trained scientific talent was absorbed by the war effort in Britain and the United States, both the British and the U.S. Navy found that they were obliged to include men trained in the life sciences and in such fields as statistics and economics. From the beginning, AAF was less tied to an exclusive reliance on scientists, and Lt. Col. Barton Leach recruited many lawyers to serve in AAF OA sections. They proved a good choice and justified the view that the essential characteristics of a good operations analyst were not so much scientific training as clarity of thought, the ability to organize and comprehend large volumes of data, and the ability to reach logical conclusions based on the evidence. In view of the propensity to use mathematical methods for the analysis of operational data and mathematical language for describing the results of that analysis, the mastery of mathematics was a desirable skill for the operations analyst, but it was not an essential one. The principal lesson derived from the World War II experience is that both scientists and non-scientists could make significant contributions in the field of operations research.

The World War II mobilization of scientists for the war effort, including the service OR programs, led to recognition of the great contribution that could be made by civilian experts to military weapons development and operations, and that recognition, combined with the political realities of the postwar period, made for a permanent involvement of scientists and other civilian experts in the nation's defense efforts and consequently the involvement of the U.S. government in American science and industry.[426] As Erik Peter Rau has noted, Vannevar Bush, the czar of American scientific research and development in World War II, saw OR as undermining his vision for a limited alliance between the federal government and civilian scientists, but "its eager promotion by military officials and Bush's own subordinates pointed toward the strong and more permanent alliance between the two that would become one of the Cold War's most striking features."[427]

Although Army service and ground forces lagged behind the Navy and Army Air Forces in the integration of OR into the decision-making process during World War II, even the limited exposure of Army civilian leaders, commanders, and staff officers had an effect. In the postwar period, OR would become an integral part of the Army decision-making process, not only for the design and improvement of weapons and other military equipment but for the development of tactical doctrine and strategic planning as well. Having lagged behind the Navy and Army Air Forces in the adoption and use of OR in World War II, the ground Army quickly closed the gap in the postwar period.

CHAPTER ONE NOTES

[1]What was called "operational research" in Great Britain was generally known as "operations research," "operations analysis," or "operations evaluation" in the United States. The terms are interchangeable and are represented throughout this work by the abbreviations "OR" or "OA," as seems convenient.

[2]U.K. Air Ministry, *Origins and Development of Operational Research in the Royal Air Force*, Air Publication 3368 (London: Her Majesty's Stationery Office, 1963), p. 3 (hereafter cited as *OR in RAF*). The preface and chapter I of this official publication form a comprehensive history of the development of radar and of operational research in Great Britain up to 1939. The same events are summarized usefully by Joseph F. McCloskey in his article, "The Beginnings of Operations Research: 1934–1941," *Operations Research* 35, 1 (1987): 143–52. Unless otherwise noted, the following narrative of events in Great Britain up to 1939 is derived directly from these two sources.

[3]W. Peyton Cunningham, Denys Freeman, and Joseph F. McCloskey, "OR Forum: Of Radar and *Operations Research*: An Appreciation of A. P. Rowe (1898–1976)," *Operations Research* 32, 4 (1984): 959.

[4]Tizard was a scientist with wide military experience, and he had directed experimental flying in the Royal Flying Corps in WWI. Hill was a 1922 Nobel laureate in physiology/medicine, and he had played a key role in proto-OR work in WWI as an Army captain directing the Anti-Aircraft Experimental Section of the Ministry of Munitions. Blackett, a physicist, had served as a naval officer in WWI, and he would later receive the 1948 Nobel Prize in physics. Wimperis was a well-respected engineer and inventor. The committee was reorganized in September 1936, and E. V. Appleton (an authority on radio who would win the 1947 Nobel Prize in physics) and T. R. Merton were later appointed as additional members.

[5]A similar committee, called the Committee for the Scientific Survey of Air Offence, also headed by Tizard, was set up in January 1937 to study

offensive air operations. The two committees merged in October 1939 to form the Committee for the Scientific Survey of Air Warfare. The combined committee was disbanded in June 1940, having contributed much to the development of radar and having brought together British scientists and military leaders (see P. M. S. Blackett, "Tizard and the Science of War," in P. M. S. Blackett, *Studies of War, Nuclear and Conventional* [New York: Hill and Wang, 1962], pp. 102–03).

[6]Harold Larnder, "The Origin of Operational Research," *Operations Research* 32, 2 (1984): 469.

[7]Cunningham and others, "Of Radar and Operations Research," p. 960.

[8]Blackett, "Tizard," pp. 102–03.

[9]The radar station at Bawdsey Manor (near Felixstowe on the east coast of England), the first of a chain of radar stations on the east and south coasts of England, was completed in 1937. The remaining stations were completed by the summer of 1939.

[10]Blackett, "Tizard," p. 103.

[11]U.K. Air Ministry, *OR in RAF*, p. 5.

[12]Larnder, "Origin," p. 470.

[13]It was in connection with the work of Williams' group, which focused on finding ways to do a better job with the existing equipment, that Rowe coined the term "operational research" (see Larnder, "Origin," p. 471).

[14]The Bawdsey Research Station did move to Dundee in September 1939. It was subsequently renamed the Air Ministry Research Establishment and moved to the south coast of England, where it became the Telecommunications Research Establishment in November 1940.

[15]U.K. Air Ministry, *OR in RAF*, p. 7; McCloskey, "Beginnings," p. 146.

[16]Harold Larnder (1902–81) was one of the pioneers of OR in Great Britain, serving at various times with the Bawdsey Research Station, RAF Fighter and Coastal commands, and the Allied Tactical Air Force. For a précis of his career, see Ronald G. Stansfield, "Harold Larnder: Founder of Operational Research—An Appreciation," *Journal of the Operational Research Society* 34 (1983): 1–7; and Larnder, "Origin," p. 465.

[17]OR sections were also formed in the Royal Australian Air Force in January 1944 and in the Royal Canadian Air Force in August 1944. The development of OR in the British armed forces in WWII is thoroughly documented in the official histories, the memoirs of participants, and secondary works. The state of the British OR organization as it existed in the summer of 1942 was described in a forty-seven–page report by Maj. W. B. Leach and Dr. Ward F. Davidson, submitted to the JNWEC of JCS. The report was titled "Report on Operations Analysis" (Washington, 15 Aug 1942), College Park, Md., NARA II, RG 218, Entry 343A, Box 9,Folder 12 (hereafter cited as Leach-Davidson Rpt). The Leach-Davidson Rpt was accompanied by a thirty-six–page memorandum outlining the state of OR work in England in more detail than in the basic report (see Memo 1, Maj W. B. Leach and Dr. Ward F. Davidson, sub: Operational Research in England, RG 218, Entry 343A, Box 9, Folder OA in England, USN, USA (hereafter cited as Leach-Davidson Memo 1). The evolution of OR in the RAF and to some degree in the other services is covered in some detail in U.K. Air Ministry, *OR in RAF.* A useful summary of developments in Great Britain can be found in McCloskey, "Beginnings," and the same author's "British Operational Research in World War II," *Operations Research* 35, 3 (1987): 453–70. Additional material of interest can be found in J. G. Crowther and R. Whiddington, *Science at War* (New York: Philosophical Library, 1948); and Erik Peter Rau, "Combat Scientists: The Emergence of Operations Research in the United States in World War II" (Ph.D. diss., University of Pennsylvania, 1999). Important first-person accounts include the several articles by P. M. S. Blackett reprinted in his *Studies of War* and by Harold Larnder in "Origin." Other sources are listed in the bibliography.

[18]Leach-Davidson Rpt, p. 9.

[19]U.K. Air Ministry, *OR in RAF*, p. 179 n.; Florence N. Trefethen, "A History of Operations Research," in Joseph F. McCloskey and Florence N. Trefethen, eds., *Operations Research for Management* (Baltimore: Johns Hopkins University Press, 1954), p. 8.

[20]McCloskey, "British OR," p. 467.

[21]In a letter to the special assistant to the secretary of war, Harvey B. Bundy, Maj. Leach wrote, "the British did not conceive this system but rather stumbled into it, and the method by which this happened has led them to make the mistake of employing almost exclusively scientific and mathematical personnel," with two unfortunate results: a drain on scarce scientific manpower and the restriction of studies to areas where the scientific component was high, although the most important tactical recommendations had not been in the scientific field. See Ltr, Maj W. B. Leach to Harvey H. Bundy, 2 Sep 42, RG 107, Entry 113, Box 68, Folder OA, 1942.

[22]McCloskey, "Beginnings," p. 152.

[23]Leach-Davidson Rpt, p. 9; Leach-Davidson Memo 1, pp. 1-10, 1-11. Of the remaining 80 percent, they found that a little more than half required routine statistical help and the rest could be accomplished without any specific scientific knowledge or training.

[24]Quoted in U.K. Air Ministry, *OR in RAF*, p. 179.

[25]Rau, "Combat Scientists," pp. 42–43 *et passim*. In the 1930s, a good number of Britain's scientific elite were political liberals or leftists, and they saw OR as a way to increase the influence of science on policy (Rau, "Combat Scientists," p. 20). Tizard, Hill, Blackett, and Watson-Watt, among others, were adherents of the Social Relations of Science Movement that flourished between 1931 and 1947, but in the end, whatever political agenda they may have had was trumped by the need to apply scientific knowledge to overcome the Axis threat.

[26]Leach-Davidson Memo 1, p. 1-9 n.

[27]Ibid., pp. 1-9, 1-10. On the problems associated with civilian versus military status for OR personnel in the RAF, see U.K. Air Ministry, *OR in RAF*, pp. 180–81.

[28]McCloskey, "Beginnings," p. 150; Rau, "Combat Scientists," p. 28. Rau noted that "by 1942, the scientific elite had enthusiastically embraced Blackett's framework for operational research and had begun to promote it. At the same time, military commanders began to adopt scientific advisors. The result was a rapid proliferation of OR groups" (p. 76).

[29]P. M. S. Blackett, "Operational Research—Document I: Scientists at the Operational Level," *Advancement of Science* 5, 17 (1948), reprinted in Blackett, *Studies of War*, pp. 171–76. McCloskey noted that "Scientists at the Operational Level" provides ample support for those who regard P. M. S. Blackett as the "father" of OR ("Beginnings," p. 149).

[30]Keith R. Tidman, *The Operations Evaluation Group: A History of Naval Operations Analysis* (Annapolis, Md.: Naval Institute Press, 1984), p. 10.

[31]Leach and Davidson noted that the British OR section was extremely efficient largely because the head of the section was a member of the commander's staff, worked in close cooperation with him, and reported only to him (Leach-Davidson Rpt, pp. 11–12)

[32]Blackett, "Tizard," in Blackett, *Studies of War*, p. 113.

[33]Rau, "Combat Scientists," pp. 16, 20, 75–76 *et passim*. Rau noted that "reliance on quantitative methods helped immeasurably by providing a common language that both sides respected" (p. 17).

[34]Stansfield, "Harold Larnder," p. 5.

[35]Leach-Davidson Memo 1, pp. 1-2, 1-30.

[36]P. M. S. Blackett, "Recollections of Problems Studied, 1940–45," in H. G. Thursfield, ed., *Brassey's Annual—The Armed Forces Year-Book, 1953* (New York: Macmillan, 1953), pp. 88–106, reprinted in Blackett, *Studies of War*, pp. 205–34.

[37]Charles F. Goodeve, "Operational Research," *Nature* 161 (Mar 1948): 377, cited in McCloskey, "British OR," p. 455.

[38]McCloskey, "British OR," p. 454.

[39]Larnder, "Origin," pp. 472–73; Stansfield, "Harold Larnder," pp. 1–7. The French had requested ten additional fighter squadrons (120 aircraft) at a time when losses were running 36 aircraft every two days, a rate that would soon deplete British resources below the level required for home defense.

[40]Dowding later told Larnder that the presentation of the study results in graphic form was what "did the trick" (see Larnder, "Origin," p. 473).

[41]Ibid., p 472.

[42]Ibid., p. 474.

[43]Leach-Davidson Rpt, p. 11; Leach-Davidson Memo 1, pp. 1-30, 1-31. The RAF estimate was 700 percent, whereas that of the Royal Navy was 400 percent (see Ltr, Com Gen, AAF [Lt Gen Henry H. Arnold], to commanding generals, all Air Forces, all AAF Commands, all Directors and Chiefs of all Air and Special Staff Divs, HQ AAF, 24 Oct 42, sub: OA, RG 107, Entry 113, Box 68, Folder OA, 1943–45). In any event, the impact of the change was sufficient to convince the German sailors that the British had developed a new and better aerial depth charge twice the size of the old one and a new radar capable of penetrating below the surface of the ocean.

[44]U.K. Air Ministry, *OR in RAF*, pp. 102–03. Additional details on the development of planned flying and planned maintenance can be found in Crowther and Whiddington, *Science*, pp. 104–06; McCloskey, "British OR," p. 457; and Rau, "Combat Scientists," pp. 71–73.

[45]U.K. Air Ministry, *OR in RAF*, p. 43; Crowther and Whiddington, *Science*, pp. 106–07.

[46]McCloskey, "British OR," pp. 458–59.

[47]Ibid. "Window" was first used in the raid on Hamburg in July 1943.

[48]Blackett, "Recollections," in Blackett *Studies of War*, p. 211.

[49]McCloskey, "British OR," p. 464.

[50]Ibid.

[51]U.K. Air Ministry, *OR in RAF*, p. 41; Blackett, "Recollections," in Blackett, *Studies of War*, pp. 220–23.

[52]Crowther and Whiddington, *Science*, pp. 101–02. See also Tidman, *Operations Evaluation Group*, p. 11; and McCloskey, "British OR," pp. 465–66. The dividing line between large and small convoys was set at forty ships.

[53]Crowther and Whiddington, *Science*, p. 102.

[54]U.K. Air Ministry, *OR in RAF*, p. 178.

[55]P. M. S. Blackett, "Operational Research—Document II: A Note on Certain Aspects of the Methodology of Operational Research," *Advancement of Science* 5, 17 (1948), reprinted in Blackett, *Studies of War*, pp. 176–98.

[56]McCloskey, "British OR," p. 456.

[57]Blackett, "Evan James Williams, 1903–45," *Obituary Notices of Fellows of the Royal Society* V (1947), reprinted in Blackett, *Studies of War*, pp. 235–36.

[58]U.K. Air Ministry, *OR in RAF*, pp. 81–83,

[59]For further development of the equation, see ibid., pp. 82–83.

[60]McCloskey, "British OR," p. 456.

[61]Ibid., p. 465. See Terry Copp, ed., *Montgomery's Scientists: Operational Research in Northwest Europe: The Work of No. 2 Operational Research Group with 21. Army Group, June 1944 to July 1945* (Waterloo, Canada: Laurier Centre for Military Strategic and Disarmament Studies, 2000).

[62]U.K. Air Ministry, *OR in RAF*, p. xviii.

[63]Ibid.

[64]The prewar contacts between British and American scientists and military leaders regarding OR are discussed in some detail in Rau, "Combat Scientists," pp. 117–24; James Phinney Baxter III, *Scientists Against Time* (Boston: Little, Brown, 1946), pp. 119–23; Irvin Stewart, *Organizing Scientific Research for War: The Administrative History of the Office of Scientific Research and Development* (Boston: Little, Brown, 1948), pp. 168–80; and Joseph F. McCloskey, "U.S. Operations Research in World War II," *Operations Research* 35, 6 (1987): 910–1. Unless otherwise noted, the following account is based on the four sources just cited.

[65]Blackett, "Tizard," in Blackett, *Studies of War*, p. 107.

[66]Among the eminent British scientists accompanying Tizard were John Cockcroft (Tizard's deputy as scientific advisor at the Air Ministry), A. E. Woodward-Nutt (secretary of the mission and involved in OR studies at RAF Bomber Command), and Ralph Fowler (who had worked with Hill on antiaircraft problems in WWI).

[67]Blackett, "Tizard," in Blackett, *Studies of War*, p. 108.

[68]Disclosure of the cavity magnetron, which made possible smaller radar sets suitable for use in aircraft, led directly to the establishment of the Radiation Laboratory at MIT and to a major redirection of U.S. radar efforts (see McCloskey, "U.S. OR," p. 910).

[69]Stewart, *Organizing Scientific Research*, p. 168.

[70]Wilson was Vannevar Bush's assistant. Hovde, the assistant to the president of the University of Rochester, was to be the resident secretary of the U.S. London mission once it was established.

[71]Baxter, *Scientists Against Time*, pp. 122–23.

[72]Ibid., p. 123. The office was set up by Frederick L. Hovde under NDRC auspices and was subsequently taken over by OSRD.

[73]McCloskey, "British OR," p. 466. Brothers would become an important proponent of OR in the AAF, and Hitch was later one of the leading characters in the "McNamara Revolution," which brought systems analysis to prominence in the U.S. Department of Defense in the early 1960s.

[74]Rau, "Combat Scientists," p. 124. Gordon Philip Saville eventually rose to the rank of major general. He was born in Macon, Georgia, in 1902, and received a commission as an Air Corps second lieutenant in June 1927. He saw WWII service as an observer in Great Britain and as a staff officer and commander in the North African and Mediterranean theaters of operations. In November 1948, he was named commanding general of the Air Defense Command, and in January 1950, he became the DCS for development, HQ USAF. He died on 31 January 1984.

[75]Ibid., p. 122.

[76]McCloskey, "U.S. OR," p. 911.

[77]The story of the role played by OSRD and its component agencies in the development of OR in the U.S. armed forces is a complex and lengthy one. Limitations of space, time, and focus permit only a bare summary in this volume. For a detailed history of OSRD's role in the mobilization of American science for WWII and the scientific support of U.S. armed forces at home and abroad, the reader is directed to the postwar series of official histories titled "Science in World War II." The series, which provides a comprehensive history of OSRD and its component agencies in WWII, includes Baxter, *Scientists Against Time*; Stewart, *Organizing Scientific Research*; and Lincoln R. Thiesmeyer and John E. Burchard, *Combat Scientists* (Boston: Little, Brown and Company, 1947), all of which have been consulted for this study. Rau, "Combat Scientists," provides a provocative interpretation of OSRD activities, particularly the ambiguous attitude of Vannevar Bush regarding OR. The documentary basis for both the official histories and Rau's dissertation can be found mainly in NARAII, RG 227 (Records of the OSRD).

[78]OSRD and its two principal components, NDRC and CMR, were wartime agencies and were disbanded after the war. CMR was terminated on 20 January 1947, and OSRD and NDRC were abolished on 31 December 1947.

[79]The National Academy of Sciences (NAS) was created by Congress in 1863 and was augmented by the National Research Council (NRC), established in May 1918 to stimulate research in the mathematical, physical, and biological sciences. The president of NAS throughout WWII was Frank B. Jewett (in 1940, the president of the Bell Telephone Laboratories). The National Advisory Committee for Aeronautics (NACA) was created in 1915, and with Bush's departure to head OSRD, the chair of NACA was taken by Jerome C. Hunsaker, a captain in the Naval Reserve and head of the departments of mechanical and aeronautical engineering at MIT.

[80]Stewart, *Organizing Scientific Research*, p. 172.

[81]This is the central thesis of Rau's dissertation. The core of Rau's argument is summarized in "Combat Scientists," pp. 144–46 and 334–36.

[82]Ibid., pp. 119–20.

[83]Ibid., p. 129.

[84]Ltr, Vannevar Bush to Brig Gen Raymond G. Moses and Rear Admiral W. A. Lee, Jr., Washington, 29 May 42, RG 218, Entry 343A, Box 57, Folder OA.

[85]Ltr, Vannevar Bush to Sir Henry Tizard, Washington, 1 Oct 42, RG 218, Entry 343A, Box 9, Folder 15.

[86]Ltr, Vannevar Bush to Karl T. Compton, Washington, 15 Feb 43, RG 227, Entry 177, Box 294, Folder OSRD in OAD, AAF.

[87]Baxter, *Scientists Against Time*, pp. 122–23.

[88]Memo, James B. Conant to Vannevar Bush, 3 Aug 42, sub: Operational Research, RG 218, Entry 343A, Box 9, Folder 15.

[89]Rau, "Combat Scientists," p. 278. Robertson had seen OR in action at Princes Risborough in the early fall of 1941 and had already done a short tour with the operational analysis section of the U.S. Eighth Air Force. Weaver, too, had been to England and had seen OR at work (see Rau, "Combat Scientists," pp. 275–76).

[90]Rough draft of memo, John H. Teeter to Carroll Wilson, Washington, 26 Jul 43, RG 227, Entry 177, Box 283, Folder Definition and Methodology of OA.

[91]Rau, "Combat Scientists," p. 277.

[92]Ibid., p. 133.

[93]Ibid., pp. 289–92.

[94]Memo, Ward F. Davidson to Vannevar Bush, 30 Mar 43, sub: Memo of Dr. Alan T. Waterman, 26 Mar 43, RG 218, Entry 343A, Box 9, Folder 14.

[95]Rau, "Combat Scientists," pp. 21, 103.

[96]Ibid., pp. 300–6 *et passim*.

[97]The formal establishment of the Office of Field Service (OFS) as a principal subdivision of OSRD was confirmed by OSRD Administrative Order 4, 8 November 1943. OFS was abolished by Executive Order 9913 on 31 December 1947. Compton left on 30 July 1945 to head the Pacific branch of OSRD, and Waterman served as chief until 31 December 1946. John E. Burchard became deputy chief *vice* Waterman. The history of OFS is covered in detail in Thiesmeyer and Burchard, *Combat Scientists*.

[98]Rau, "Combat Scientists," p. 24.

[99]Baxter, *Scientists Against Time*, pp. 412–13. Stewart (*Organizing Scientific Research*, pp. 130–31) listed six functions performed by OFS, but they are refinements of the basic three functions noted.

[100]Rau, "Combat Scientists," pp. 313–14. The role of OFS in sponsoring OR/field service organizations in the central and southwest Pacific theaters is discussed in greater detail below.

[101]Ibid., p. 262.

[102]Stewart, *Organizing Scientific Research*, p. 143.

[103]Ibid.

[104]Memo 2, Maj W. B. Leach and Dr Ward F. Davidson, sub: OA in the U.S. Army and Navy, Washington, 7 Jul 42, RG 218, Entry 343A, Box 57, Folder OA, pp. 2-49–2-53 (hereafter cited as Leach-Davidson Memo 2).

[105]Baxter, *Scientists Against Time*, pp. 409–10; Rau, "Combat Scientists," p. 118.

[106]Rau, "Combat Scientists," pp. 118–19.

[107]Quoted in Rau, "Combat Scientists," pp. 127–28.

[108]Ibid., p. 23 n. 38. Most civilian scientists preferred the "functional" arrangement inasmuch as it corresponded with the usual organization of scientific work.

[109]Baxter, *Scientists Against Time*, p. 19.

[110]Ibid., pp. 19–20.

[111]On the difficulties of obtaining necessary data, see Stewart, *Organizing Scientific Research*, pp. 155–58.

[112]Ibid., pp. 154–55.

[113]Ibid., pp. 151–54. Initially, the Operations Division of the War Department General Staff (WDGS) was designated as the Army ground forces liaison with OFS, but that responsibility soon shifted to the WDGS New Developments Division headed by Maj. Gen. Stephen G. Henry, an enthusiastic supporter of OR as well as of effective fielding of new weapons (see Stewart, *Organizing Scientific Research*, p. 139; Thiesmeyer and Burchard, *Combat Scientists*, pp. 40–41). From June 1940 to 2 September 1945, seven officers occupied the War Department liaison officer position, only three of whom served more than one year. However, Rear Admiral Julius A. Furer served as the Navy's coordinator of research and development, and thus as the Navy's liaison officer with OFS, from mid-December 1941 to May 1945. It was only at the very end of the war that the AAF established an office to provide direct liaison with OFS.

[114]Baxter, *Scientists Against Time*, p. 29.

[115]Ibid.

[116]Rau, "Combat Scientists," pp. 120–21.

[117]Baxter, *Scientists Against Time*, pp. 29–30.

[118]The basic report (Leach-Davidson Rpt) was accompanied by a long memorandum on OR in Britain (Leach-Davidson Memo 1) and another fifty-three–page memorandum on the state of OR in the U.S. Army and Navy (Leach-Davidson Memo 2).

[119]The interesting but relatively uncomplicated history of OR in the U.S. Navy during WWII can be gleaned adequately from just three sources: George Shortley, "Operations Research in Wartime Naval Mining," *Operations Research* 15, 1 (1967): 1–10; Tidman, *Operations Evaluation Group*; and ORG, HQ, COMINCH/CNO, Summary Report to the OFS, OSRD, Washington, 1 Dec 45, Appendix C, pp. 38–39, located in College Park, Md., NARA II, RG 227, Entry 179, Box 301, Folder Summary Rpt to the OFS, OSRD (hereafter cited as ORG Summary Rpt). McCloskey, "U.S. OR," and Rau, "Combat Scientists," contain additional useful details.

[120]McCloskey, "U.S. OR," p. 911. The development of MWORG is covered in some detail in Shortley, "Operations Research in Wartime," pp. 1–10, and in Rau, "Combat Scientists," pp. 160–72. Curiously, MWORG is not mentioned at all in Tidman, *Operations Evaluation Group*.

[121]Ellis A. Johnson was one of the major figures in Navy OR in WWII and, from 1948 to 1961, he led Army OR work as director of the Operations Research Office of The Johns Hopkins University. His long and distinguished career in OR is outlined in Thornton L. Page, George S. Pettee, and William A. Wallace (assisted by Capt James Martin, USNR, and Alice L. Johnson), "Ellis A. Johnson, 1906–1973," *Operations Research* 22, 6 (1974): 1141–55. Degaussing is a process by which an electrical current is passed around the hull of a ship to cancel its normal magnetic field and thus make it less likely to set off magnetic mines.

[122]John Burchard, *Q.E.D.: M.I.T. in World War II* (New York: John Wiley & Sons, 1948), p. 93

[123]Page and others, "Ellis A. Johnson," p. 1143.

[124]Shortley, "Operations Research in Wartime," p. 5; Page and others, "Ellis A. Johnson," p. 1144.

[125]Page and others, "Ellis A. Johnson," p. 1144.

[126]Ibid.; Rau, "Combat Scientists," p. 163.

[127]Rau, "Combat Scientists," p. 162.

[128]McCloskey, "U.S. OR," p. 912.

[129]Ibid.

[130]Shortley, "Operations Research in Wartime," pp. 5–6.

[131]Ibid., p. 6.

[132]Burchard, *Q.E.D.*, p. 98. Bitter had been called to Washington in June 1940 to work with NOL on developing countermeasures to the German magnetic mine. He had first gone to England with two naval officers to observe British work on magnetic mines, and when he returned it was decided that he should be commissioned as a commander, USNR, and act as the middleman between the Navy and the civilian scientists working on naval matters. On 1 September 1944, Commander Bitter left MWORG to form the new Air Warfare Operations Research Group for the deputy chief of naval operations for air, Admiral John S. McCain. Dr. Michels resumed the position of director of MWORG for the rest of the war (see Rau, "Combat Scientists," p. 168; and Trefethen, "History of OR," p. 15).

[133]Rau, "Combat Scientists," pp. 163–64.

[134]Leach-Davidson Rpt, p. 16.

[135]Leach-Davidson Memo 2, p. 2-16.

[136]Ibid., pp. 2-18, 2-19.

[137]Rau, "Combat Scientists," p. 161.

[138]Leach-Davidson Memo 2, p. 2-19.

[139]Ibid., pp. 2-20, 2-21; Rau, "Combat Scientists," pp. 162–63.

[140]Rau, "Combat Scientists," p. 165. MWORG operated under the Base Maintenance Division's Mine Warfare Section.

[141]Leach-Davidson Memo 2, pp. 2-21, 2-22.

[142]Ibid., p. 2-22.

[143]Page and others, "Ellis A. Johnson," pp. 1144–45.

[144]Ibid., p. 1145. The Navy preferred that scientists dispatched for service in overseas theaters be commissioned, and most of the Navy OR specialists who deployed to the Pacific were given at least temporary commissions, usually in the USNR. Thus, several of Ellis Johnson's colleagues (notably Shirley Quimby and Thornton Page) also accepted commissions in the Naval Reserve and served in uniform for the remainder of the war.

[145]Ibid.

[146]Ibid. Wallace returned to Hawaii on 7 February 1944.

[147]Page and others, "Ellis A. Johnson," p. 1145.

[148]The story of the useless "sterilizers" is told by Rau ("Combat Scientists," pp. 167–68).

[149]Rau, "Combat Scientists," pp. 167–68.

[150]Ibid., p. 168.

[151]Page and others, "Ellis A. Johnson," pp. 1145–46.

[152]Ibid., p. 1146.

[153]Rau, "Combat Scientists," pp. 169–70.

[154]Ibid., p. 170.

[155]Ibid., pp. 170–71.

[156]Ibid., p. 171. According to Shortley, the operation was conceived over coffee in the NOL cafeteria ("Operations Research in Wartime," p. 7).

[157]Ibid. By that time, Johnson had shifted the focus of the campaign from the Shimonoseki Straits to the Inland Sea of Japan.

[158]Ibid., p. 172. AAF heavy bombers dropped some thirteen thousand mines of various types in a five-phase campaign that lasted until the end of the war, and Operation STARVATION resulted in the sinking of or damage to more than seven hundred Japanese ships (ca. 1.5 million tons), reducing Japanese shipping to a trickle at a cost of one B–29 lost for every forty-five Japanese ships sunk (see Shortley, "Operations Research in Wartime," p. 8).

[159]Shortley, "Operations Research in Wartime," p. 8.

[160]Ibid., p. 9. Johnson also contributed to XXI Bomber Command flight operations by recommending single, low-level sorties to lessen the flight time, conserve fuel, reduce maintenance time, lower crew fatigue, and reduce losses to Japanese air defenses. Happily, his ideas coincided with those of Lt. Gen. Curtis LeMay, the commander of XXI Bomber Command, for low-level night bombing using radar rather than visual aiming. One result was the reduction in B–29 attrition from 10 percent to 1 percent (see McCloskey, "U.S. OR," p. 912; Shortley, "Operations Research in Wartime," pp. 7–8).

[161]Rau, "Combat Scientists," pp. 172–73.

[162]McCloskey, "U.S. OR," p. 913.

[163]Only a brief summary of the history of the Anti-Submarine Wartime Operations Research Group (ASWORG) can be presented here, based primarily on the ORG Summary Rpt. Tidman (*Operations Evaluation Group*, chapter 1), and Rau ("Combat Scientists," chapter 4) devoted chapters to ASWORG and they should be consulted for details. A useful summary is contained in McCloskey, "U.S. OR," and there is a firsthand account by the leader of ASWORG in Philip M. Morse, "The Beginnings of Operations Research in the United States," *Operations Research* 34, 1 (1986): 10–17. Leach and Davidson outlined the history of ASWORG up to the middle of 1942 in their Memo 2.

[164]Ltr, Capt Wilder D. Baker to Coordinator of R&D, Office of the Sec Navy, Boston, 16 Mar 1942, sub: Records and Analyses of Anti-Submarine Warfare (reproduced in ORG Summary Rpt, Appendix C, pp. 29–32). Baker had observed ASW operations in Great Britain and had read a number of ORS RAF Coastal Command reports as well as Blackett's "Scientists at the Operational Level" (see Morse, "Beginnings of OR," pp. 11–12).

[165]Philip McCord Morse (1903–85) subsequently became "the grand old man" of American OR. Morse received his doctorate in physics from Princeton University in 1929, and began his teaching career at MIT in 1931. An expert on acoustics, he did some work on hydrophones and acoustic mines before being tapped to head ASWORG. After WWII, he was for a time the director of Brookhaven National Laboratory, served as the deputy director of the JCS Weapons Systems Evaluation Group (WSEG), and wrote and spoke widely on OR. He became the first president of the Operations Research Society of America in 1952–53. Details of his life and career can be found in his many writings, his autobiography (Philip M. Morse, *In at the Beginnings: A Physicist's Life* [Cambridge, Mass.: MIT Press, 1976]), and in William J. Horvath and Martin L. Ernst, "Philip McCord Morse, 1903–1983: A Remembrance," *Operations Research* 34, 1 (1986): 7–9.

[166]Leach and Davidson noted, "NDRC has no responsibility other than seeing that proper personnel is [sic] provided, and that the details of salaries, travel authorization, etc. are taken care of; the direction of operational research activities is assumed by the Navy" (Memo 2, p. 2-49). NDRC was reimbursed by the Navy for the costs incurred. Morse prepared an initial budget estimate that included $100,000 for salaries, $100,000 for travel, and about $50,000 for overhead expenses (see Leach-Davidson Memo 2, p. 2-4 n.).

[167]The original group included Morse (part-time), Shockley, A. T. Craig, Phillip J. McCarthy, Arthur F. Kip, Maurice E. Bell, and Robert F. Rinehart. The original seven were soon joined by W. A. Ambrose, Albert Thorndike, James K. Tyson, and John R. Pellam (see McCloskey, "U.S. OR," p. 913). William Bradford Shockley (1910–89) became one of America's best-known scientists. Born in London of American parents and educated in California, he received his doctorate in physics from MIT in 1936 and

immediately went to work for Bell Labs, to which he returned after the war. In 1956, Shockley shared the Nobel Prize in physics with John Bardeen (another WWII Navy OR scientist) and Walter Brattain for their work on the solid-state semiconductor (the transistor). From 1963 to 1975, Shockley was a professor of physics at Stanford University and became notorious for his controversial public pronouncements on genetics.

[168]The official Navy designation of ASWORG came into general public use only after August 1942.

[169]When Leach and Davidson compiled their report in the summer of 1942, the ASWORG "stable" included eight mathematicians and statisticians and eight physicists, of whom four were sound experts and two were radio experts. Their average age was 29 (see Leach-Davidson Memo 2, p. 2-10).

[170]Ibid., p. 2-11. As executive head, Shockley received $6,300 per annum. Morse was unpaid.

[171]When the OSRD OFS was created in January 1944, the administration of ASWORG contract and all other Navy OR activities supported by NDRC were transferred to OFS control (see ORG Summary Rpt, p. 11).

[172]ORG Summary Rpt, pp. 26–28. They included 32 mathematicians/statisticians, 26 physicists, 6 chemists, 5 biologists/zoologists, 4 engineers, 3 astronomers, 2 geologists, 2 economists, 2 people with library science degrees, and 1 architect.

[173]Leach-Davidson Memo 2, p. 2-6. In July 1942, ASWORG had personnel attached to the headquarters of the commander in chief, U.S. Fleet (COMINCH), in Washington; Atlantic Fleet in Boston; Eastern Sea Frontier in New York City; Gulf Sea Frontier in Miami; and Caribbean Sea Frontier in San Juan, Puerto Rico. Subsequently, ASWORG personnel were attached to nearly all Navy units concerned with antisubmarine warfare at home and overseas (see Tidman, *Operations Evaluation Group*, pp. 38–46).

[174]Trefethen, "History of OR," p. 14.

[175]Leach-Davidson Memo 2, pp. 2-6, 2-7.

[176]ORG Summary Rpt, p. 10.

[177]Ibid., pp. 4–8; Tidman, *Operations Evaluation Group*, pp. 49–51.

[178]McCloskey, "U.S. OR," p. 914.

[179]Ibid.

[180]Tidman, *Operations Evaluation Group*, p. 49. McClelland was replaced by Brig. Gen. Larson in April 1943.

[181]Ibid., pp. 51–54.

[182]Ibid., p. 50.

[183]McCloskey, "U.S. OR," p. 915.

[184]Morse, "Beginnings of OR," pp. 12–15; Leach-Davidson Memo 2, p. 2-10.

[185]Morse, "Beginnings of OR," p. 12.

[186]Ibid., p. 15.

[187]Ibid., pp. 15–16.

[188]ORG Summary Rpt, p. 10. The commander in chief, U.S. Fleet, Admiral Ernest J. King, approved the transfer on 9 July 1943.

[189]Ibid., pp. 14–15, 23–25. The projects undertaken by ASWORG are summarized in Tidman, *Operations Evaluation Group*, pp. 61–71.

[190]Morse, "Beginnings of OR," p. 13. McCloskey ("U.S. OR," p. 913) noted that almost all of the initial data on which the U.S. "theory of search" was built came from the British, but the analysis was entirely homegrown.

[191]McCloskey, "U.S. OR," pp. 913, 915. Koopman was the author of a paper titled "A Quantitative Aspect of Combat" in which he reworked Lanchester's equations using probability theory rather than averages.

[192]Memo, Frank Knox to COMINCH/CNO, all Bureaus and Offices, Navy Dept, Washington, 10 Sep 43, sub: OR—Special Assistance for, RG 227, Entry 177, Box 283, Folder Steps Leading to the Establishment of OFS.

[193]Memo, Admiral Ernest J. King (COMINCH/CNO) to Director, ASWORG, Washington, 7 Oct 44, sub: Operations Research Group (reproduced in ORG Summary Rpt, Appendix C, pp. 34–35). The evolution of the ORG is discussed in Thiesmeyer and Burchard, "Combat Scientists," pp. 106–20.

[194]ORG Summary Rpt, Appendix C, 36. The ORG was the largest single contribution of OSRD to OR (see ORG Summary Rpt, p. 1). A list of personnel who served in the ORG is in Thiesmeyer and Burchard, "Combat Scientists," p. 121.

[195]ORC conducted specialized OR studies, provided administrative and scientific backup support for the various ORG subgroups, and acted as liaison between ORG and other Navy organizations and OR groups in the other services (see ORG Summary Rpt, pp. 16–22; Thiesmeyer and Burchard, "Combat Scientists," pp. 113–15; Tidman, *Operations Evaluation Group*, pp. 89–92).

[196]The five main lessons cited here are listed by Tidman, *Operations Evaluation Group*, pp. 92–94.

[197]In fact, the Navy preferred that OR analysts and supervisors assigned to the fleets be commissioned in the USNR. The Navy actually tried a variety of modes for employing scientists for OR work. MWORG used civilians on per diem contracts. ASWORG used civilians obtained under an OSRD contract with Columbia University, and the various ORG subgroups after 1944 relied on civilian scientists provided on loan from the Office of Field Service, OSRD.

[198]The authors of the ORG Summary Rpt (p. 1) concluded that "some of these [OR] activities can be carried out by a group assigned to a single field command. But for all of the activities to be carried on effectively it is necessary that part of the group be in the field and another part work with the General Staff in Washington; with arrangements for free interchange of ideas and men between field and headquarters."

[199]Like the Navy ORG, the AAF OR program was large and complex and it cannot be treated in great detail here. Unlike the Navy program, however, the AAF program has yet to find its scribe. There is no comprehensive history of OR in the U.S. Air Force (USAF) similar to Tidman's *Operations Evaluation Group*. Nor is there a comprehensive published history of OR in the AAF during the World War II period. LeRoy A. Brothers' "Operations Analysis in the United States Air Force" (*Journal of the Operations Research Society of America* 2, 1 [1954]: 1–16) is a mere summary. Charles W. McArthur, *Operations Analysis in the U.S. Army Eighth Air Force in World War II*, History of Mathematics, vol. 4 (Providence, R.I.: American Mathematical Society, 1990) does provide some details on the World War II AAF OR program in general, but focuses on the Eighth Air Force program. LeRoy A. Brothers and others, *Operations Analysis in World War II—United States Army Air Forces* (Philadelphia: Stephenson-Brothers, 1949) is useful but offers only a simple listing of the various units that made up the AAF OR program, the key dates, and lists of the leaders of the various units and the personnel who served in them. As always, McCloskey, "U.S. OR," provides interesting details. Despite the relative scarcity of published material on OR in the AAF in World War II, the documents on the subject to be found in the National Archives are plentiful. Most of them are in RG 18 (Records of the Army Air Forces) but many useful items are to be found in RG 107 (Records of the Sec Army), RG 218 (Records of the JCS), and RG 227 (Records of the OSRD). Items of particular interest include the August 1942 Leach-Davidson Rpt and Leach-Davidson Memo 2; Lt Col W. B. Leach (chief, OA Div, HQ AAF), Washington, 15 Oct 43, sub: Army Air Forces OA in Combat Commands, with "Notes on OA in HQ AAF in US, in US Services outside the AAF, and in OCSigO," RG 107, Entry 113, Box 68, Folder OA, 1943–45) (hereafter cited as Leach, "AAF OA in Combat Commands"); and Memo, Col W. B. Leach (chief, OA Div, HQ AAF) to Brig Gen Byron E. Gates (chief, Management Control

Div, HQ AAF), Washington, 1 Jan 45, sub: Two-Year Rpt on OA, with a summary and two enclosures: 1. List of OA Rpts as of 1 Nov 44; 2. Robert L. Stearns (Chief, OAD, HQ, Twentieth Air Force), "Progress Report # 3 (Period 28 July 1944–15 November 1944)," Washington, ca. 15 Nov 44, RG 107, Entry 113, Box 68, Folder OA, 1943–45 (hereafter cited as Leach, Two-Year Rpt).

[200]In general, the AAF personnel involved in OR preferred the term "operational analysis" (OA), although the analysts with the Eighth Air Force in England commonly used the term "operational research" to describe their work, just as did their nearby British colleagues.

[201]McCloskey, "U.S. OR," p. 921.

[202]Rau, "Combat Scientists," pp. 122–23.

[203]McCloskey, "U.S. OR," p. 911.

[204]Rau, "Combat Scientists," p. 123.

[205]Ibid., pp. 123–24.

[206]Leach-Davidson Rpt, p. 19; Leach-Davidson Memo 2, p. 2–25; Rau, "Combat Scientists," p. 125. Cyril Moreau Jansky, Jr., was born in 1895 and held a master of science degree from the University of Wisconsin (1919). He was a former professor of radio engineering at the University of Minnesota (1920–28) and a consultant on radio engineering in Washington with a large clientele. He died in 1975. His papers are at the State Historical Society of Wisconsin, Madison, , and at the University Libraries, University of Maryland, College Park.

[207]Leach-Davidson Rpt, pp. 19–20. In May 1942, Jansky defined his function as, "to assist in the organization of the [OA] groups in the various Interceptor Commands and then to standardize and correlate their work." See Cyril M. Jansky, Jr. (special consultant, Directorate of Air Defense, HQ USAAF) and William L. Everitt (director, ORG, Radar and Air Communications Div, OCSigO), Memo for Col Tom C. Rives and Col Gordon P. Saville, Washington, 9 May 42, sub: Delineation of Functions between Operational Analysis in Air Defense in the Army Air Force and Operational Research in Radar and Air Communications in the Signal Corps," RG 111, Entry 1024, Box 3027, Folder 00–400.112–Operational Research—General.

[208]Leach-Davidson Rpt, p. 20; Leach-Davidson Memo 2, pp. 2-25, 2-26. The problem was that such consultant contracts were limited to 180 days, and Jansky later ran into problems with this hiring method (see Rau, "Combat Scientists," p. 159). Jansky, who had earned $27,000 per year as a private consultant, accepted the maximum government rate of $25 per day, or $9,125 per year (see Leach-Davidson Memo 2, p. 2-25).

[209]See Rau, "Combat Scientists," pp. 154–60. In a letter to Frank B. Jewett on 7 February 1942, Karl T. Compton, the president of MIT, characterized Saville as "the 'spark plug' of this [OR] effort for our Army for at least eighteen months" (Ltr, Karl T. Compton to Dr Frank B. Jewett, [Boston], 7 Feb 42, sub: Operations Research Sections, RG 227, Entry 177, Box 284, Folder OSRD in OAD, AAF).

[210]Leach-Davidson, Memo 2, p. 2-26; Rau, "Combat Scientists," pp. 155–56. Jansky's memo is reproduced in Leach-Davidson Memo 2, pp. 2-31–2-34.

[211]Cyril M. Jansky, Jr., Memorandum on Operational Analysis in the War Department, Washington, ca. Apr–May 42 (hereafter cited as Jansky Memo on OA), reproduced in Leach-Davidson Memo 2, p. 2-31.

[212]The extent of the system envisioned by Jansky is clear from the two charts that accompanied his "Memo on Operational Analysis." See Chart I (Operational Analysis in a Typical Defense Command or Theatre of Operations) and Chart II (Operational Analysis in Directorates), reproduced in Leach-Davidson Memo 2, following p. 2-34; Rau, "Combat Scientists," p. 156.

[213]Jansky Memo on OA, reproduced in Leach-Davidson Memo 2, p. 2-32.

[214]Rau, "Combat Scientists," p. 157.

[215]They were apparently accompanied by Col. Saville (see Leach-Davidson Memo 2, p. 2-27).

[216]McArthur, *Operations Analysis*, p. 3; Trefethen, "History of OR," p. 12.

[217]Leach-Davidson Rpt, p. 19; McArthur, *Operations Analysis*, p. 3; Rau, "Combat Scientists," pp. 158–59.

[218]Cited by Rau, "Combat Scientists," pp. 159–60.

[219]McArthur, *Operations Analysis* , p. 3.

[220]Leach-Davidson Rpt, p. 2.

[221]The terms of reference for the reporting team are included in Memo, Vannevar Bush to Ward F. Davidson, Washington, 11 Jul 42, sub: Investigation and Rpt on OA, RG 218, Entry 343A, Box 9, Folder 15. Maj. (later Brig. Gen., USAFR) Walter Barton Leach (1900–71) deserves more than any other person the title of "Father of U.S. Army Operations Research." For details of his life and career, see the brief biographical sketch in Appendix A of this volume.

[222]Leach-Davidson Rpt, pp. 23–47.

[223]Ibid.

[224]Ltr, Maj W. B. Leach to Harvey H. Bundy, Washington, 2 Sep 42, transmitting a memo by Leach on OA, RG 107, Entry 113, Box 68, Folder OA, 1942.

[225]Ibid. The role of the coordinating office recommended by Leach and Davidson would be filled in the AAF by OAD in the Management Control Div of HQ USAAF with Leach as chief. The Navy did not form a similar unit, but its functions were, in effect, performed by ORG after October 1944.

[226]McArthur, *Operations Analysis*, p. 4. By August 1942, Jansky's office in the Directorate of Air Defense was already in operation, two analysts were enroute to Lt. Gen. Andrews' Caribbean Defense Command, the I Bomber Command was taking advantage of the Navy's ASWORG, and steps were in progress to create an OA section in the VIII Bomber Command in England.

[227]The establishment and history of the Eighth Air Force OA section is discussed in greater detail below.

[228]Rau, "Combat Scientists," p. 258

[229]Ltr, Com Gen, AAF [Lt Gen Henry H. Arnold], to commanding generals, All Air Forces; All Army Air Forces Commands; All Directors and Chiefs of All Air and Special Staff Divs, Washington, 24 Oct 42, sub: OA, RG 107, Entry 113, Box 68, Folder OA, 1942.

[230]Ibid., p. 3.

[231]The directive establishing OAD and prescribing its functions is at Tab G of Leach, "Army Air Forces OA in Combat Commands."

[232]Rau, "Combat Scientists," p. 259. A month before the creation of OAD, Capt. John M. Hall, the assistant executive officer in the Office of the Assistant Secretary of War, prepared a memo for Harvey H. Bundy in which, after noting he did not believe that "sufficient attention has been paid to the problem of integrating Operations Analysis with the rest of the Army at staff level," he recommended the creation in the Operations Division of the WDGS of an OA section, the chief of which would report to the ACS, Operations Division. The eleven functions of such an OA section listed by Capt. Hall included all of those that OAD would perform for the AAF. See Memo, Capt John M. Hall to Harvey H. Bundy, Washington, 1 Dec 42, sub: Organization of OA in the Army, RG 107, Entry 113, Box 68, Folder OA, 1942.

[233]Leach, Two-Year Rpt, p. 22.

[234]Ibid. A total of eight commissioned officers served in OAD between 31 December 1942 and 2 September 1945. Col. Leach remained the chief until July 1945 and was then replaced by Lt. Col. Roscoe C. Crawford as acting chief until 2 September 1945. At various times, eight scientific and clerical personnel also served in OAD (see Brothers and others, *Operations Analysis*, pp. 41–42).

[235]Brothers and others, *Operations Analysis*, p. 41.

[236]McCloskey, "U.S. OR," p. 920.

[237]Leach, Two-Year Rpt, p. 21.

[238]Ibid.

[239]Ibid., p. 22. The recommended staffing for any future OAD was chief of section (1 colonel); executive officer (1 major); personnel section (1 lieutenant colonel and 1 captain); training section (1 lieutenant colonels and 4 civilian instructors); publication and dissemination section (1 major, 1 civilian librarian, and 1 civilian scientist); and overseas liaison section (1 lieutenant colonel and 1 major).

[240]Leach-Davidson Rpt, pp. 44–45.

[241]Ibid.

[242]Civilian operations analysts in the AAF were often known to their uniformed colleagues as "Doc," "the Quiz Kids," or "Op Annies" (see Charlotte Knight, "Ask Them Another," *Air Force* 28, 8 [1945]: 31).

[243]Leach, "Army Air Forces Operations Analysis" p. 1.

[244]Brothers and others, *Operations Analysis,* pp. 1–2.

[245]Jansky oversaw six operations analysts stationed in Panama and Florida, with I Fighter Command, and at Drew Field (see Leach, "Army Air Forces Operations Analysis," additional p. 1). The principal AAF OA elements created during WWII are listed in Appendix B of this volume.

[246]Brothers and others, *Operations Analysis*, p. 36; Leach, Two-Year Rpt, pp. 20–21.

[247]Brothers and others, *Operations Analysis*, p. 36. The five men served at various times and for various periods between August 1944 and September 1945. Ball had a distinguished career as a diplomat and foreign policy expert after the war.

[248]Leach, Two-Year Rpt, pp. 20–21.

[249]Burchard, *Q.E.D.*, p. 74.

[250]Brothers and others, *Operations Analysis*, p. 40.

[251]Tannenwald was a New York lawyer and served with USSBS in the European Theater from September 1944 to January 1945 (see Brothers and others, *Operations Analysis*, p. 40).

[252]The COA is discussed by McArthur, *Operations Analysis*, pp. 8–14.

[253]Earle was the editor of a well-known anthology of military thought, *Makers of Modern Strategy* (Princeton, N.J.: Princeton University Press, 1941).

[254]McArthur, *Operations Analysis*, p. 9.

[255]Henry L. Stimson (Sec War), Memo for the Chief of Staff (Gen. George C. Marshall), Washington, 6 Dec 43, sub: OA, RG 107, Entry 113, Box 68, Folder OA, 1943–45.

[256]Twelve "principles" for the assignment of civilian analysts to a military command were laid out in the Leach-Davidson Rpt (pp. 5–6).

[257]A few AAF commanders at first declined the opportunity to add an OA section to their headquarters. Maj. Gen. Claire L. Chennault, the commander of the Fourteenth Air Force in China, was known for his crusty character and is said to have responded to an offer of an OA section by requesting "the equivalent in gasoline" (see McCloskey, "U.S. OR," p. 919).

[258]A notable exception was the refusal of the VIII Bomber Command Intelligence (A-2) Section to allow the newly formed OA section access to any technical information. The problem was soon solved by the intervention of the commander, Maj. Gen. Ira Eaker (see Rau, "Combat Scientists," p. 245).

[259]Memo, Maj W. B. Leach and Dr Ward F. Davidson, Washington, 20 Jul 42, sub: Memo as to Investigation of Branches of the Army and Navy in Which OA Could Be Used, RG 218, Entry 343A, Box 57, Folder OA.

[260]U.S. War Department, *United States War Department Table of Organization and Equipment No. 1–787S: Army Air Forces—Operations Analysis Section, Special* (Washington: U.S. War Dept, 4 Oct43). A copy can be found in RG 107, Entry 113, Box 68, Folder OA, 1943–45. The impetus for publication of the TOE came from OAS Eighth Air Force (see McArthur, *Operations Analysis*, pp. 29–30).

[261]U.S. War Department, *Field Manual 30–27: Regulations for Civilian Operations Analysts, Scientific Consultants, and Technical Observers Accompanying U.S. Army Forces in the Field* (Washington: U.S. War Dept, 31 Aug 44).

[262]Leach, Two-Year Rpt, Summary.

[263]Knight, "Ask Them Another," p. 34.

[264]The AAF OA section elements created during the war, the approximate number of analysts employed, and the section chiefs are listed in Appendix B of this volume.

[265]For example, the nine analysts who served in the Fifth Air Force in the Southwest Pacific Area were commissioned officers. Their chief, Sidney K. Wolf, was a lieutenant colonel.

[266]Leach-Davidson Rpt, p. 4.

[267]Knight, "Ask Them Another," p. 31.

[268]Leach, Two-Year Rpt, pp. 7–9.

[269]Knight, "Ask Them Another," p. 60. The uniform and other administrative details pertaining to civilian scientists posted overseas are discussed in Thiesmeyer and Burchard, "Combat Scientists," pp. 88–91.

[270]In June 1942, Capt. John M. Hall, assistant executive to the assistant secretary of the Army, stated that it was not necessary for analysts to have any particular scientific training or background, writing, "In fact, it might be better if they had none. What is needed is a type of cool-headed person with common sense who can analyze what comes in in a cold-blooded manner and make unbiased criticisms" (Memo, Capt John M. Hall, 23 Jun 42, sub: Use of Competent Civilians in the Analysis of Operational Efficiency, RG 107, Entry 113, Box 68, Folder OA, 1942 [hereafter cited as Hall Memo]). Whereas Bart Leach might have agreed, Phil Morse and P. M. S. Blackett surely would not.

[271]Leach-Davidson Rpt, pp. 23–28 *passim*. For example, the distinguished New York lawyer John M. Harlan was selected to head the Eighth Air Force OA section. He proved an excellent choice and later became an associate justice of the U.S. Supreme Court.

[272]Hall Memo, p. 1.

[273]The possibilities had already been discussed in the Leach-Davidson Rpt (pp. 23–28) with attention given to lawyers, business executives, and other non-scientific types.

[274]Leach, Two-Year Rpt, p. 3.

[275]Leach-Davidson Rpt, p. 28.

[276]Ibid., pp. 28–29. Leach and Davidson noted that the civil service methods had been tried by the Army Signal Corps group headed by William Everitt and were found to be extremely clumsy, the more so because "the Civil Service and Classification Acts were formulated to eliminate politics, nepotism, and the spoils system from the lower ranges of government employment; they were never designed for a situation where men are being begged to take jobs that are bound to represent sacrifices to them." Analysts could be employed under per diem consultant contracts for a maximum of only 180 days. The commissioning of analysts in the Army offered possibilities, particularly for those being assigned to overseas commands where there was some danger of capture by the enemy, but there were limits on the number of annual officer accessions to the Army. Employment by the President's Emergency Fund was not a viable alternative, and the Army Specialist Corps was soon to be dissolved.

[277]Ltr, Maj W. B. Leach to Harvey H. Bundy, 30 Sep 42, sub: Contract for Employment of Operations Analysts, p. 1, RG 107, Entry 113, Box 68, Folder OA, 1942 (hereafter cited as Ltr, Leach to Bundy, 30 Sep 42). The National Research Council headed by Dr. George Barrows was a subsidiary of NAS led by Dr. Frank B. Jewett.

[278]Ibid.

[279]Ibid., pp. 1–2.

[280]Bush was already uneasy with the ASWORG-Columbia University arrangement and was under some pressure from the Bureau of the Budget. He thus wanted to avoid any further entanglements and controversy (see Rau, "Combat Scientists," pp. 283–85).

[281]Ltr, Leach to Bundy, p. 2. The analysts working for Jansky in the Directorate of Air Defense, hired under similar arrangements, had already been working more than six months, and it was being suggested that their employment violated Administrative Order No. 50.

[282]Arrangements for payment of AAF analysts is outlined in Leach, Two-Year Rpt, pp. 5–6.

[283]Leach, Two-Year Rpt, p. 5.

[284]Ibid.

[285]Ibid., p. 6.

[286]Ibid. The average annual salary for an analyst was $6,637.91.

[287]Rau ("Combat Scientists") discusses the friction between OSRD and the AAF OA program in some depth. See, in particular, pp. 236–40, 265–71, 283–86, and 293–300.

[288]Ltr, Vannevar Bush to Karl T. Compton, Washington, 15 Feb 43, RG 227, Entry 177, Box 284, Folder OSRD in OAD.

[289]See, *inter alia*, memo, Alan T. Waterman to Vannevar Bush, ca. 4 Apr 43, sub: Notes on Future Manpower Needs and Availability in the Radar Field, RG 218, Entry 343A, Box 9, Folder 14.

[290]Rau, "Combat Scientists," pp. 326–27.

[291]Ibid., p. 327.

[292]Alan T. Waterman, then Karl Compton's deputy at OFS, discussed the problem with Vannevar Bush in a 27 December 1943 memo (see memo, Alan T. Waterman to Vannevar Bush, 27 Dec 43, sub: Requests to OFS for Permanent Appointments with the Armed Services, RG 227, Entry 177, Box 284, Folder OA—Projects with OAD).

[293]Leach, Two-Year Rpt, pp. 3–4.

[294]Baxter, *Scientists Against Time*, pp. 406–07.

[295]Leach, Two-Year Rpt, p. 4.

[296]Ibid.

[297]Baxter, *Scientists Against Time*, pp. 84–85.

[298]The story of OAS Eighth Air Force is admirably told in McArthur, *Operations Analysis*.

[299]Leach-Davidson Memo 2, p. 2-29.

[300]Ibid. A member of Maj. Gen. Eaker's staff discussed the matter with Dr. B. G. Dickins of ORS RAF Bomber Command as early as May 1942 (see U.K. Air Ministry, *OR in RAF*, p. 46).

[301]McArthur, *Operations Analysis*, p. 6; Rau, "Combat Scientists," pp. 131–32.

[302]McArthur, *Operations Analysis*, pp. 6–7. The other members of the team were Leslie H. Arps (another lawyer), James Alexander (a mathematician on loan from the Navy MWORG), W. Norris Tuttle (research director for the General Radio Company and OSRD consultant), William J. Youden (a biochemist and statistician from the Boyce Thompson Plant Research Institute), and Howard P. Robertson (an NDRC physicist from Princeton University). Alexander and Robertson both returned to the United States in January 1943 under something of a cloud (see McArthur, *Operations Analysis*, pp. 27–29, and Rau, "Combat Scientists," pp. 253–58). Harlan served as a civilian until July 1943 when he accepted a commission as a lieutenant colonel. Later promoted to colonel, he headed the section until August 1944, when he was reassigned and replaced by Leslie Arps, who had received his commission as a major in July 1943 and was subsequently promoted to lieutenant colonel (see Leach, Two-Year Rpt, p. 13). On Harlan's reassignment and Arps' tribulations as the new section chief, see McArthur, *Operations Analysis*, pp. 205–10.

[303]Rau, "Combat Scientists," p. 248.

[304]Leach, "Army Air Forces Operations Analysis," p. 3; McArthur, *Operations Analysis*, pp. 19–20.

[305]McArthur, *Operations Analysis*, p. 20; Brothers, "Operations Analysis," p. 1.

[306]McArthur, *Operations Analysis*, pp. 22–25.

[307]For the organization and tasks performed by the various subsections, see McArthur, *Operations Analysis*, pp. 30–45.

[308]A new OA section for VIII Bomber Command was promised but never materialized. Maj. Gen. James H. Doolittle replaced Lt. Gen. Eaker as commander of Eighth Air Force in January 1944.

[309]Brothers and others, *Operations Analysis*, p. 13; McArthur, *Operations Analysis*, pp. 35–36, 87–100. OAS VIII Fighter Command also covered the VIII Air Support Command, which became the nucleus for the Ninth Air Force in November 1943, and OAS VIII Fighter Command lost most of its personnel to the new OA section, Ninth Air Force.

[310]McArthur, *Operations Analysis*, pp. 210–13.

[311]Leach, Two-Year Rpt, pp. 1–2. The first WAC [member of the Women's Army Corps], Sgt. Eileen Hazelton, was assigned to the Bombing Accuracy Subsection in July 1943; by the end of the war thirteen WACs were assigned (see McArthur, *Operations Analysis*, p. 34).

[312]Brothers and others, *Operations Analysis*, p. 13.

[313]Ibid., p. 1. Leach went on to list ten major accomplishments of the OA sections.

[314]Knight, "Ask Them Another," p. 31.

[315]Some idea of the variety of the problems studied by AAF analysts can be gleaned from the short list of reports presented in Leach, Army Air Forces Operations Analysis, pp. 5–7.

[316]McArthur, *Operations Analysis*, p. 328.

[317]Brothers and others, *Operations Analysis*, p. 1.

[318]Brothers, "Operations Analysis," p. 6.

[319]Ibid., p. 9,

[320]McArthur, *Operations Analysis*, p. 328; Brothers and others, *Operations Analysis*, p. 2.

[321]Baxter, *Scientists Against Time*, pp. 168–69.

[322]Lauriston S. Taylor, "Operations Analysis," *Military Review* 26, 6 (1946): 25.

[323]Ibid.

[324]Ibid.

[325]Leach, Two-Year Rpt, p. 7.

[326]McCloskey, "U.S. OR," p. 918.

[327]Ibid., p. 920. The work of Ellis Johnson, a Navy operations analyst assigned to the XXI Bomber Command to plan the aerial mining campaign against Japan, has already been mentioned.

[328]Ibid.

[329]Ibid., p. 921; Leach, Two-Year Rpt, p. 7.

[330]One notable exception is the definition by OAS VIII Bomber Command analysts of the concept of "circular error probable," a concept subsequently much used by the armed forces, particularly in planning the use of nuclear weapons (see Brothers, "Operations Analysis," pp. 3–4).

[331]Brothers and others, *Operations Analysis*, Dedication. Arneson was awarded the Medal of Freedom posthumously.

[332]McArthur (*Operations Analysis*, pp. 323–25) noted many of the individual decorations and awards made to Eighth Air Force analysts, and Brothers and others (*Operations Analysis*, *passim*), indicated the decorations and awards earned by all the AAF analysts.

[333]Brothers and others, *Operations Analysis*, p. 1.

[334]Quoted by McArthur, *Operations Analysis*, p. 323.

[335]Ibid., p. 324.

[336]Rau, "Combat Scientists," p. 124. The basic source for the establishment of the Signal Corps OR section is Leach-Davidson Memo

2, pp. 2-42–2-46. Unless otherwise noted, most of the following account is based on that source. Other sources for the history of the Operational Research Branch, Office of the Chief Signal Officer (ORB OCSigO) include Rau, "Combat Scientists," pp. 149–54 *et passim*, and the documents included in RG 111, Entry 1024 and Entry 1036A. The official history volumes on the Signal Corps in the series *United States Army in World War II—The Technical Services* produced by the Army's chief of military history contain practically nothing about Signal Corps OR activities, and what is written is often incorrect. For example, George R. Thompson, George Raynor, and Dixie R. Harris, *The Signal Corps: The Outcome (Mid-1943 Through 1945)* (Washington: OCMH, DA, 1966), pp. 5, 613, put the date of the establishment of the ORB OCSigO in *late* 1942. As the Army officer responsible for radar development, Maj. Gen. Olmstead was familiar with British radar developments and the application of OR to solve the problems of integrating radar with the British air defense system.

[337]Leach-Davidson Memo 2, p. 2-42. William Litell Everitt was born in Baltimore, Maryland, on 14 April 1900. He served in the U.S. Marine Corps (1918–19) and received a doctorate in electrical engineering from Ohio State University in 1933. A well-known consultant, he was a major in the Signal Corps reserves from 1932 to 1941, serving his active-duty tours at the laboratories at Wright Field in Ohio, and at Fort Monmouth, New Jersey. After the war, he was a professor of electrical engineering at the University of Illinois and dean of the university's College of Engineering. He was president of the Institute of Radio Engineers in 1945. He died on 6 September 1986. Col. Meade had first approached Vannevar Bush at OSRD for assistance, but, as was his usual practice, Bush palmed him off to Jewett at NAS and then warned NDRC division chairmen to inform Jewett if they heard "of any moves looking toward the establishment of such sections" (see Memo, Vannevar Bush to Chairmen of NDRC Divs, Washington, 30 Jan 42, RG 227, Entry 177, Box 284, Folder OSRD in OAD).

[338]Rau, "Combat Scientists," p. 152.

[339]Leach-Davidson Memo 2, p. 2-42. Everitt even suggested at one point that the name of the group be changed to the Technical Research Group.

[340]Thompson and others, *Signal Corps*, pp. 310, 613.

[341]William L. Everitt, ca. Oct 43, draft titled "Operational Research in the Signal Corps," p. 9, RG 111, Entry 1036A, Box 51, Folder unmarked.

[342]Leach-Davidson Memo 2, p. 2-46. See also Rau, "Combat Scientists," pp. 152–53. Leach and Davidson (Leach-Davison Rpt, p. 28) noted that Everitt had encountered "fantastic problems" in dealing with the civil service and that those problems had cost him two months of delay.

[343]Ibid. The initial hires included Lynne E. Smeby (as associate director), Norton, Singer, Smith, Omberg, and Bateman.

[344]Leach, "Army Air Forces Operations Analysis," additional p. 2.

[345]Leach-Davidson Memo 2, p. 2-44. Rau ("Combat Scientists," p. 154) noted, however, that the projects proposed by Everitt "were not dissimilar to those pursued by British scientists working in operations research."

[346]Cyril M. Jansky, Jr., and William L. Everitt, Memo for Col Tom C. Rives and Col Gordon P. Saville, Washington, 9 May 42, sub: Delineation of Functions between Operational Analysis in Air Defense in the Army Air Force and Operational Research in Radar and Air Communications in the Signal Corps, RG 111, Entry 1024, Box 3027, Folder 00–400.112 Operational Research—General.

[347]Ltr, Lt Col W. B. Leach to OCSigO, Army Service Forces, Attn: Planning Director, Washington, 16 Apr 43, sub: Procurement and Training of Operations Analysts for the Army Air Forces and Coordination of Their Technical Activities, RG 111, Entry 1024, Box 3027, Folder 10 00–400.112 Engineer and Analyst Indoctrination.

[348]For a detailed discussion of Everitt's difficulties in dealing with Alan T. Waterman and OSRD on technical training for Signal Corps and AAF OR personnel (for whom Everitt had agreed to act as agent), see Rau, "Combat Scientists," pp. 279–83, 327–32.

[349]Memo, John H. Teeter, 7 Apr 43, sub: Operations Analyst Studies, RG 227, Entry 177, Box 284, Folder Definitions and Methodology of OA—J. H. Teeter's Memoranda on Training for OA. See also Memo, J. H. Teeter, ca. 15 Apr 43, sub: Operation Analyst Training Program, RG 227, Entry 177, Box 284, Folder Definitions and Methodology of OA—J. H. Teeter's Memoranda on Training for OA.

[350]The history of the Operational Analysis Branch, Technical Liaison Division, Signal Section, Headquarters European Theater of Operations, U.S. Army, is summarized in Lucien L. Farkas (acting chief, Operational Analysis Branch, Technical Liaison Division, Office of the Chief Signal Officer, European Theater of Operations [ETO]) to chief signal officer, War Dept, Washington, Attn: director, NDD, 25 May 45, sub: Activities of the Operational Analysis Branch in the European Theater of Operations (hereafter cited as Farkas Memo to CSO); and Lucien L. Farkas (field service consultant) to Alan T. Waterman (OFS, OSRD), 25 Oct 45, sub: Rpt of Activities during Time Employed by the Office of Field Service, Office of Scientific Research and Development, both in RG 227, Entry 179, Box 292, Folder OFS-NDD ETO Rpts; Smeby.

[351]Farkas Memo to CSO, p. 2.

[352]Ibid., pp. 4–5. Howard returned to the United States on 27 October 1944, and Farkas took over as acting chief.

[353]Karl R. Spangenberg, ca. 4 Sep 44, sub: Rpt of Activities, ETO, Jul 22 to Sep 4, 44, pp. 1, 6, RG 227, Entry 179, Box 292, Folder OFS-NDD ETO Rpts; Smeby.

[354]Ibid.

[355]The Leach-Davidson Rpt and Memo 2 make no mention of any Ordnance Department OR activity, and an admittedly perfunctory examination of the extensive files on WWII Ordnance Department activities in the National Archives has disclosed no material on Ordnance OR work—at least none under the heading "Operations Research" or "Operations Analysis." Similarly, the official history of BRL (John G. Schmidt, *Volume I: A History of the United States Army Ballistic Research Laboratories, 1914–1956*. Ballisticians in War and Peace Series, 3 vols. [Aberdeen Proving Ground, Md.: U.S. Army BRL, 1956] covers the WWII period) makes no mention of any specific OR section or activity.

[356]Schmidt, *History of BRL*, p. 25.

[357]Ibid., pp. 28. Lt. Col. Simon was an expert on statistical methods, sampling, and quality control.

[358]Ibid., pp. 52–55.

[359]Oral history interview with Arthur Stein conducted by Eugene P. Visco and James Williams, Institute for Defense Analysis, Alexandria, Va., 2 Apr 92, p. 7. The interview was conducted as part of the Office of the Deputy Under Secretary of the Army for Operations Research Oral History Project.

[360]Ibid., p. 5.

[361]Ibid., p. 8.

[362]Oral history interview with Dr. Frank Grubbs conducted by Eugene P. Visco, Aberdeen Proving Ground, Md., 26 Oct 94, pp. 1–2. The interview was conducted as part of the Office of the Deputy Under Secretary of the Army for Operations Research Oral History Project.

[363]Ibid., p. 3.

[364]Baxter, *Scientists Against Time*, p. 85.

[365]Leach-Davidson Rpt, pp. 28–29. No further information on this activity has been found.

[366]Allied Forces, 21. Army Group, No. 2 ORS. *Operational Research in North West Europe: The Work of No. 2 Operational Research Group with 21. Army Group, June 1944–July 1945* (London: Allied Forces, 21. Army Group, No. 2 ORS, 1945), p. i.

[367]Jansky Memo on OA, reproduced in Leach-Davidson Memo 2, p. 2-31.

[368]Ltr, Robert W. King to Vannevar Bush, Washington, 2 Jul 42, RG 218, Entry 343A, Box 9, Folder 15.

[369]Leach-Davidson Rpt, pp. 46–47.

[370]Memo, Harvey H. Bundy to Maj Gen Stephen Henry, Washington, 9 Nov 43, forwarding Ltr, Lt Col W. B. Leach to Harvey H. Bundy, 4 Nov 43 (hereafter cited as Ltr, Leach to Bundy, 4 Nov 43); and Memo, Lt Col W. B. Leach to Harvey H. Bundy, 2 Nov 43, sub: Desirability and Method of Establishing an OA in the Ground Forces, RG 107, Entry 113, Box 68, Folder OA, 1943–45 (hereafter cited as Memo, Leach to Bundy, 2 Nov 43).

[371]Ltr, Leach to Bundy, 4 Nov 43.

[372]Memo, Leach to Bundy, 2 Nov 43, pp. 1–2.

[373]Memo, Lt Col W. B. Leach (chief, OAD, HQ AAF) to the sec war, Washington, 25 Nov 43, sub: Desirability and Method of Extending OA to Ground and Amphibious Operations, RG 107, Entry 113, Box 68, Folder OA, 1943–45).

[374]Draft one-page letter to theater commanders *re* "Extension of OA to Ground and Amphibious Operations," Appendix A to Alan T. Waterman, "Outline of Developments Leading to Establishment of ORS, CPA," after Jul 44, RG 227, Entry 179, Box 308, Folder CPA–2 Miscellaneous–General (hereafter cited as Waterman, "Outline of Developments").

[375]Memo, Henry L. Stimson to Gen George C. Marshall, Washington, 6 Dec 43, sub: OA, RG 107, Entry 113, Box 68, Folder OA, 1943–45.

[376]Memo, Lt Col W. B. Leach to Maj Gen Stephen G. Henry (director, NDD WDGS), Washington, 6 Dec 43, sub: Analysis Section for Jungle Warfare Requested by Lieutenant General Harmon, RG 107, Entry 113, Box 68, Folder OA, 1943–45. Lt. Gen. Harmon suggested that the proposed jungle warfare OA could be integrated with Robert L. Stearns' Thirteenth Air Force OA section and that Stearns (along with Harmon himself) could act as the supervisor of the new OA team.

[377]Msg, Operations Div, WDGS (for the chief of staff) to Com Gen, South Pacific Area, Washington, 20 Dec 143, RG 107, Entry 113, Box 68, Folder OA, 1943–45.

[378]Writing to Karl T. Compton on 15 December 1943, Harvey Bundy indicated that the team for Lt. Gen. Harmon's headquarters was being activated, but no further evidence regarding the team or its activities has been found, and it is not mentioned in the official OSRD histories (see Memo, Harvey H. Bundy to Karl T. Compton, Washington, 15 Dec 43, sub: Conf with Gen MacArthur Concerning OA, RG 107, Entry 113, Box 68, Folder OA, 1943–45). Harmon's team may well have been canceled or disapproved at some stage.

[379]Memo, Vannevar Bush (director, OSRD) to Harvey H. Bundy (special asst to sec war), Washington, 7 Jan 44, RG 107, Entry 113, Box 68, Folder OA, 1943–45. The two staff officers in question were Col. Thomas North and Lt. Col. C. W. Leihy.

[380]The history of the Research Section, HQ SWPA, is summarized in H. Kirk Stephenson, "Summary of Activities of the Research Section, Southwest Pacific Area," after 13 Sep 45; H. Kirk Stephenson, "Summary of Principal Projects," late 1945; and H. Kirk Stephenson, "Civilians in the Army, The Story of the Research Division, Southwest Pacific Area," 1945, all in RG 227, Entry 177, Box 284, Folder SWPA—Research Section SWPA—Reports by H. K. Stephenson and A. T. Waterman. Unless otherwise noted, these three documents form the basis for the following account. See also Stewart, *Organizing Scientific Research*, pp. 137–38; Thiesmeyer and Burchard, "Combat Scientists," pp. 294–304 *et passim*; and Rau, "Combat Scientists," pp. 315–19, *et passim*.

[381]Harrison was the dean of science at MIT and the chief of NDRC Division 16. The Research Section, GHQ SWPA, was formally established by General MacArthur's directive in July 1944.

[382]Stephenson, "Summary of Activities," p. 2. Maj. Gen. Akin was MacArthur's representative for research and technical matters, and it was anticipated that much of the Research Section's work would deal with communications and radar. General MacArthur was well known for trying to minimize the impact of "outsiders" on his command, which may explain why the Research Section did not enjoy a more prominent placement.

[383]Rau, "Combat Scientists," p. 317. Moreover, Maj. Gen. Akin placed the section under the supervision of one Maj. Harrington, a man Dr. Harrison described as neurotic and homosexual and whom Harrison succeeded in having dismissed from the Army (see Rau, "Combat Scientists," p. 317).

[384]Stephenson, "Civilians in the Army," p. 4.

[385]Ibid., p. 12.

[386]Stephenson, "Summary of Principal Projects," p. 4.

[387]Maj. Gen. Marquat had hoped for two men right away and perhaps three or four later (see Ltr, Karl T. Compton [chief, OFS] to Harold Hazen [professor of electrical engineering, MIT], Washington, 15 Mar 44, RG 227, Entry 180, Box 310, Folder SWPA 9, Projects, Army). Darlington held a doctorate in theoretical physics from Columbia University, had worked at Bell Telephone Labs for fifteen years, and had spent the previous three to four years working on antiaircraft matters and radar bombing (see Ltr, Alan T. Waterman [deputy chief, OFS] to George R. Harrison [Research Section, GHQ SWPA], Washington, 10 Jul 44, RG 227, Entry 180, Box 310, Folder SWPA 9, Projects, Army).

[388]Stephenson, "Summary of Principal Projects," pp. 9–10. See also William L. Everitt, Memo for the Record, Washington, ca. Apr 44, sub: Herbert F. Goodwin and OA in SWPA, RG 111, Entry 1024, Box 3026, Folder 00–370.2 OA.

[389]Ibid., p. 9.

[390]Stephenson, "Summary of Activities," pp. 2–3. The change was fortuitous in that the USAFFE Board (later renamed the Pacific Warfare Board) was composed of Army officers from all of the technical services who functioned as field observers for new tactics and equipment. Thus, the Research Section scientists and the officers most interested in their work had easy access to one another. On the other hand, the subordination of the Research Section to the USAFFE Board meant that it was yet another step removed from the top of the chain of command inasmuch as the head of the USAFFE Board, Col. Alexander reported to the USAFFE deputy chief of staff, Maj. Gen. Richard J. Marshall (see Stewart, *Organizing Scientific Research*, p. 141).

[391]Ibid., p. 4.

[392]Ibid. The Moreland mission was assisted by Dr. L. D. Leet, who was attached to the Research Section, GHQ SWPA, in August 1945 after having drawn up lists of Japanese scientific personnel for intelligence targeting (see Stephenson, "Summary of Principal Projects," p. 10).

[393]Ibid., p. 1.

[394]Baxter, *Scientists Against Time*, pp. 407–17 *passim*.

[395]Stephenson, "Summary of Principal Projects," pp. 1–14 *passim*. See also Baxter, *Scientists Against Time*, p. 412; Stewart, *Organizing Scientific Research*, pp. 137–38.

[396]Lt. Gen. Richardson's command was renamed several times during the war. Initially, it was U.S. Army Forces in the Central Pacific Area (USAFICPA), then U.S. Army Forces Pacific Ocean Area (USAFPOA), and finally U.S. Army Forces in the Mid-Pacific Area (USAFMIDPAC). For convenience, Lt. Gen. Richardson's command is referred to throughout this work as USAFPOA. The history of the establishment and operation of the ORS, HQ USAFPOA (ORS POA), is deftly summarized in Waterman, "Outline of Developments," after Jul 44, with Appendices: A. Draft letter to theater commanders *re* "Extension of OA to Ground

and Amphibious Operations"; B. Ltr, Maj H. F. Henderson (acting director, WDGS NDD) to Karl T. Compton (chief, OFS), 4 Mar 44, sub: Operational Analysis Group for Central Pacific; C. Paul E. Klopsteg (consultant, OFS), Encl. No. 1 (List of Proposed OR Projects); D. Ltr, John E. Burchard to Karl T. Compton, 9 Jul 44, sub: Rpt to Chief, OFS, RG 227, Entry 179, Box 308, Folder CPA–2 Miscellaneous–General, and Memo, Lauriston C. Marshall (chief, ORS USAFMIDPAC) to Alan T. Waterman (chief, OFS), 21 Nov 45, sub: Final Rpt of Activities, ORS, AFMIDPAC (hereafter cited as Memo, Marshall to Waterman, 21 Nov 45), encl "Final Rpt of Activities, ORS, HQ, AFMIDPAC, 31 May 44 to 2 Sep 45," RG 227, Entry 182 Box 331 Folder Final Rpt of Activities, 21 Nov 45. See also Thiesmeyer and Burchard, "Combat Scientists," pp. 288–93. Unless otherwise noted, the following account is based on these sources.

[397]Waterman, "Outline of Developments," p. 1. Lt. Gen. Richardson was responding in part to the letter sent by General Marshall in December 1943.

[398]Rau, "Combat Scientists," p. 316.

[399]The details of Leach's activities in Hawaii and his recommendations are in Memo, Lt Col W. B. Leach to Lt Gen R. C. Richardson, 22 Feb 44, sub: Recommendations as to OAS, USAFICPA (hereafter cited as Memo, Leach to Richardson, 22 Feb 44), plus a memo *re* Leach's discussions with officers of the 7th, 27th, and 38th Infantry Divisions about studies needed *re* Army ground operations (RG 227, Entry 179, Box 308, Folder Klopsteg's CPA Survey).

[400]Memo, Leach to Richardson, 22 Feb 44, p. 1. Leach's discussions with Maj. Gen. Ralph Smith and officers of the 7th and 27th Infantry Divisions were summarized by Maj. Fred J. Sengstacke and are at pp. 1–3 of Tab A, Leach's memorandum to Richardson.

[401]Klopsteg's list is reproduced in Waterman, "Outline of Developments," Appendix C. In the end, it bore little resemblance to the work actually undertaken by Richardson's "balanced team."

[402]Waterman, "Outline of Developments," p. 6.

[403]Ibid., pp. 4–5. Burchard was an architect and the chief of NDRC Division 2. Marshall had been the director of MIT Radiation Lab's British branch. Burchard apparently had other reasons for going to Hawaii, as he explained in a letter to Karl Compton on 9 July 1944, reporting his stay in Hawaii from 30 May to 7 July 1944 (reproduced in Waterman, "Outline of Developments," Appendix D).

[404]The various elements of the ORS POA mission are discussed in detail in Memo, Marshall to Waterman, 21 Nov 45, pp. 5–15.

[405]Memo, Marshall to Waterman, 21 Nov 45, p. 5.

[406]Ibid., pp. 3–4. Details of the organization of ORS POA, including its Administrative Group, are summarized in Memo, Marshall to Waterman, 21 Nov 45, pp. 16–19. The Work Simplification program was discontinued around 1 June 1945.

[407]Stewart, *Organizing Scientific Research*, p. 136. A roster of the scientific consultants, operations analysts, and administrative personnel who served in ORS POA is in Memo, Marshall to Waterman, 21 Nov 45, pp. 1–3.

[408]The status of the ORS within the headquarters is covered in detail in Memo, Marshall to Waterman, 21 Nov 45, pp. 20–26.

[409]Waterman, "Outline of Developments," pp. 9–10. For the problems encountered with communications, see Memo, Marshall to Waterman, 21 Nov 45, pp. 27–29.

[410]The OSRD–ORS POA relationship is discussed in Memo, Marshall to Waterman, 21 Nov 45, pp. 30–33.

[411] Memo, Marshall to Waterman, 21 Nov 45, p. 33.

[412]Ibid., p. 36.

[413]The relationship of ORS POA with other agencies is discussed in detail in Memo, Marshall to Waterman, 21 Nov 45, pp. 40–47.

[414]For the ORS POA relationship with the Navy, see Memo, Marshall to Waterman, 21 Nov 45, pp. 42–44.

[415]Stewart, *Organizing Scientific Research*, p. 137. For the ORS POA relationship with the AAF, see Memo, Marshall to Waterman, 21 Nov 45, pp. 41–42.

[416]Ibid.

[417]For the operations of ORS POA, see Memo, Marshall to Waterman, 21 Nov 45, pp. 37–40. The initial topics for investigation listed by Leach, with a few exceptions, turned out to be substantially the program followed by ORS POA.

[418]Oddly enough, there is at this time no comprehensive published history of the WDGS Historical Branch field historical program in WWII, but see John E. Jessup, Jr., and Robert W. Coakley, *A Guide to the Study and Use of Military History* (Washington: U.S. Army Center of Military History, 1978), pp. 312–15.

[419]"Summary of Analysis of Battle Records (Major Davis) Project," ca. Oct 44, p. 1, RG 227, Entry 177, Box 284, Folder OA—AGF—Nettleton-Piedem Study.

[420]Ibid., pp. 1–2.

[421]Burchard, *Q.E.D.*, p. 261.

[422]Baxter, *Scientists Against Time*, p. 9; U.K. Air Ministry, *OR in RAF*, p. xx.

[423]Lynn H. Rumbaugh, "A Look at US Army Operations Research—Past and Present," Combat Systems Technical Paper RAC–TP–102 (McLean, Va.: Research Analysis Corporation, Apr 1964), p. 5.

[424]McCloskey, "U.S. OR," p. 923.

[425]Trefethen, "History of OR," p. 17.

[426]Rau, "Combat Scientists," pp. 2, 4; Burchard, *Q.E.D.*, p. vi.

[427]Rau, "Combat Scientists," pp. 5–6..

CHAPTER TWO

Operations Research in the Postwar Era, 1945–50

Although the contribution of operations research (OR) to the Allied victory in World War II cannot be measured, the widespread use of OR gave the Allies a decided edge over the Axis powers. By V-J Day, 2 September 1945, the armed services of the British Commonwealth and the United States had created OR establishments that were contributing substantially to the development and introduction of new weapons and equipment and to the evolution of more-effective organizations, tactics, and strategies. However, the successful OR structures created during the war were significantly reduced in the immediate postwar demobilization as civilian analysts and administrators hurried home to their families and former employers. Even so, in the United States the Navy Operations Research Group (ORG) continued at reduced staffing, and the Army Air Forces (AAF) retained a substantial portion of its wartime operations analysis (OA) capability. The ground Army, which had not developed a comprehensive OR capability during the war, abandoned what few OR organizations it had, although such research continued to be an "embedded" part of the research and development (R&D) activities of the Army's technical services. Nevertheless, the general consensus was that OR was a valuable tool and that civilian scientists were a necessary complement to military professionals and career civil servants, particularly in the R&D field. In September 1946, Lauriston S. Taylor, who had played an active role in wartime OR in AAF, noted that

> with the advent of even more complicated scientific warfare than we have ever known, I am personally convinced as to the necessity of maintaining a program of operations analysis not only for peacetime operations but to constitute a liquid reserve for instant action if another war should threaten us.[1]

After the euphoria of the war's end had passed, all of the armed services took positive steps to rebuild and reorganize their OR capabilities. A number of factors affected that rebuilding and reorganization from 1945 to 1950. Not only were the problems of warfare more complex, as Taylor suggested, but the perception of a lack of threat in the immediate postwar period led to a significant reduction in the financial and human resources available to the services. Consequently, interservice competition for the available resources made OR an important means for determining priorities and the optimal use of scarce resources. The onset of the atomic age, the growing threat of the Soviet Union, and America's new global commitments all required the development of new equipment, organizations, tactics, and strategies in the services. Operations research provided a means of determining priorities for the effective and efficient distribution of scarce resources to meet these new commitments.

The postwar demobilization of the Office of Scientific Research and Development (OSRD) and its adjunct, the Office of Field Service (OFS), both of which had played a prominent role in the wartime organization and management of scientific manpower, including OR analysts, obliged each of the services to find new ways of attracting and administering the scientific personnel needed to continue their OR programs. Each of the services subsequently found its own unique solution to the problem of continuing and expanding the OR organizations that had proven so successful during the war. The Navy set up a contractual relationship with the Massachusetts Institute of Technology (MIT) to administer the Operations Evaluation Group (OEG), the successor to the wartime Operations Research Group. To deal with the broader problems of strategy and policy, AAF established Project RAND, which was converted in 1948 to the RAND Corporation, an independent nonprofit foundation. The U.S. Air Force, newly independent from the Army in 1947, also relied on the civil service to staff a revived Operations Analysis Division (OAD) on the Air Staff and OA cells at each of the major command headquarters to handle operational problems. Following passage of the National Security Act of 1947 (NSA), the newly created Department of

Defense (DOD) also quickly established an OR capability by creating in December 1948 the Weapons Systems Evaluation Group (WSEG) to support the Joint Chiefs of Staff. As it had during the war, the Army lagged behind the other services in creating a postwar OR capability. However, the recognition of the value of OR to the Army R&D program led to the establishment in August 1948 of the General Research Office (GRO), soon renamed the Operations Research Office (ORO), under contract with The Johns Hopkins University (JHU). By June 1950, all of the U.S. armed services once again had fully functioning OR organizations prepared to confront the challenges of a new war in Korea.

The Demobilization of OSRD and OFS

Despite its many faults and problems, the Office of Scientific Research and Development and its adjunct, the Office of Field Service, played important roles in mobilizing and coordinating the scientific resources of the United States during World War II. Both organizations were especially important to the development of OR in the services. The contribution of OSRD was recognized by the United States Congress in a report of the House Appropriations Committee on 17 October 1945:

> This splendid agency but a few months hence will go out of existence. The contribution that it has made to the winning of the war is inestimable. Without such contribution, it is safe to say that victory still would await achievement. However, the office has been essentially a war agency, and it is now engaged in liquidation. To its distinguished and internationally known head, Dr. Vannevar Bush, and the staff of great scientists he gathered around him to aid in the development of new weapons, the Nation owes much.[2]

OSRD had been the focal point for contracting with civilian scientists to support the military forces during the war. Its postwar demobilization raised the question of how the services would recruit, train, manage, and compensate scientific talent in the future. Although Vannevar Bush believed that a successor to OSRD specifically oriented toward supporting the military was unnecessary, he did advocate the creation of a "national research foundation" to continue the management of scientific endeavor in the national interest.[3] The proposed foundation was to include a military section dedicated to assisting the armed forces on technical and scientific matters, including OR.[4] Although there was general agreement that some sort of national organization to coordinate scientific R&D was desirable, there was no consensus on the shape it ought to take. Bush and others warned that the needed research would be expensive and that "the government, the Congress, and the country would have to understand . . . that results would come about through time, often after many failures, and in ways not always foreseeable or expected."[5] In June 1944, the secretaries of war and Navy already had recognized that OSRD would be demobilized at the end of the war and that some mechanism would be needed to continue the participation of civilian scientists in military R&D. Accordingly, on 22 June 1944, the secretaries created a Committee on Postwar Research headed by Charles E. Wilson, the vice chairman of the War Production Board, for the purpose of studying postwar R&D needs of the services and how those needs might be met.[6] The Wilson committee recommended establishing within the National Academy of Sciences the Research Board for National Security, comprising civilian scientists and representatives of the Army and Navy and funded by transfers from Army and Navy appropriations until Congress could establish the board on a permanent basis.

Although the recommendation of the Wilson committee was accepted by the service secretaries, its implementation was blocked by the refusal of the Bureau of the Budget to permit the necessary transfer of Army and Navy funds. Bills were introduced in Congress to establish the board in law, but no immediate action was taken.[7] On 22 July 1947, the Congress passed an act for the creation of a National Science Foundation as the successor to OSRD, but President Harry Truman vetoed the bill.[8] Meanwhile, a committee headed by Vannevar Bush was created in early July 1946 to coordinate R&D of joint interest to the Army and the Navy.[9] Veterans of the wartime Navy and AAF OR programs also lobbied successfully for the National Research Council to form a Committee on Operations Research in 1948.[10]

OSRD and OFS began to dissolve as soon as the war ended. Both scientists and administrators were eager to return to their peacetime tasks, and the lack of an immediate threat to the national security lessened the apparent need for their services. A rump staff was retained to liquidate OSRD contracts and assets, but all active coordination of scientific support for the armed forces was terminated. OSRD and its adjuncts—the National Defense Research Committee, the Committee on Medical Research, and the Office of Field Service—were formally abolished on 31 December 1947 by Executive Order 9913 of 26 December 1947. As a consequence, the armed services were left to their own devices to find new mechanisms for reestablishing and maintaining their OR capabilities.

Operations Research in the United States Navy, 1945–50

At the end of World War II, the Navy had the most comprehensive and centralized OR program of all the U.S.

armed services. By the summer of 1945, the Navy Operations Research Group, which had evolved from the Anti-Submarine Warfare Operations Research Group (ASWORG), included some ninety scientists and had an annual budget of $800,000.[11] Headed by Dr. Philip M. Morse, ORG had subgroups working on antisubmarine warfare, fleet air defense, naval air operations, submarine operations, and amphibious warfare. ORG analysts had made substantial contributions in all of those areas.

As the end of the war approached, the commander in chief, U.S. Fleet, and chief of naval operations (COMINCH/CNO), Fleet Admiral Ernest J. King, expressed to Secretary of the Navy James V. Forrestal his satisfaction with the work done by ORG and recommended that "uninterrupted continuation of this service into peacetime is necessary. Action should be taken at this time in order to preclude any discontinuity upon cessation of hostilities."[12] Admiral King recommended that ORG be continued into peacetime at approximately 25 percent of its wartime strength. His rationale for continuing ORG was that it had been "of active assistance" to the Navy in the evaluation of new equipment, in the evaluation of specific phases of operations (such as naval gunfire), in the evaluation and analysis of tactical problems and the development of new tactical doctrines, in the technical aspects of strategic planning, and in liaison between the fleets and the Navy and civilian R&D establishments.[13]

Secretary Forrestal quickly approved Admiral King's recommendations, and plans were made to continue ORG.[14] In view of the successful wartime relationship between the Navy and Columbia University for the administration of ASWORG, it was decided to establish the postwar Navy OR program on a similar basis, and contract negotiations were opened with MIT. Despite some reluctance on the part of the institute, an initial three-year contract was signed on 1 November 1945, and the reorganized ORG came into existence under the supervision of the Navy deputy chief of naval operations (fleet operations and readiness).[15] The new organization was named the Operations Evaluation Group to assuage the concerns of the chief of the Office of Naval Research (ONR).[16] The staff was reduced to approximately twenty-five professionals, chiefly physical scientists and mathematicians, and a budget of $300,000 was provided.[17] Philip M. Morse remained for several months as the director of OEG before returning to MIT. He was replaced by Dr. Jacinto Steinhardt, who had received his doctorate in chemistry from Columbia University in 1934 and had served in the Navy OR organization during the war.[18] Morse, George Kimball, and other wartime ORG members continued as consultants.

Soon after the contract with MIT was signed, it became apparent that the Navy's OR needs were greater than originally envisioned, and the Navy began to call for an enlargement of OEG. Dr. Steinhardt was reluctant to increase the size of the group rapidly, fearing a loss of cohesion and focus, and it was not until 1949 that the OEG complement grew to thirty-five professionals.[19] Thereafter, OEG grew more rapidly, and by the start of the Korean War it had a staff of sixty, including forty scientists, and an annual budget of more than $500,000, although budgetary restrictions all but eliminated its field programs.[20]

OEG maintained a central office in Washington, D.C., and field teams with the major naval commands. OEG director reported to the head of the New Developments and Operational Evaluation Subsection of the Office of the Deputy Chief of Naval Operations for Fleet Operations and Readiness. Individual OEG members were assigned as analysts to eight different "desks" in the Office of the Chief of Naval Operations (OCNO), an arrangement that recalled the wartime subsections of ORG.[21] In addition, two members served on the staff of the commander, Operational Development Force (ODF); one member served part-time on the staff of the commander, Naval Forces Europe; and from time to time OEG members lectured at the Naval War College and the National War College and took part in fleet maneuvers.[22] OEG worked closely and effectively with the Navy ODF, which was created to conduct operational tests of new weapons, equipment, and methods proposed for introduction into the fleet, to explore ways and means of improving the effective use of existing weapons and equipment, and to recommend training procedures, countermeasures, and changes in tactical doctrine.[23] Additional tasks performed by OEG members included maintaining operational statistics, recording the results of training exercises, providing mathematical computations in support of ongoing projects, gathering and analyzing technical intelligence, and supervising the preparation of publications and the performance of other administrative duties.[24]

As provided in its contract with MIT, the purpose of OEG was to "furnish liaison for the fleets with the development and research laboratories . . . and conduct studies and make reports" to the deputy chief of naval operations (fleet operations and readiness).[25] The broad array of studies undertaken by OEG included analyses of past operations; analyses of the operational capabilities of new equipment, in the light of the Navy's requirements; development of tactical doctrine; formulation of new requirements; and analyses of strategic alternatives.[26] Within the contractual parameters, OEG was also charged with providing operations analysts for selected Navy field units and for other agencies within the Navy Department.[27]

In OEG's first year (November 1945–November 1946), its analysts were called on to complete more than 120 projects but spent much of their time writing up the results of war-

time ORG research.[28] In 1946, OEG published five reports dealing mostly with World War II antisubmarine warfare, OR methods, and search and screening operations, as well as fifty-five studies dealing with such subjects as World War II combat air patrols, zigzag patterns, coastal early warning systems, search theory, and the evaluation of fleet antiaircraft defense patterns.[29] Other projects were undertaken in the fields of naval tactics and doctrine, antisubmarine warfare, antiaircraft defenses and gunnery, naval air operations, guided missiles, radar, and atomic warfare.[30] OEG published three studies in 1946 that subsequently became classics in the OR literature. They included Charles M. Sternhell and Alan M. Thorndike's *Antisubmarine Warfare in World War II* (originally *OEG Report 51*), Philip M. Morse and George E. Kimball's *Methods of Operations Research* (originally *OEG Report 54*), and Bernard O. Koopman's *Search and Screening* (originally *OEG Report 56*).[31]

Operations Research in the United States Air Force, 1945–50

By the end of the war, like the Navy, AAF had a large and effective OR program making substantial contributions to the improvement of aircraft, weapons, equipment, organization, tactics, and operational strategy. Under the direction of Col. W. Barton Leach, the Operations Analysis Division at Headquarters, Army Air Forces, oversaw the recruitment and training of some 275 operations analysts in twenty-six operations analysis sections assigned to, and controlled by, the major Air Force field commands.[32] Unlike the Navy program that was highly centralized, administered by OSRD or under contracts with academic institutions, and composed almost entirely of scientists, the Air Force OA program was decentralized, relied on the civil service and individual consultants for the recruitment and administration of its personnel, and included a number of non-scientific people.

Eight months before the end of the war, Col. Leach wrote to Harvey H. Bundy, special assistant to the secretary of war, expressing his views on the "post-war handling of Operations Analysis."[33] In a memorandum that he prepared for Bundy, Col. Leach expressed the opinion that there would be no place for a large OA organization staffed by civilian analysts in the peacetime Air Force because there would be sufficient uniformed officers to handle the reduced OA workload. Nevertheless, Leach recommended that measures be taken to ensure a rapid and effective expansion of OA in any future war. To that end, he recommended that Air Force officers receive orientation on the use of OA, that forty to one hundred key civilians be trained in OA and subject to call-up to form the nucleus of a revived Air Force OA group in the event of war, and that a permanent OA division be created in Air Force headquarters consisting of three officers rotated every six months.[34] Leach also warned against adopting without careful study the use of commissioned analysts, letting OSRD handle the problem, turning OA over to Army officers, or putting the civil service in charge. As he noted:

> Experiments have been made with all of these ideas, and all have badly failed. A system has been developed, after two and a half years, which works with considerable effectiveness. Before major changes are made in this system, at the very least it should be determined whether experience in this war offers any evidence as to the desirability of such a change.[35]

This time, Leach, who had almost single-handedly created the wartime Air Force OA program, missed the mark badly in his basic premise. In fact, the Air Force's need for OR would expand significantly in the postwar period, and it would be necessary to reconstitute an active OA structure, albeit at a reduced staffing level, as well as to create a new agency for dealing with problems of higher-level strategy and policy in a nuclear age.

Reconstitution of the Air Force OA Program

Although highly valued by Air Force leaders, much of the existing Army Air Forces OA organization disappeared in the immediate postwar demobilization as commands were merged or abolished. Consequently, AAF lost most of its OA capability. However, a vestigial organization was retained. In October 1945, LeRoy A. Brothers, a leading veteran of the wartime program, was appointed chief analyst of the vestigial OAD under the assistant chief of Air Staff, A-3.[36] In the spring of 1946, Lt. Gen. Ira C. Eaker, an early OA enthusiast and then deputy commander of AAF, wrote to the commanders of major units with remaining OA sections and asked their views on the future peacetime role of OAD.[37] All men replied positively, recommending that the Air Force OA work continue and that a pool of experienced analysts be assembled for that purpose.

Subsequently, AAF began to reconstitute its OA program. In April 1946, LeRoy Brothers was appointed as assistant for operations analysis to oversee the revived OAD under the deputy chief of staff for operations in AAF headquarters. Operations analysis offices were reestablished in each of the major AAF commands. As was the case during the war, the revived Air Force OA organizations relied on civilian analysts hired and managed under the regular civil service system.

On 11 October 1946, the new AAF OA organization was formally approved by the publication of *Air Force Regulation 20–7: Operations Analysis*. The mission of OA, as stated in *AFR 20–7*, was to "provide commanders and their staffs with ready and informal access to scientists with specialized training in the techniques applicable to the analysis of air warfare" and to "analyze the problems of air warfare

with the objective of improving equipment, weapons and weapons systems, tactics, and strategy" to "furnish, wherever possible, a quantitative basis for command and management decisions."[38]

The organization prescribed by *AFR 20–7* replicated that of the wartime period. An Operations Analysis Division under a civilian assistant for operations analysis was established in the Operations Directorate of Air Force headquarters to conduct studies in support of the Air Staff and to coordinate AAF OA activities. Initially, OAD did not exercise centralized control over the OA offices attached to each major command, but later editions of *AFR 20–7*, published after the Air Force gained independent status, gave OAD general authority to "monitor and coordinate programs of all Operations Analysis offices" and to "select, indoctrinate, and recommend assignment of all operations analysts employed by the Air Force."[39]

AFR 20–7 limited the OAD staff to ten analysts, but the new assistant for operations analysis, LeRoy Brothers, developed a good working relationship with the Air Staff as well as a reputation for turning out high-quality studies, and, by May 1947, the OAD staff included 6 physicists, 5 mathematicians, 3 statisticians, 7 engineers, and 1 "educationalist."[40]

The relatively small OAD staff was known for the objectivity and professionalism of its studies and it turned out a "good deal of solid work in the decade following the war."[41] Among the major subjects taken up by OAD analysts in the postwar period were weapons effectiveness, continental air defense operations, and the development of an air operations attrition model.[42] OAD also undertook the preparation of a history of OR in the Army Air Forces in World War II. Pieces were prepared, but no comprehensive formal publication resulted.[43]

AFR 20–7 also authorized the creation of an Operations Analysis Office (OAO) under a civilian chief in each major Air Force command that wanted one. These offices were the lineal descendants of the wartime OA sections, being similarly organized and performing similar functions. OAOs operated independently under their respective commanders and conducted OR studies of immediate practical value to their command, focusing on the performance of aircraft, weapons, and equipment and on the improvement of tactics and operational procedures. The need for, and attractiveness of having, an OAO soon became apparent to every Air Force commander. As Prof. I. B. Holley has noted:

> virtually every major organization within the Air Force had learned that the best defense against a scheme proposed by the outside professionals, the PhDs at RAND or elsewhere, was to have a PhD or a whole roster of them on the staff or on contract to call up for the counter-battery fire when threatened . . . the battle of the doctors.[44]

With only loose control exercised by OAD, each OAO had the opportunity to set an independent course. In some cases, the OA offices were larger and more influential than OAD itself. For example, OAO at Strategic Air Command headquarters was able to build a strong program including fifteen analysts in 1948, when OAD had only ten.[45]

Project RAND and the RAND Corporation

As World War II drew to a close, the commanding general of the Army Air Forces, Gen. Henry H. Arnold, Dr. Theodore von Karman (Arnold's scientific advisor), Dr. Edward L. Bowles (a consultant to the secretary of war), and other senior officials in the War Department recognized the need to retain at least some of the scientific talent that had been assembled during the war, particularly in view of the increased importance of R&D to the American armed forces.

Meeting on 1 October 1945 at Hamilton Field in California, AAF and industry leaders devised a concept for a new organization to provide independent scientific analysis, particularly in the areas in which military policy, planning, and technology intersected.[46] Believing that it would be difficult to recruit and administer suitable scientific personnel for the project through the existing civil service system and that a university would not want to take on a highly classified project, AAF leaders decided to attach the project to an existing commercial firm located outside the Washington, D.C., area so as to insulate its staff from day-to-day requests for assistance.[47] General Arnold persuaded Donald Douglas, the president of Douglas Aircraft Company, to take on the project, and Project RAND (an acronym for **r**esearch **and** **d**evelopment) was initiated by a $10 million letter contract issued on 2 March 1946. Under the terms of the contract, Douglas Aircraft was to conduct "a program of study and research on the broad subject of intercontinental warfare, other than surface, with object of recommending to the Army Air Forces preferred techniques and instrumentalities for this purpose."[48]

Franklin Collbohm was named director of Project RAND. Responsibility for the project was assigned to a new Air Staff agency created on 1 December 1945—the Office of the Deputy Chief of the Air Staff for Research and Development (later the Deputy Chief of Staff, Development)—headed by Maj. Gen. Curtis LeMay.[49] By early 1948, the Project RAND staff had grown to more than two hundred scientists and engineers recruited from industry and academia and organized in three main divisions: aircraft, missiles, and evaluation of military worth.[50]

In May 1947, Project RAND moved into its own offices in Santa Monica, California, but the AAF contract with the Douglas Aircraft Company had already raised questions of conflict of interest. General Arnold was a close friend of Donald Douglas, and Douglas' competitors were suspicious

that the Air Force–Douglas research connection might give Douglas an advantage in other contracting.[51] For its part, by 1948 Douglas Aircraft was eager to free itself from the arrangement, believing that it may have lost other government contracts because of the government's concern with being even-handed. Accordingly, it was agreed that the relationship of Project RAND with Douglas Aircraft be terminated and that a new, independent, nonprofit corporation would be set up to manage Project RAND. The RAND Corporation was chartered in California in May 1948 with Franklin Collbohm as president.[52] In late July 1948, the new nonprofit corporation secured some $1 million in operating capital in the form of an interest-free loan from, and a private bank loan guaranteed by, the Ford Foundation.[53] Some three hundred Douglas employees working on Project RAND were transferred to the new corporation on 1 November 1948.[54]

The relationship of the Air Force to Project RAND and the RAND Corporation was subsequently laid out in *Air Force Regulation 20–9: Air Force Policy for the Conduct of Project RAND*, which defined Project RAND as

> a continuing program of scientific study and research on the broad subject of air warfare with the object of recommending to the Air Force preferred methods, techniques, and instrumentalities . . . operated by The RAND Corporation under contract with the Department of the Air Force.[55]

AFR 20–9 also created a Project RAND Military Advisory Group chaired by the Air Force deputy chief of staff, development, for the purpose of advising the Air Force chief of staff on the RAND research program and other matters having to do with Project RAND and the RAND Corporation.[56]

Day-to-day OR problems continued to be handled by OAD and the OA offices at major Air Force headquarters. The RAND research program constituted what the Air Force called "background research," that is, the application of scientific analysis of the weapons, equipment, methods, and organization of air warfare, including economic, political, and social factors, to enable the Air Force to take advantage of new scientific discoveries and counter their development by potential enemies.[57] Accordingly, the RAND research program focused on such general areas as future air warfare and the development of nuclear weapons, and it included studies on such major topics as strategic bombing systems, air defense, tactical air operations, and Air Force logistics.[58]

RAND's first publication, *Preliminary Design of an Experimental World-Circling Spaceship*, was published on 2 May 1946.[59] The work of fifty analysts, it dealt with matters far from the day-to-day operational problems of concern to World War II operations analysts. Overall, initial progress in research and publication by Project RAND was slow, and the results were disappointing to the project's sponsors.[60] In fact, a good deal of the early work was subcontracted by Project RAND to other research and industry firms.[61]

The wartime Air Force OR program had been heavily focused on the physical sciences and mathematics. Although a few social scientists and other non-scientific personnel were employed as administrators and analysts, the wartime work did not generally extend to studies involving anything other than operational problems. The RAND research program, however, was more comprehensive and more theoretical, and it often involved political, economic, and social considerations. Accordingly, RAND sought to hire a number of social scientist to complement its staff of physical scientists, mathematicians, and engineers.[62] The idea of integrating social scientists into the RAND research effort was sold by John D. Williams, a mathematician on the RAND staff, to Gen. Curtis LeMay, the Air Force deputy chief of staff for research and development, at a meeting in Washington, D.C., in late 1946.[63] Following a meeting in New York with prominent social scientists, RAND created an Economic Division under Charles J. Hitch and a Social Science Division under Hans Speier and produced a number of useful studies in the social sciences.[64]

Operations Research in the Department of Defense

Two years after the end of World War II, the armed forces of the United States underwent a major reorganization with passage of the National Security Act of 1947 (NSA 1947).[65] The NSA 1947 created a National Military Establishment (NME) comprising three separate military departments—Navy, Army, and the newly established and coequal Air Force—each headed by its own civilian secretary with cabinet status, a seat on the newly created National Security Council, and direct access to the president.[66] NME was to be overseen by a secretary of defense who also had cabinet rank and served as the principal military advisor to the president. The NSA 1947 formally recognized the status of the Joint Chiefs of Staff (JCS) and created the Central Intelligence Agency.

The NSA 1947 represented a compromise between the single unified armed forces advocated by the Army and the Army Air Forces, and the totally independent services championed by the Navy. Accordingly, the secretary of defense had only weak "general authority, direction and control" over the separate military departments. Indeed, James V. Forrestal, the secretary of the Navy appointed by President Truman as the first secretary of defense, proclaimed that "this office will probably be the biggest cemetery for dead cats in history."[67] The arrangement proved unwieldy, and following the report of the Hoover Commission[68] in 1949, the 1947 act

was amended by the National Security Act of 1949 (NSA 1949), which replaced NME with a Department of Defense and eliminated the cabinet status of the service secretaries, subordinating them to the secretary of defense. The authority of the secretary of defense to oversee the military departments was strengthened, and a position was created for a deputy secretary of defense. The NSA 1949 also provided the secretary of defense with a staff, increased the size of the Joint Staff from 100 to 210, and provided for a non-voting JCS chairman.

The NSA 1947 established a Research and Development Board (RDB) to integrate and coordinate military R&D programs, advise the secretary of defense on scientific research relating to national security, allocate responsibilities among the services for projects of joint interest, and formulate policy in connection with R&D for agencies outside the Department of Defense. RDB, which consisted of two officers from each of the three services and Dr. Vannevar Bush as chairman, came into existence on 30 September 1947.[69]

JCS evaluated the relative importance of the major types of military operations to its strategic plans, and RDB estimated the adequacy of present equipment and techniques for performing those operations successfully. RDB then combined both the strategic and technological assessments to arrive at the relative importance of each major area of R&D. This set of ratings constituted the board's master plan, which served as a broad guide to the military effort in the whole R&D program. RDB was assisted in its work by some two thousand expert consultants drawn from the ranks of both civilian and military scientists and technologists who met in various committees, panels, and working groups to review military R&D programs and recommend to RDB the direction that each program should take.[70]

Although the Joint New Weapons and Equipment Committee headed by Vannevar Bush had played a major role in promoting the establishment of OR organizations during the war, the Joint Chiefs of Staff did not have its own OR organization. In view of the involvement of DOD, JCS, and RDB in complex matters of weapons development, organization, and strategy, both the Hoover Commission and a special committee appointed by Secretary Forrestal recommended establishing an organization to provide an impartial evaluation of weapons systems at the JCS level.[71] Accordingly, on 11 December 1948, Secretary Forrestal directed the formation of the Weapons Systems Evaluation Group to provide "rigorous, unprejudiced, and independent analyses of present and future weapons systems under probable future combat conditions."[72]

WSEG was officially established on 21 February 1949, by JCS and RDB, with the concurrence of the secretary of defense.[73] Lt. Gen. John E. Hull, then commanding general, U.S. Army Pacific, and commander of the Eniwetok atomic bomb tests, was appointed as director of WSEG, and, on 14 March 1949, Dr. Philip M. Morse, a veteran of the Navy ORG and OEG, joined WSEG as deputy director and research director.[74] WSEG was placed under the administrative direction of the assistant secretary of defense for research and development but worked directly for the secretary of defense, JCS, and RDB.[75] The assigned mission of WSEG was twofold:

> (1) To provide DOD with comprehensive, objective, and independent analyses and evaluations under projected conditions of war, which will include but not necessarily be confined to:
> (a) Present and future weapons systems;
> (b) The influence of present and future weapons systems upon strategy, organization, and tactics;
> (c) The comparative effectiveness and costs of weapons systems;
> (2) To make available to the Department of Defense timely advice and assistance to aid decisions in the allocation of resources for the development of the most effective combination of weapons systems.[76]

The staff of the group was composed in equal parts of officers of the three armed services and civilian scientists hired under the regular civil service system, organized into three divisions plus a review board.[77] The Analysis and Evaluation Division was composed of all permanently assigned civilian scientists and was divided into project teams to study specific problems. The Military Studies and Liaison Division was composed of the assigned military personnel who worked with the project teams and provided the civilian analysts with information on military needs and requirements. The executive secretariat handled routine administrative matters, and the review board, comprising the deputy director and the heads of the three divisions, recommended research priorities, reviewed the results of major projects, and advised the group director on policy matters.

By 31 December 1949, the WSEG staff had grown to 13 full-time civilian analysts, 6 civilian analysts on loan from various organizations, 15 military officers, and 8 civilian and 3 military part-time consultants.[78] Ultimately, the combination of military officers and civilians managed by the civil service system proved less than adequate, and, in September 1955, the Department of Defense negotiated a contract with MIT to provide the scientific personnel required by WSEG.[79] Subsequently, in April 1956, representatives of five universities (MIT, Case Institute of Technology, Stanford, California Institute of Technology, and Tulane) met and incorporated as the nonprofit Institute for Defense Analyses to provide scientific staff for WSEG.[80]

As of 1 November 1949, WSEG had been assigned eight projects, and seven other preliminary studies were under way in anticipation of future assignments.[81] The first and most

important of the original eight projects was an evaluation of certain aspects of the strategic air offensive plans. The other topics under study included nuclear- and chemical-powered aircraft, nuclear-powered submarines, air defense, antisubmarine warfare, airborne operations, carrier operations, and ground force operations.[82] In general, WSEG studies were of high quality, and, in his 1949 report, the secretary of defense echoed the directive that established the group, noting that "these analyses are being made by the ablest professional minds, military and civilian, employing the most advanced analytical methods that can be brought to bear."[83]

The WSEG staff was small, and the analyses undertaken were often complex and demanded immediate attention. Accordingly, the group frequently relied on the OR organizations of the three services to provide data for its own studies.[84] An informal Joint Operations Research Group was also formed under DOD auspices to conduct periodic seminars for the exchange of information on OR methods among WSEG and the OR organizations of the three services.[85] The heads of the five service OR groups (OEG, OAD, Project RAND, WSEG, and Army ORO) also met monthly to coordinate their work to avoid duplication.[86]

International Cooperation

By the end of World War II, operational research was well established in the armed services of the British Commonwealth, and after the war the British armed forces maintained substantial OR organizations.[87] As early as 1942, the British Army had considered plans for a postwar operational research establishment staffed by serving officers.[88] A number of such officers were trained and they served alongside civilian analysts in the British Army's OR sections during the war. On 1 November 1945, they were absorbed in the Military Operational Research Unit (MORU) organized under the War Office. MORU operated in conjunction with the Army Operational Research Group (AORG), which at the end of 1945 employed 365 scientists.[89] Subsequently, the two organizations were merged under the AORG title and charged with the scientific study of the soldier and his weapons, equipment, and clothing; requirements for new weapons and equipment; the content and methods of military training; and logistical problems.[90]

The Royal Canadian Air Force had established an OR unit in 1942 under the direction of Prof. J. O. Wilhelm, and the Royal Canadian Navy had followed suit with the formation in 1943 of a Directorate of Operational Research under Dr. J. H. L. Johnstone.[91] In 1944, the Canadian Army formed a similar directorate at Army headquarters in Ottawa as well as a Canadian Army Operational Research Group under Dr. J. T. Wilson. In Canada, the wartime military OR organizations were subsumed in the postwar period under the Defence Research Board (DRB).[92] DRB controlled an operational research group that served as a holding group for civilian OR analysts attached to the armed forces or to DRB itself. Some trained active-duty officers were also involved.[93] The Canadian Army Operational Research Establishment (CAORE) was created at the Royal Military College, Kingston, effective 22 December 1949, but its staff was restricted to five people until May 1950.[94]

To provide liaison with their British counterparts, WSEG and the U.S. armed services OR groups jointly maintained a representative in Great Britain.[95] A tripartite agreement between the armies of Great Britain, Canada, and the United States was also established to provide a forum for the standardization and exchange of OR methods and information.[96] A series of periodic conferences on Army operational research was also initiated by the British Army Operational Research Group, the Canadian Army Operational Research Establishment, and the U.S. Army ORO. The First Tripartite Conference on Army Operational Research was held in London on 21–29 April 1949.[97] The Second Tripartite Conference on Army Operations Research was hosted by ORO in Washington, D.C., on 23–27 October 1950, and included representatives from the Office of the Secretary of Defense and WSEG, the Department of the Army (DA) and ORO, the Department of the Air Force and the RAND Corporation, the Office of the Chief of Naval Operations and OEG, the British defense ministries and their OR organizations, and the Canadian defense ministries, DRB, and CAORE.[98] The Tripartite Agreements on Army Operations Research were put in final form at the 1950 conference and included agreement that the priorities for research by the OR groups of all three armies should be armored warfare; air support of ground operations; lightening the load of the infantry soldier; the effect of atomic weapons on future army organization and operations; and general study of the optimum system of ground weapons, including command and control and training.[99]

Army Operations Research Developments, 1945–50

The rapid growth of military technology triggered by World War II greatly increased the importance of scientific research and development, and the Army's postwar R&D establishment expanded to deal with such new developments as guided missiles, electronics, and nuclear weapons that were needed to meet America's new global commitments in the growing confrontation with the Soviet Union.[100] Despite a strong economy, the United States had only limited resources with which to meet its obligations. The fundamental problem faced by all of the armed forces in the postwar period was how to achieve maximum mili-

tary results with a minimum of men, money, and materiel, and how to use U.S. industrial, technological, and scientific superiority to overcome deficits in manpower vis-à-vis the main potential enemy, the Soviet Union. Accordingly, OR assumed great importance as a means of rationalizing decisions about the overall allocation of resources as well as the development of effective weapons systems, organization, tactics, and strategy.

The Army ground forces had lagged far behind the Navy and the Army Air Forces in establishing a widespread and effective OR organization during World War II, and the few OR units that the Army did stand up were quickly inactivated in the rapid demobilization after V-J Day.[101] However, the need for OR to support research and development of Army weapons systems was widely recognized, and the integrated OR activities embedded in the Ordnance Corps and Signal Corps continued for the most part. Until the Air Force gained its independence in September 1947, however, the OR activities pursued by the Army Air Forces constituted the Army's principal OR undertaking.[102] It was not until the summer of 1948 that the Army moved to establish a comprehensive OR organization that was capable of dealing with the analysis of organization, tactics, and strategy, as well as with weapons analysis. In part, the delay was caused by the continued assumption that the problems of land warfare were less amenable to OR techniques and by ignorance of how OR methods might be applied to ground combat that stemmed from the Army ground forces having had little wartime experience with OR.[103] However, the creation of ORO in 1948 provided a focal point and model for subsequent development, and ORO was instrumental in broadening the scope of OR in the Army. As a result, by 1950, the Army used OR in a number of areas and had progressed far beyond an exclusive focus on engineering and weapons development applications to studies of international politics, economics, national policy, and global strategy.

Embedded Operations Research in the Technical Services and Army Field Forces, 1945–50

The few specific OR agencies created by the Army during World War II were disbanded in the postwar demobilization.[104] For the first three years following the war, the only operations research conducted by the Army, except for that conducted by AAF, was the embedded OR conducted by the Army's technical services—primarily the Ordnance Corps—and the Army ground forces test and evaluation boards as part of their weapons and equipment development programs. OR techniques were applied extensively to problems of weapons analysis but generally did not extend to the analysis of operational problems.

In May 1946, Headquarters, Army Service Forces, was abolished and the technical services resumed their R&D functions.[105] In the performance of those functions, the technical services relied on a variety of OR methods but generally did not form identifiable OR sections until after 1950. Accordingly, the degree to which OR played a role in the R&D activities of the technical services in the 1945–50 period cannot be defined with any degree of certainty. Most of the evidence for such OR activity is anecdotal, and in most cases no mention of OR under that name is made in official reports and documents. However, as Dr. Ellis A. Johnson, the director of the Army Operations Research Office, told his audience at a conference of social science consultants on 19 September 1949:

> There are, in addition, in all of the Services, groups which are not formally designated as operations research groups, but which do carry out what the more formally recognized groups recognize as operations research. For example, in the Army, the Aberdeen Laboratories of Army Ordnance carry out some of the most successful operational research studies on the weapons analysis level. These are used by all of the Services in the Department of Defense.[106]

Many of the people involved in the R&D field in the postwar years later related that some OR activity was "embedded" in the activities of the technical services. Dr. Floyd Hill, for example, recalled that after being drafted in August 1945, he was brought into the Ordnance Corps' Ballistic Research Laboratories (BRL) at Aberdeen Proving Ground, Maryland, as a private, and he worked there until December 1946, when he was discharged from the Army. He then was hired as a civilian in the same job under Herman Gay in the Terminal Ballistics Laboratory of BRL. In 1949, he became the section head of the Tank Effectiveness (Vulnerability) Section. Hill recalled that the work conducted by him and his associates clearly involved OR techniques, but was not identified as OR.[107]

During and shortly after World War II, BRL indeed conducted a variety of studies on the vulnerability and survivability of various Army equipment, notably aircraft, as well as studies on weapons effectiveness and bombing patterns.[108] In the postwar period, BRL continued to conduct "overall weapon system studies from an engineering and operations analysis viewpoint," "applied research on factors affecting system performance in order to establish desirable characteristics and proposed basic designs for new and improved weapons," and technical feasibility studies.[109] Operations research methods were embedded in such studies, but OR was not considered a distinct specialty in its own right.

Similar work took place at other Ordnance Corps laboratories. George Schechter, who went to work in 1941 at the Pittman-Dunn Laboratories at Frankford Arsenal, later had

a hand in the development of the recoil-less rifle and the aircraft ejection seat. He also worked for a number of firms, such as Analytics, Inc., and the Battelle Memorial Institute, both of which used OR techniques extensively. However, Schechter recalled that he was always identified as a physicist and never as an OR analyst. Speaking of his time at the Pittman-Dunn Laboratories, Schechter noted that he worked for Dr. William J. Kroeger, "a good physicist, a good engineer, a good sort of country manager, and OR didn't mean a thing to him except he did it all the time. He just did it."[110]

Operations Research techniques were also embedded in the work of the Army test and evaluation boards that became the responsibility of the Office of the Chief of Army Field Forces (OCAFF) following the November 1948 reorganization of the Army. OCAFF initiated requirements for new equipment, determined the desired military characteristics, and oversaw the service tests conducted by the various test and evaluation boards that were consolidated after the war into just four main boards with a functional rather than branch orientation.[111] All four OCAFF boards used OR methods to a limited extent as part of their primary mission of conducting service tests and evaluations of new equipment.[112]

The Operations Research Office, 1948–50

Although by 1948 both the Army technical services and the Army field forces boards were using OR techniques to support the development of weapons and equipment, the Army still had no dedicated OR organization capable of applying OR techniques to the study of Army strategy, tactics, and organization. The Army thus lacked an important tool in the growing competition with the Navy and the Air Force for roles and missions and the associated budget dollars.[113] In the spring of 1948, the Army finally acted to create its own comprehensive OR organization. Formed in August 1948, ORO quickly became the Army's answer to the Navy OEG and the Air Force OAD, OAOs, and Project RAND.

A number of factors prompted the Army to create its own OR organization. In an April 1946 memorandum, the Army chief of staff, General of the Army Dwight D. Eisenhower, had strongly urged the creation of a research organization outside the Army, and the director of army logistics, Lt. Gen. Henry S. Aurand, had called attention to the Army's need for scientific advisors as well as its lack of an OR capability.[114] At the end of 1947, the Defense Research and Development Board recommended that the armed forces "expand the facilities and the scope of their operational analysis groups," and noted in their report that

> our general investigations into these matters revealed that although the Navy and the Air Force have operational analysis sections working on problems peculiar to their respective services, the Army Ground Forces and the Joint Chiefs of Staff have no analytical groups of a similar nature within their organizational structure. This, we believe, is a serious shortcoming and one which we recommend should be corrected at the earliest possible date.[115]

The board report produced the same reaction in the Department of the Army as it did in the Department of Defense—an acceleration of efforts already under way to create a credible OR organization—and $1 million was appropriated for operations research in the FY49 Army budget. The Army Staff officer charged with overseeing R&D matters, Maj. Gen. Anthony C. McAuliffe, the deputy director of logistics for R&D, was tasked to conduct a study of how the $1 million OR appropriation might best be spent.[116] There were several options for how such a group might be organized—the two basic models were a nongovernmental, independently administered group and a group under the civil service integrated into the military agency that it served.[117] The Navy OEG operated under the first type of arrangement with a contract with MIT. The Air Force had both types: OAD and OAO were integrated into the Air Force structure with some military personnel and all civilian employees under civil service, and Project RAND operated independently under a contract with the Douglas Aircraft Company.

The model of an independent nonprofit organization affiliated with a university had many advantages. It presumably provided more-flexible hiring and firing procedures, more-generous salary opportunities, and a congenial, professional, and academic atmosphere, as well as a means of hiring consultants.[118] It was thought that such a nongovernmental agency would also provide maximum objectivity because of its independent status, maximum flexibility because of its divorce from day-to-day problems, and increased attractiveness as a career outside the civil service.[119] It would also provide a means to recognize and reward superior performance quickly and to rapidly eliminate personnel who did not meet the desired standards of proficiency.[120] After some study, the decision was made to proceed with the formation of a university-based, independent, nonprofit OR organization. That choice was shaped in large part by the influence of Dr. Vannevar Bush who thought that creating an atmosphere of intellectual independence conducive to good scientific research would provide a better opportunity to attract scientific talent.[121]

Negotiations with The Johns Hopkins University

Maj. Gen. McAuliffe began with a survey of potential university sponsors. To guide his efforts, he prepared an outline of the proposed General Research Office, including the general fields of study and the proposed administrative organization and contractual arrangements.[122] The organi-

zation envisioned by Maj. Gen. McAuliffe was to be "under the direct supervision of a civilian scientist" who would have "at his disposal a General Research Office, staffed with the necessary scientific and administrative personnel."[123] The project was to be run on a contract basis with a civilian university or institute, and, although most problems were to be formulated, analyzed, and evaluated by the GRO staff, other problems were to be subcontracted out to various universities and nonprofit research institutions.

Maj. Gen. McAuliffe foresaw that two types of research would be conducted by the proposed GRO: "Operations Research" and "basic research of a non-materiel nature," with the latter initially constituting a minor part of the program.[124] The problems to be studied would be those "unique to the Department of the Army" and would include problems in the general fields of combat and strategic intelligence techniques, combat psychology and morale, analysis of weapons and weapons systems, comparative overall economic costs of various methods of waging ground warfare, psychological warfare and "cold war" techniques, logistics, analysis of general progress in psychology as it pertained to Army applications, and other related broad fields of nonmateriel research. McAuliffe also noted that "although the initial cost of this type of research is expensive, the eventual savings to the Government in time, money, materials and manpower, will be immeasurably greater" and that "only those [studies] that have the very highest priority can be undertaken with the amount of money requested for this Fiscal Year."[125] The close connection of the Army proposal to the December 1947 recommendations of the Defense Research and Development Board was evident in the long quotation from that report included in Maj. Gen. McAuliffe's memorandum.[126]

In April 1948, McAuliffe settled on The Johns Hopkins University in Baltimore, Maryland, as the best choice to administer the Army OR program.[127] JHU offered several distinct advantages: It was conveniently located close to Washington, D.C.; it enjoyed a good reputation in science, technology, the professions, and scholarship; and it had experience in managing military programs, having been the site of the Navy's Applied Physics Laboratory since 1942.[128]

In early May 1948, McAuliffe opened negotiations with the JHU president, Dr. Isaiah Bowman, that led in August to establishing the General Research Office under JHU auspices. The initial reaction of the authorities at JHU to the Army proposal was not entirely positive. In a 2 May 1948 memorandum to President Bowman, Dr. Arthur E. Ruark, assistant director of the JHU Institute for Cooperative Research (ICR), noted that although "participation in the growing science of quantitative scientific strategy and operations planning" was perhaps a good thing, if a choice had to be made, ICR preferred to work with the Navy with which negotiations had already been under way for six months.[129] Three days later, on 5 May, Ruark prepared a checklist of points for the forthcoming discussion with the Army in which he laid out the pros and cons of working with the Army and/or Navy.[130] Noting that the field of "operational studies is here to stay" but had yet to receive the attention it deserved, Ruark stated that "the Army is behind the game in operations analysis. Clearly the pressure to establish a hard-hitting activity, promptly, comes from very high quarters."[131] He then summarized the potential JHU contract with the Navy, noting the narrow scope of the proposed Navy work and pointing out that "if we work for only one service, let it be the Navy."[132] With regard to the Army proposal, Ruark noted that the decision could not be postponed beyond 20 May at the latest, that the total number of people involved would probably approach 130–140 (versus 7 to 10 for the Navy project), and that JHU ought to envision a ten-year commitment. He went on to point out that the personnel required for the two projects would be quite different because the Navy requirement was specialized whereas the Army proposal was broader and carried with it a heavy long-term commitment for JHU. Noting that there would "of course, be wails from the pacifists and appeasers and the campus Commies," Ruark concluded that, although

> personally, my task will be easier if the Army's kind offer is rejected. . . . I believe the work should be undertaken, hedging the contract about with understandings and agreements which will permit steady, conservative progress rather than hurried construction of a jerry-built crew and an ineffective sub-contract structure; which, indeed, would defeat the goals in which we are all interested.[133]

Eventually, Maj. Gen. McAuliffe and the authorities at JHU were able to reach an agreement, and a contract was signed.[134] On 5 May, Ruark had outlined the tentative terms for the Army contract, addressing such matters as the types of analysis to be performed, how tasks would be assigned, liaison arrangements, training activities, the responsibilities of the Army and of JHU, subcontracting, and overhead costs.[135] In his memorandum, Ruark suggested it was understood that the work would be administered through the Institute for Cooperative Research and that there would be an administrative group in Baltimore to handle business and contracting matters and a working group at the Pentagon or elsewhere in the Washington, D.C., area. In addition, the university would carry on "extensive sub-contracting of the research work assigned to it, in Universities and other nonprofit institutions, but not in industrial companies without written permission of the Army."[136]

The arrangement worked out between the Army and JHU assumed certain mutual responsibilities.[137] For its part,

the Army was expected to provide up-to-date information on Army plans, programs, and policies that might result in requirements for future studies; complete background information, data, and reports available to the Army and pertinent to assigned projects; vigorous and effective general supervision of the OR program to include the assignment and approval of projects, establishment of project priorities, periodic review of the work program, and prompt evaluation and distribution of OR publications; and constructive criticism of the OR work. For its part, JHU undertook to ensure that the OR group became thoroughly familiar at first-hand with all the pertinent military aspects of the assigned problems; translate its studies into language that simply and clearly showed the values, costs, and effects of proposed courses of action; and keep the Army fully advised of the status of its current program and its capability to undertake new work.

Establishment of the General Research Office

Although the new General Research Office began operations on 8 August 1948, it was not until the publication of *Department of the Army Memorandum No. 3–50–2* on 20 September 1948 that its existence was made official.[138] *DA Memo 3–50–2* announced that JHU would act as contractor to conduct the general research program of the Department of the Army, and that program would consist of "Operations research and/or analysis on problems that are not unique to any one Army agency [and] basic research of a nonmateriel nature for which primary cognizance has not been assigned to a specific Army agency."[139] The memorandum also prescribed that the Army contract with JHU would be under the supervision of the deputy director for R&D in the Logistics Division of the General Staff, and it created a Department of the Army Ad Hoc Advisory Committee under the chairmanship of the GRO project officer; the committee would have one officer from each General Staff division, each technical service, OCAFF, and an officer from the Office of the Army Comptroller, whose purpose was to assist in the selection and coordination of problems proposed for inclusion in the general research program and to recommend assignment of priorities to those selected.[140] Channels were established for the submission of proposed study topics by Army agencies, and all Army agencies were instructed to furnish "appropriate assistance" to GRO on request, to include providing access to reports and data, facilitating visits to Army installations, and giving advice and assistance.[141] The memorandum also prescribed procedures for handling classified information.

On 27 December 1948, GRO was renamed the Operations Research Office, and, on 13 January 1949, *DA Memo 3–50–2* was superseded without substantial change by *Special Regulations No. 705–5–5: Research and Development—Operations Research Office*.[142] The "general research program" became "the operations research program of the Department of the Army," and a representative of the adjutant general was added to the Department of the Army Advisory Committee.[143] The most significant change, however, was the inclusion of a formal mission statement that would remain essentially unchanged for the life of ORO:

> The mission of the Operations Research Office is to apply scientific, qualitative, and quantitative analysis to the study of warfare with the objective of improving the strategy, tactics, logistics, weapons, and weapons systems of the future.[144]

An article in the 21 August 1948 edition of the *Baltimore Evening Sun* announced the formation of the new office under the leadership of Dr. Ellis A. Johnson and noted that Lt. Col. W. C. Farmer of the Army General Staff had been designated as project officer to work closely with Dr. Johnson.[145] The twenty to thirty scientists under Johnson's direction were to be quartered at Fort Lesley J. McNair in the District of Columbia and would work on problems of weapons development, strategy, tactics, and logistics, including studies of antiaircraft weapons and defenses; training motivation; the application of biomechanics to weapons design; logistical support of airheads; and individual protection against nuclear, biological, and chemical weapons.[146]

Staff Recruitment

In early August 1948, GRO was assigned office space in the Industrial College of the Armed Forces at Fort McNair, and newly appointed director Ellis A. Johnson began to recruit a top-notch administrative staff and a battery of highly competent professional analysts from various disciplines.[147] To support the full-time ORO staff, Johnson also formed a panel of consultants with broad interests and established relations with a number of contract research organizations that were able to perform work for ORO on a subcontract basis.[148] Although his efforts were successful, the recruitment and retention of high-quality professional staff members would be a chronic problem despite the ORO structure as an independent, nonprofit, university-affiliated entity.[149]

In May 1948, the assistant director of JHU's Institute for Cooperative Research, Arthur Ruark, had estimated that support of the proposed Army GRO would require an addition to the JHU payroll of sixty-five to eighty-five people, more than half of them in Washington, D.C.[150] Ruark's estimate was fairly accurate. At the end of the first six months, the ORO professional staff consisted of just 8 analysts working on five projects, but by 30 June 1949, the ORO staff had grown to 26 professional and 34 administrative personnel plus 9 consultants.[151] In addition to the sixty full-time ORO employees, subcontractors were employing another sixty-six people on ORO projects on both a full-time and a part-time

basis.[152] At the end of the first full year of operations (in August 1949), the ORO staff had grown to forty-one professional and forty-nine administrative personnel.[153] Fourteen of the staff members held a doctoral degree, and a total of six projects had been assigned. At that time, the growth of the ORO staff was projected to reach a total of 130 personnel (75 professional and 55 administrative) by 1 July 1950, with seventeen projects assigned. In fact, by the summer of 1950, ORO still had only about 40 professional analysts but did boast a list of more than 100 consultants and a number of subcontractors.[154]

The senior staff assembled by Dr. Johnson were for the most part distinguished scientists with World War II experience in OR. It is not surprising that they included the physicists George H. Shortley, Lynn H. Rumbaugh, and William L. Whitson, all of whom had worked with Johnson in the Navy Ordnance Laboratory's mine warfare OR unit and on the Pacific mining campaign during the war.[155] Robert J. Best, a chemist who joined ORO in January 1949, had experience in the Navy OEG and later made major contributions in the analysis of tactical combat operations.[156] In April 1949, Johnson recruited Dr. George S. Pettee, a political scientist, to work on military aid and psychological warfare problems.[157] Pettee became deputy director of ORO in 1950. In August 1949, Johnson selected Lester D. Flory, a retired Army brigadier general who had earned a master of science degree in electrical engineering from MIT in 1930, to serve as the ORO executive director.[158]

As the recruitment of George Pettee demonstrated, a notable aspect of Johnson's recruiting efforts for ORO was the selection not only of physical scientists but of representatives of the social sciences. For example, the early ORO staff included a number of historians, recruited on the assumption that their skills would be required to help locate and analyze World War II Army operational records, the most likely source for data on operational matters.[159] Ellis Johnson was also no respecter of gender roles. He hired many women for professional positions in ORO, including historian Dorothy Kneeland Clark who did seminal work on casualties; the chemist Grace Donovan who served for a time as the ORO representative to the Army Operational Research Group in Britain; Kay Hafstad, a meteorologist; and Jean Taylor who supervised a very successful ORO program for employing high school students as junior analysts during the summer.[160]

One issue that arose soon after Johnson began to assemble the professional staff for ORO was that of training. Although many of the hired analysts had wartime experience in military OR organizations, many did not, and it was necessary to train new ORO staff in "Army ways."[161] Given the ignorance of OR throughout the Army, it was also necessary to orient ORO customers on what OR could and could not accomplish. The problem was resolved, albeit slowly and haltingly, by on-the-job training of ORO analysts, the visits of ORO personnel to Army installations, and the sharing within ORO of experience by those ORO personnel who did have military experience.[162] ORO also undertook a vigorous internal effort to gather information about the Army and build an understanding of what the Army did and how it worked.

Organization of the GRO/ORO

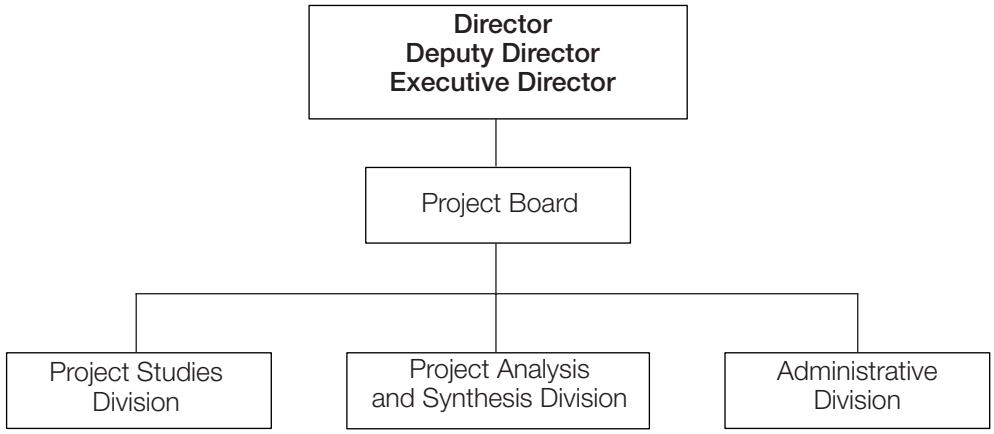
In the beginning, the General Research Office was, like the biblical Earth, "without form and void," and it was not until March 1949 that a plan for internal organization emerged. On 4 March 1949, Ellis Johnson wrote to the director of the Institute for Cooperative Research at JHU to propose a flexible organization for ORO divided into three main parts as shown in Figure 2–1.

The Project Analysis and Synthesis Division (PASD) would be the locus of the principal operations research work, with each project carried out by an ad hoc team headed by a project chairman who would report to the ORO director.[163] The ad hoc PASD project teams would be supported by the Project Studies Division (PSD) under the supervision of the deputy director. Fixed groups within PSD would conduct studies required to support particular PASD projects or studies that were common to a number of such projects.[164] The Administrative Division would perform the usual administrative, personnel, and fiscal work under the supervision of the ORO executive director. The executive director would also oversee the Project Board, comprising senior ORO members, which would review completed or ongoing projects.

Dr. Johnson's 4 March 1949 proposal was apparently never adopted, and ORO operated for some time without a formal internal structure, but by June 1949, both the staff and the work program had grown to such an extent that a new organization was proposed.

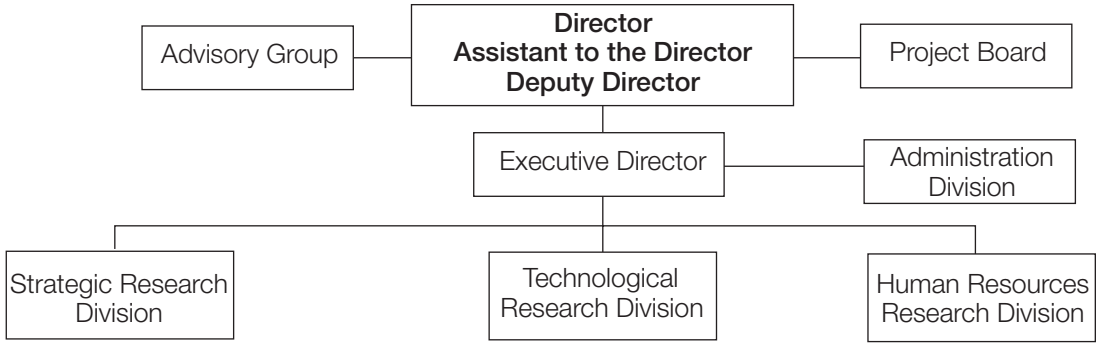
The proposed June 1949 structure, shown in Figure 2–2, was predicated on the view that a military action contains three important elements: a military element (considerations of strategy and tactics), a technological element (questions of weapons and their capabilities), and a human element (considerations of the interface of men with machines).[165] It also anticipated additional growth in the ORO staffing and work program inasmuch as it had not yet been considered necessary to actually subdivide the ongoing ORO projects. It appears that the June 1949 organizational plan was also never actually adopted, and a fixed organizational structure for ORO was not set until the early 1950s.

Figure 2–1—Proposed ORO Organization: March 1949



Source: Memo, Dr. Ellis A. Johnson (director, ORO) to director, ICR, Fort McNair, Washington, 4 Mar 49, sub: Proposed Organization for the ORO, JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR/ORO, Jan–Dec 49.

Figure 2–2—Proposed ORO Organization: June 1949



Source: ORO, Administrative Operations Report for the Two Quarters Ending 30 June 1949, p. 32, Figure 5, in *Quarterly Report*, vol. II, no. 1, 2, 30 Jun 49 (Fort McNair, Washington: JHU ORO, 1949), pp. 33, RG 319, Entry 82, Box 2129, Folder Quarterly Rpt.

Because ORO was a creature of both the Army and JHU, the director of ORO reported to two higher authorities. In the Army chain he reported to the deputy director of logistics for R&D. Day-to-day coordination was routed through the assigned ORO project officer, the first of whom was Lt. Col. W. C. Farmer.[166] As an employee of JHU, the director of ORO also reported to the JHU president and board of trustees through the Institute for Cooperative Research.

ORO Fiscal Arrangements

Although ORO fiscal management was in the hands of JHU, the level of staffing and the annual work program depended on the annual Army appropriations passed by the Congress. The initial appropriation for FY 1949 was $1 million, and, as part of the negotiation with the Army, Dr. Ruark, prepared a detailed projection of the costs to support GRO in FY 1949.[167] He proposed a contract for FY 1949

TABLE 2–1—ORO BUDGETS: FY 1949 AND FY 1950 (PROJECTED)

	FY 1949					
Current Projects	Professional Salaries and Wages ($)	Other Costs ($)	Subtotal ($)	Subcontracts ($)	Total Obligations ($)	Estimated for FY 1950 ($)
ALCLAD	13,767	61,083	74,850	26,850	101,700	170,000
ANALAA	39,122	73,141	112,263	240,943	353,206	320,000
EVANAL	5,794	8,412	14,206	Not available	14,206	7,500
GUNFIRE	5,794	16,156	21,950	103,583	125,533	75,000
MAID	22,459	42,534	64,993	219,000	283,993	100,000
POWOW	3,622	5,390	9,012	32,350	41,362	200,000
Subtotal	90,558	206,716	297,274	622,726	920,000	872,500
Proposed Projects						
DONKEY						220,000
TREMABASE						105,000
TEAM						200,000
SITE						160,000
ATTACK						95,000
FREVO						40,000
Reserve for additional projects						99,500
TOTAL					920,000	1,792,000

Note: The FY49 budget supported thirty-one professional analysts working on six projects. The proposed FY50 budget was intended to support seventy-five analysts working on seventeen projects. The project codes are expanded in the discussion of the ORO work program below.

Source: Memo for Lt. Gen. Thomas B. Larkin (director of logistics, Army Staff), Washington, JHU ORO, 10 Aug 49, sub: Condensation of the Third and Fourth Quarterly Rpts of the JHU ORO, pp. 1–2, RG 319, Entry 153, Box 519, Folder P&O 020 ORO.

for $1 million, plus $64,500 in overhead costs, distributed as follows: Washington, D.C., office salaries, $385,000, plus $38,500 in overhead (10 percent); Contract Technical Group in Baltimore salaries, $45,000, plus $18,000 in overhead (40 percent); Contract Business Group in Baltimore salaries, $20,000, plus $8,000 in overhead (40 percent); miscellaneous expenses at the Pentagon and in Baltimore, $85,000; and subcontracts, $465,000.[168] The actual ORO obligations for FY 1949 totaled $920,000, as shown in Table 2–1.

The ORO budget originally projected for FY 1950 was $1,792,000, of which $1,740,000 was to be provided to support the ORO contract with JHU and $52,000 was to be held in reserve by the quartermaster general for use by ORO to obtain services from other government agencies.[169] However, as of 30 September 1949, the figures for FY 1950 were still not firm and it was anticipated that there would be a cut of approximately 10 percent, thereby reducing the FY50 ORO budget to around $1,584,000.[170]

The actual Army appropriation for FY 1950 provided approximately $1.5 million for the Operations Research Office.[171] By comparison, the Air Force FY50 budget included $4 million for Project RAND and $300,000 for operations analysis (OAD and OAO), and the Navy's FY50 budget included $400,000 for OEG.[172]

The Army's contractual arrangement with JHU was not without some problems in the first few years, generally as a result of late appropriations by Congress and the Army's reluctance to issue a multiple-year contract. The original DA–JHU contract expired on 30 June 1949 and had to be extended for three months, for a sum of $230,000.[173] This caused considerable concern at JHU, and, on 29 December 1949, JHU president Detlev Bronk wrote to the assistant secretary of the Army, Archibald Alexander, about the failure of the Army to renew the ORO contract in a timely manner.[174] After noting that JHU had agreed to accept the initial ORO contract "as a part of its patriotic duty in spite of severe disadvantages to the University," President Bronk emphasized the need for "a stable research program and a realization of the fact that a research program usually leads to practical results only after a considerable period of prosecu-

tion of the program."[175] He then complained that, although the original one-year ORO contract had been extended several times, JHU had been forced to conduct scientific studies for the Department of the Army for the period from 1 July to 10 August 1949, without a formal contract or fiscal support from the Army. Moreover, he noted, the extensions were for only short periods, and the failure of the Army to enter into long-term renewals promptly was a matter of concern to him, the JHU board of trustees, and the ORO staff. The solution proposed by President Bronk was that the Army execute the ORO contracts for a period of three years to "assure to present and prospective members of the Operations Research Office staff a certain amount of stability . . . prerequisite to the recruitment of the able personnel needed for this work."[176] After considerable internal discussion and delay, the Army eventually acceded to President Bronk's request.

The ORO Research Program, August 1948–June 1950

The raison d'être for ORO was to conduct operational research studies on matters of interest to the Army. Thus, the annual ORO work program was a matter of high interest to Army leaders and to JHU. *DA Memo 3–50–2* provided several mechanisms for shaping and controlling the ORO work program. The deputy director of logistics for R&D on the Army Staff was charged with general supervision of ORO operations, and day-to-day coordination and oversight was provided by the assigned ORO project officer, a staff officer assigned to the Logistics Division R&D Group. A Department of the Army Ad Hoc Advisory Committee, chaired by the ORO project officer (later by the deputy director of logistics for R&D), oversaw the ORO work program, assisted in the selection and coordination of problems for study, and recommended priorities.[177]

DA Memo 3–50–2 also prescribed procedures by which the Army staff, the technical services, and other Headquarters, Department of the Army agencies could submit proposals for ORO study projects directly to the deputy director of logistics for R&D.[178] Other Army agencies were enjoined to submit such proposals through the proper military channels, and other DOD agencies were invited to do so through the chief of staff, U.S. Army.

To provide greater detailed control of approved ORO projects, the DA advisory committee early on recommended that an ad hoc project advisory group (PAG) be formed to oversee the progress of each project. The deputy director of logistics for R&D approved the recommendation, and thereafter a PAG comprising representatives of interested Army Staff and other Army agencies was formed for each ORO project. Each PAG was chaired by a representative from the Army Staff agency that held primary interest in the particular study area.[179] PAG's task was to review periodically ORO's work on the project "to insure that the results obtained will fulfill a need of the Department of the Army" and "to render appropriate advice and assistance to the ORO upon the request of the ORO Project Chairman."[180] PAG was not empowered to issue any directives to ORO but was to recommend changes and remedial actions to the deputy director of logistics for R&D.[181] The chairman of each PAG submitted periodic progress reports along with any recommendations for changes.[182] One notable weakness of the PAG system was that, for each of the officers assigned to a PAG, the work was an additional duty and thus perhaps did not receive all of the attention it merited.[183]

In November 1949, Ellis Johnson wrote to Detlev Bronk, suggesting the creation of yet another mechanism for reviewing the work of ORO—probably as a means of creating an "academic" counterweight to Army criticism of the ORO work program.[184] Noting that "the University could give the Operations Research Office essential and important assistance by an appropriate review of our findings prior to their submission to the Army," Johnson recommended the formation under JHU auspices of a high-level "Review Committee" to be chaired by President Bronk. Among the potential members of the committee suggested by Johnson were Vannevar Bush to represent the physical sciences; Gen. Dwight D. Eisenhower or Gen. Jacob D. Devers to represent the military needs of the Army; Dr. Lee DuBridge, Dr. Enrico Fermi, or Dr. E. O. Lawrence to represent the atomic weapons field; Dr. Donald Young or Dr. Pendleton Herring to represent the social sciences; Dean Edward Mason to represent the field of economics; and Dr. Donald Marquis to represent the field of psychology.[185] Apparently Johnson's recommendation was never implemented by JHU, although the university board of trustees established a committee headed by Robert W. Williams to oversee ORO, and the JHU Committee on Sponsored Research provided additional oversight.[186]

Determining what projects to pursue proved an enduring challenge for ORO throughout its existence.[187] As one historian has written:

> Many researchers at ORO, in their original conception of their mission, saw themselves as scientists who were to explore all aspects of warfare and its long-range implications, while the Army appeared to be primarily interested in seeking ways to apply operations research to questions concerning logistics and supply. Also, the Army did not seem to be interested in applying operations research to the use of weaponry in combat. . . . This difference in viewpoint was the start of the troubled relationship between the Army and ORO that would persist throughout ORO's history.[188]

In practical terms, the approval and design of each project undertaken by ORO was the product of a joint Army–ORO consideration of several factors, including the nature

and scope of the problem, the relative importance of the study to the Army, the probability that the problem could actually be solved, the approximate time required to complete the study, and the effect of the proposed study on the overall ORO work program.[189] For the most part, the Army was focused on the near term and generally wanted quick, easily accomplished studies that would produce concrete solutions to immediate problems.[190] Ellis Johnson and key members of the ORO staff, however, were forward looking and preferred to take on studies of emerging problems, particularly those outside traditional weapons and tactical analysis topics.[191]

The system of individually authorized projects that prevailed until 1951 created certain problems in budgeting and recruiting competent staff members.[192] For example, it made difficult the recruitment and retention of a staff of analysts representing a span of knowledge and expertise broad enough to ensure that ORO could begin work immediately on urgent problems. In 1951, the problem was mitigated by the adoption of a new system for initiating and reviewing projects that included reserving 30–40 percent of the ORO capability for urgent, unprogrammed studies requested by the Army and a small percentage for work on basic OR techniques.[193]

It has often been stated that ORO focused initially on weapons evaluation and tactical analysis problems, in part because the Army had a backlog of such problems and in part because Army commanders and staff officers were unfamiliar with the capabilities of OR.[194] This was not entirely the case. From the beginning, in fact, the scope of the ORO research program was quite broad and included an emphasis on matters other than military weapons and equipment, much more so than the OR programs of the other services.[195] The first two approved ORO projects—Project ANALAA and Project EVANAL—both assigned in August 1948, dealt with air defense systems and the means for analyzing the performance of Army equipment, respectively. However, the third approved project—Project MAID—also assigned in 1948, was a major study of the pros and cons of providing military assistance to foreign countries, and thus it focused on questions of international relations and economics.[196] Moreover, although the Army was definitely interested in applying OR to questions of logistics and supply, such topics involved more than a technical analysis of weapons systems alone.[197] During the process that led to forming ORO, Maj. Gen. McAuliffe and others had assumed that operations research would be used early on for the study of problems related to Army training and organization, and this, too, soon came to pass.[198]

As the Army educated itself with respect to OR and recognized the importance of such fields as international relations, economics, and psychology to the postwar Army, the ORO work program was expanded to include studies with a social science component (for example, Project MAID and Project POWOW, which dealt with the techniques of psychological warfare).[199] Analysts trained in the physical sciences were not particularly well suited to address such topics, and ORO was obliged to recruit a team of competent social scientists to ensure its ability to take on projects in the social sciences.[200] On 19–21 September 1949, ORO sponsored a conference of its social science consultants for the purpose of "obtaining criticism and guidance with respect to the undertaking of ORO to establish research patterns and methodology in the social sciences upon the highest level of competence."[201] The conference was attended by representatives of DOD, the U.S. armed services, and other government agencies, as well as twenty-two social science consultants. Dr. Edward S. Mason, dean of the Graduate School of Public Administration at Harvard University, served as chairman. Recommendations were sought with respect to current and potential new methods of attacking problems involving the social sciences, research methods in general, the progress and direction of work under contract, the organization and functions of the ORO staff, and the general relationship between research and actions and decisions.[202] The attendees provided candid assessments of the state of play at ORO regarding such matters, and their advice was subsequently quite useful in fine-tuning the ORO research program.

In its first two years of existence, ORO was tasked with several major studies including analyses of air defense systems, military aid to other countries, the accuracy of artillery fire, and armor operations, as well as the use of tactical nuclear weapons, protection of the individual soldier, mines and other antitank weapons, intelligence operations, the threat to overseas lines of communication, logistics, military costing, guerrilla warfare, and psychological warfare.[203] Each project typically consisted of several subprojects or studies conducted either by ORO staff, by subcontractors, or by a combination of the two under the chairmanship and direction of a senior ORO analyst.

As of 30 September 1949, six main projects were under way[204]:

1. *Project ANALAA* (Project No. 99–48–1) was assigned on 25 August 1948, and involved an analysis of antiaircraft weapons and systems.[205] The ANALAA project chairman was Dr. Ervin H. Bramhall (later Dr. James H. Henry) and the vice chairman was Col. Seymour I. Gilman. The project required fifty-four ORO man-months in FY 1949, at a cost of $353,206; and it involved several contractors, including the Stanford Research Institute, the American Power Jet Company, the Battelle Memorial Institute, the Louisiana Polytechnic Institute, and Curtiss-

Wright Corporation, at a cost of $240,942 in FY 1949. The FY50 costs were estimated at $320,000 for ORO staff and $170,000 for subcontractors. The recommendations put forward by Project ANALAA were important factors in the Army decision to accelerate development of antiaircraft missiles and to retain reasonable numbers of heavy antiaircraft guns until suitable missiles were available.

2. *Project EVANAL* (Project No. 99–48–2) was assigned in August 1948 and was completed on 12 July 1950, under the chairmanship of Emery L. Atkins.[206] The task of Project EVANAL was to determine a means for analyzing the performance of Army equipment under various environmental conditions, particularly arctic ones, and to determine the feasibility of using business machines for that purpose. Project EVANAL involved eight ORO man-months in FY 1949, at a cost of $14,207. No subcontractors were involved. The principal recommendation was that the Army undertake additional research in the development of military characteristics and specifications for business machines capable of aiding the rapid analysis of the performance of Army equipment under various climatic conditions.
3. *Project MAID* (Project No. 99–48–3), also begun in 1948 and completed in early 1950, was headed personally by Ellis Johnson. It involved analyzing the potential value of U.S. military aid programs to foreign countries.[207] Project MAID required thirty-one ORO man-months in FY 1949, at a cost of $283,992 and involved several contractors, including the Stanford Research Institute, Harvard University, the University of Washington, and International Public Opinion Research, Inc., at a cost in FY 1949 of $219,000. Estimated FY50 costs were $100,000 for ORO staff, with no subcontractor costs. Project MAID was the earliest ORO project to extend beyond a strictly Army topic into the fields of international relations and economics, and the extensive report on Project MAID (issued in final form in early 1950) had a significant influence on the Army's support for passage of the Mutual Defense Act of 1949, which established the Military Assistance Program, a key element of America's Cold War strategic policy.
4. *Project ALCLAD* (Project No. 99–49–4), assigned on 1 October 1948, involved the analysis of individual protection means from all known forms of warfare and recommendations for future research on, development, and use of the optimum equipment and systems to protect the individual soldier.[208] Active work on Project ALCLAD began on 15 February 1949, under the chairmanship of Dr. John H. Gardner with the assistance of Norman A. Hitchman and Robert J. Best, and the project was completed on 31 May 1952. For purposes of the study, the known hazards to the individual soldier on the battlefield were divided into seven groups (missiles and missile fragments, concussion from explosion, nuclear radiation and radioactive substances, pathogenic and chemical agents, heat radiation, flaming agents, and insects and insect-borne diseases). Each hazard group was assigned to a team of three ORO staff members and two consultants. In all, ORO expended nineteen man-months on Project ALCLAD in FY 1949, at a cost of $101,700, plus $26,850 for a subcontract with the Midwest Research Institute. Estimated costs for FY 1950 were $170,000 for ORO staff and $50,000 for subcontracting. Project ALCLAD produced several important recommendations, including one against the use of body armor; also addressed were the need to reduce the combat load of the individual soldier, a redesign of the helmet, the wearing of gas masks during training exercises, and the need for additional research on chemical warfare agents and defenses. The recommendation against the development and use of body armor is particularly interesting as an example of how a logical scientific analysis might lead to conclusions that run counter to common sense or might be politically or morally unsound.
5. *Project GUNFIRE* (Project No. 99–49–5) was assigned on 23 November 1948 but was closed out in favor of the more-general Project REDLEG.[209] The purpose of Project GUNFIRE was to determine the nature and extent of existing deficiencies in equipment, techniques, computational procedures, organization, training, and doctrine that adversely affected the accuracy of predicted artillery fires, and to outline a program to correct the deficiencies. The project was chaired by Wayne E. McKibben (later William L. Whitson). Project GUNFIRE involved eight ORO man-months in FY 1949, at a cost of $125,533, plus $103,583 paid to subcontractors, including the Franklin Institute Laboratories for Research and Development, Snow and Schule, and Dunlap and Associates. The FY50 costs were estimated at $75,000 for ORO staff and no subcontractor support. Recommendations derived from Project GUNFIRE included the need to develop a method of delivering predicted artillery fire without the need for meteorological corrections, a revision in artillery training methods, and the development of operational steps to reduce the possibility of gross personnel errors.

6. *Project POWOW* (Project No. 99–49–6) was assigned on 26 February 1949.[210] Its purpose was to determine by scientific analysis and synthesis the effectiveness of weapons, instruments, and techniques that might be used by ground forces in conducting psychological warfare (PSYWAR) operations. Project POWOW was headed by Kenneth W. Yarnold (later Willmoore Kendall) and involved a long list of ORO personnel, consultants, and subcontractors, the most important of which was the University of Chicago. The study focused on an assessment of tactical psychological warfare operations in northwest Europe during World War II with the expectation that it would reveal probable effects of psychological warfare on the Russians. Project POWOW involved five ORO man-months in FY 1949, at a cost of $41,362, plus $32,350 paid to the University of Chicago. The FY50 costs were estimated at $200,000 for ORO staff and $80,000 for subcontractors. Recommendations derived from Project POWOW included establishment of a roster of qualified Army PSYWAR personnel, the need to prepare manuals of area studies, the re-examination of the use of aerial loudspeakers, and the establishment of Army research facilities for PSYWAR outside ORO.

As of 30 September 1949, ORO also had six proposed projects pending approval[211]:

1. *Project DONKEY*: to analyze the use of surface-to-surface guided missiles in support of Army operations[212]
2. *Project TREMABASE*: to analyze the comparative feasibility of transporting by air, sea, or land the personnel, weapons, and supplies necessary to establish and maintain an advanced base[213]
3. *Project TEAM*: to determine the most important factors in interpersonal relations as they apply to the organization, motivation, and utilization of groups of men for military purposes, and to determine the most effective methods of controlling such social behavior as a means of increasing the tactical efficiency of the military unit
4. *Project SITE*: to determine the most effective methods, techniques, and organization for planning and conducting Army training and educational programs
5. *Project ATTACK*: to evaluate on a continuing basis the use of atomic weapons in support of Army operations[214]
6. *Project ARMOR*: to determine the most effective methods of destroying, damaging, delaying, and canalizing enemy forces (particularly armor) by the use of land mines.[215]

Preliminary and final results of ORO projects and studies were distributed in a number of forms, including briefings and published reports. In most cases, the studies were classified or otherwise restricted in their distribution. The two principal types of ORO publications were technical memoranda and final reports. Technical memoranda were published in the "T" series (for example, ORO-T-4: *Antiaircraft Artillery Materiel and Personnel in the Type Field Army*, 9 February 1950); they were working papers developing specific aspects of an approved ORO project or special studies assigned by the Department of the Army. Final reports were published in the "R" series (for example, ORO-R-1: *Economic and Logistic Study of the Tactical Employment of Three Guided Missiles at Specified Monthly Rates*, 21 November 1949); they contained the final conclusions and recommendations of ORO on a given project. By 30 June 1950, ORO had published more than one hundred technical memoranda and five final reports. Internal ORO matters and internal staff papers were addressed in the project report ("PR") series, the staff paper ("SP") series, and the staff memorandum ("S") series. Technical memoranda and final reports were carefully vetted by internal review groups (the so-called murder boards), whereas project reports and staff papers were less well vetted and were limited in distribution. Staff memoranda could be prepared on any topic but were not distributed outside ORO.

The Influence of Ellis A. Johnson

The nature and scope of the projects undertaken by ORO as well as the office's organization, staffing, and overall philosophy were profoundly influenced by one man, Dr. Ellis A. Johnson.[216] ORO, and with it the bulk of the Army's postwar OR program, was largely Johnson's creation. In much the same way that W. Barton Leach created and sustained the Army Air Forces operations analysis program during World War II, Ellis Johnson fostered the use of OR in the Army after the war. A competent scientist and OR analyst in his own right, Johnson was also a consummate manager and bureaucratic in-fighter, and he seldom let pass an opportunity to strengthen and broaden the ORO program. His forceful, enigmatic, and sometimes quarrelsome personality was a major factor in the establishment and growth of ORO, as well as in its ultimate demise.

Johnson's vision of the nature and possibilities of operations research as a discipline was broad. Addressing the ORO social science consultants in September 1949, he defined the function of OR in the Army as being

> to develop analytical theories of action, checked by experience, capable of predicting, within specified limits of error, the probable results and costs of military action. Such predictions can be used by the Army as one of the important elements in the decisions reached by the Army commanders . . . for major deci-

> sions, operations research can play approximately a 30 percent part in the decisions.[217]

Johnson's attitudes toward military affairs and the role to be played there by science—operations research in particular—were shaped by his experiences in World War II. The realization that the aerial mining campaign against Japan—which he had done so much to design and promote—had resulted in substantial destruction and loss of life imbued him with some degree of skepticism about the usefulness of military conflict as a means of resolving international problems. He is reported to have expressed his revulsion for war, stating, "I've always thought a scientist could do more for his country before a war."[218] At the same time, he gleaned from his experience several principles that he subsequently applied to ORO. Among these were the ideas that

> fine research simply could not be done under dictated direction by a user; it had to be invented, if possible, by the scientist. Successful results could not be guaranteed, and finished results could not be promised for a deadline time. There might be many successes, but surely also occasional failures.[219]

Johnson believed that those who directed operational research programs such as those of ORO should also be qualified practitioners of the art and frequently turn their hand to actual analysis.[220] He also developed a keen appreciation for the need of OR analysts to gain a degree of competence in military affairs, and for close cooperation between the OR analyst and those responsible for the military decisions.[221]

Well known for having little patience with the limitations of the so-called military mind, Johnson nonetheless was able to work effectively with Army leaders. As Maj. Gen. Ward H. Maris, the deputy assistant chief of staff, G-4, for research and development, told his audience at the Second Tripartite Conference on Army Operations Research in October 1950:

> I consider Dr. Johnson an outstanding leader. He enjoys our complete confidence, and the confidence of his co-workers.
>
> As a soldier it is my duty to keep the military viewpoint and the military requirements before him and his splendid group of scientists. Possibly, he may feel at times that he is suffering from the so called military mind as opposed to the scientific mind. When those two minds get together, it is really something.
>
> We have had many, many discussions bordering on arguments. Neither of us ever wins, naturally. I was very happy to have him accuse me last night of indicating or giving the impression that he didn't need to know anything about military science and tactics. That is what I have been trying to impress upon him in the past months. Unfortunately, I apparently had not succeeded.[222]

From the beginning, despite his skepticism regarding both the usefulness of military operations and the enlightenment of military officers, Ellis Johnson dedicated himself to exploring

> the possibilities of OR helping the armed forces with the complex and fast-changing problems of warfare, convinced of its importance, and dedicated to patriotic service and the advancement of operations research as a science and a profession.[223]

Both his experience and his instincts told him that ground warfare was in many ways more complex than air or sea warfare, and that it would be necessary to develop effective methods of operations analysis to deal with those complexities almost from scratch.[224] Accordingly, he intended to create in ORO an organization that would be

> large, diverse, and strong, to emphasize innovative methods and approaches, and to extend the boundaries of the field—from effectiveness studies to cost-effectiveness work, from tactics to logistics and procurement investigations, from studies centered on technical hardware options to ones focusing on the human element.[225]

Johnson's experience with the aerial mining campaign in the Pacific made clear to him the degree to which OR was useful at the strategic level and what substantial results could be obtained.[226] As director of ORO, he became a forceful and consistent advocate of the extension of OR to problems well beyond the usual matters of weapons analysis and the improvement of tactics to the strategic level and the broader fields of national and international policy. Johnson's ideas on the broad application of OR to matters of policy and international affairs were reflected in the early addition of social scientists to the stable of ORO analysts. In part, he saw OR as a means for building rather than destroying society, and he lobbied the president of The Johns Hopkins University to support OR work in improving the lot of developing countries.[227]

On a more-basic level, Ellis Johnson was a skilled and inspirational leader. He created in ORO an internal ethos that placed a high value on technical competence, cooperative endeavor, and enthusiastic pursuit of knowledge. He demonstrated sincere interest in the professional development of ORO staff and established an atmosphere that made the work easy and enjoyable.[228] Johnson delegated authority and supported his staff. As the long-time ORO technical librarian Margaret Emerson recalled, "we were really one big family."[229]

Although often suspected of being an "empire builder," Johnson's vision of ORO was a good deal broader. Addressing the participants at the Second Tripartite Conference on Army Operations Research on 27 October 1950, Johnson praised the OR work being done at the weapons analysis level in the technical services and the Army field forces and noted that the

> ORO has to fit into the Army as one of the organizations carrying out operations research as a team. . . . It is my own opinion that we will eventually have in the Army a family of operations research organizations of whom we will be a member, a notable member, I hope.[230]

For good or ill, ORO *was* Ellis Johnson. He guided its formation, staffing, and development with a strong hand and labored mightily to find for it a central role in the Army's decision-making process. For the most part he was successful, and he, more than any other individual, dominated and advanced the field of Army operations research in the postwar period.

ORO—An Early Assessment

The degree of success achieved by ORO in its program of analytical studies in the first years of its existence was mixed. Despite the best intentions of all concerned, the early ORO products left something to be desired both in focus and quality. In general, ORO was able to tackle successfully problems involving discrete technical and tactical issues, but "the more complex the problem and the greater the number of non-quantitative aspects involved, the less chance it [had] for success."[231]

Inexperience on the part of newly minted ORO analysts, a lack of focus on matters of central importance to the Army, a tendency to take up operational planning issues best left to the Army Staff, and the lack of tangible results on some early projects all contributed to criticism of ORO within the Army.[232] Ignorance and misperceptions on the part of some Army commanders and staff officers also contributed to the criticisms directed at ORO. Many Army officers continued to be uninformed about the capabilities, methods, and limitations of operations research, and the old problems that had hampered the development of OR in the military in World War II resurfaced. Some officers complained that ORO was seeking to usurp military functions by becoming involved in operational matters, and that ORO analysts were "spying" on military leaders.[233] Others simply could not accept "the intrusion of 'civilian long-hairs'" in military matters.[234] Still others complained that ORO work was far too broad and "theoretical" and that it did not address day-to-day issues of pressing importance to the Army.

There were also those people in both ORO and the Army who questioned the value of ORO studies when all too often the Army seemed to have failed to implement those recommendations contained in the ORO reports. In fact, even given a "successful" study, the nexus between the study recommendations and positive Army action remains difficult to demonstrate. It would appear that the number of ORO recommendations actually implemented by the Army was quite small, with perhaps only one study in ten resulting in a substantial payoff during the entire period up to approximately 1956.[235] However, as the Army and the ORO learned to work together and the Army's needs and desires became clearer, the ORO was better able to satisfy the Army's demands.

Ellis Johnson and the leaders of the ORO were aware of the many problems facing the new organization, including the challenge of meeting Army expectations regarding the scope and usefulness of ORO studies. In the ORO quarterly report issued on 30 June 1949, Johnson addressed these problems directly, noting that

> it is important to outline the problems whose solutions are now for the most part well and favorably under way: (1) the recruiting of a scientific staff of high quality; (2) the training of this staff in the methodology of Operations Research; (3) the familiarization of the ORO staff and of the Army with respect to problems of mutual concern; (4) the organization of ORO as an effective working part of the General Staff of the Army; and (5) the provision of high level guidance from the Army as to its needs and the orientation of our efforts.[236]

Other problems included the usual difficulties of a new organization—internal administrative issues, adequate facilities, and underfunding—as well as morale problems among the ORO analysts that stemmed from a feeling that their efforts were not appreciated.[237]

Evaluating the first six months of ORO operations, Johnson reached three main conclusions. First, "close coordination and cooperation of the Operations Research programs of the United States, Britain, and Canada are necessary and desirable and should be extended for mutual benefit."[238] Second,

> Operations Research should not be centralized in the Army in a single group such as ORO, but . . . should be situated at each . . . of three principal levels: in the weapons laboratories, for analysis of weapons; at the headquarters and boards of the Army in connection with the development of new tactics; and at the General Staff level in connection with strategic decisions. . . . It is true that there are several important and highly successful Operations Research activities in a few commands of the Army, as for example at the Ballistic Research Laboratory, Aberdeen, Maryland. These deserve full recognition and might well be formalized as independent Operations Research activities. In general, however, the aiding of command decisions by Operations Research needs to be further implemented at the weapons analysis and tactics level.[239]

Third,

> ORO scientists must work in close cooperation with their military colleagues . . . guarantee should be provided that the military aspects of ORO projects will be given fully realistic attention . . . representation of the military interest cannot be provided solely by civilians even though they may have had actual combat experience . . . vital and necessary military knowledge must be furnished directly by officers on active duty, working full-time in ORO at actual project problems.[240]

At the time the ORO was formed in the summer of 1948, there had been an agreement between the Army and The Johns Hopkins University that Johnson would be given at least three years to overcome initial problems and establish an effective working organization capable of providing the Army with such advice and assistance as the most advanced operational research techniques could make practicable.[241] However, after only one year the Army undertook a comprehensive review

of the ORO organization and performance that included a number of substantial criticisms and recommendations for redirection of the course set by Johnson and his team. On 30 September 1949, the Plans and Operations (P&O) Division of the Army General Staff completed a staff study to "examine the organization, functions, and working relationships of the [ORO] with a view to recommending changes if any appear desirable."[242] The study, approved by the Army chief of staff, Gen. J. Lawton Collins, on 31 October and released on 3 November 1949, contained the following conclusions:

3. The execution of the Army operations research program under the Director, Logistics Division, by contract with The Johns Hopkins University should continue.
4. ORO's work, which encompasses the Army-wide operations research program, should have greater emphasis on the weapons use level; problems at the General Staff level should be limited during ORO's formative period.
5. ORO's work should be directly related to the basic over all mission of the Army. Research on matters of joint concern should not normally be undertaken except on request of the Research and Development Board or the Weapons Systems Evaluation Group.
6. Existing projects should be reviewed and where appropriate abandoned or narrowed in scope in consonance with paragraph 5 above.
7. A closer working relationship should be established between ORO and the Army. To this end the assignment of additional military personnel to ORO should be effected.
8. The responsibility of the Army Advisory Committee should be broadened to provide the means by which the Deputy Director for Research and Development, Logistics Division, can obtain advice on general policy guidance.
9. Increased liaison should be maintained with the field. The Army operations research program should envisage the creation of a field office at the Office, Chief, Army Field Forces. Upon the creation of this office, ORO personnel located at Hqs. Department of the Army should then perform the function of serving the General Staff only.
10. Appropriate steps should be taken to educate military personnel at the Hqs. Department of the Army and the Office, Chief, Army Field Forces in the aims and purposes of operations research.
11. After a period of six months, Plans and Operations Division should make appropriate recommendations as to the desirability of re-locating ORO within the Department of the Army organization.[243]

The P&O Division study addressed many of the concerns already expressed by Ellis Johnson, notably the need for better Army guidance, a closer working relationship between the ORO and the Army, increased liaison with units in the field, and the education of Army officers about OR. However, the study conclusions regarding the scope of the ORO study program struck a sensitive nerve, particularly because these criticisms appeared to have been introduced by that segment of the Army Staff eager to restrict the work of the ORO to mundane (but nevertheless important) matters of weapons analysis and improvements in tactical doctrine.

Johnson and many members of the ORO staff were committed to the idea that OR techniques could be applied effectively to the study of problems of strategy and policy rather than only at the weapons analysis and tactical level. However, as the 30 September 1949 staff study revealed, this idea found considerable opposition in the Army, and Johnson was already struggling to ensure that ORO efforts to apply OR to strategic and policy decisions continued. As he told the attendees at an ORO conference of social science consultants in September 1949:

> With respect to the extension of operations research to the strategic problem, there is a great deal of difficulty. The tactics approach uses the results of weapons analysis. The strategic approach must make use of both the weapons analysis and tactics operations research. However, it comes to problems of another order of magnitude and difficulty. In particular, it comes to problems, at the present time, which are associated with problems of human relations to a far greater extent than the weapons analysis or the tactics problems, and there is a question of whether or not we can develop a methodology in any reasonably short time.[244]

The negative view of the ORO attempts to extend the use of OR into the field of strategy and policy contained in the P&O study prompted Johnson to react in several ways to "protect" the ORO. On 11 November 1949, he wrote to JHU president Dr. Detlev Bronk to advise Bronk that he (Johnson) had an appointment to meet with the Army chief of staff, General Collins, on 21 November—a meeting that he believed would result in important policy decisions regarding the ORO.[245] Johnson's concerns centered around three issues raised by the P&O staff study that he believed would be discussed in the meeting with General Collins. The first was whether the scope of the ORO work should be "very wide and include a serious attempt to apply operations research methods to the strategic problems of the Army."[246] He noted that

> on the extreme right are officers who believe that this is solely the function of military personnel, and that scientists should be concerned solely with consideration of the design of weapons. On the extreme left are officers who believe that the strategic problems can be solved only by civilian groups who work with some assistance from the military. It is difficult to determine where the median lies.[247]

The second issue was "whether or not operations research should attempt to integrate the findings of social science in its solutions of action problems."[248] Johnson mentioned that he had discussed this problem with leaders in the social sciences as well as with the other members of the Joint Operations Research Group. In meetings with the latter, it became clear to Johnson that

> the Navy was neutral, or possibly negative to the use of the social science disciplines in operations research, that the WSEG was at the best luke warm, that the Air Force, and in particular the RAND Corporation, was enthusiastic and believed that the application of the social science disciplines constituted the only new and hopeful approach toward the solution of action problems.—RAND and ourselves are interested in cold war solutions that go toward peace as well as the ones that need to be considered as going toward a hot war.[249]

The third issue concerned the degree of freedom that the ORO was to be given to do its work. Johnson told Bronk that

> at the present time there is an intensive effort on the part of the Army to develop a system for detail [sic] and specific control over all of ORO's research work. This is accompanied by a very high pressure to provide immediate and useful answers to the General Staff. This is the usual effect which results from a lack of understanding on the part of the customer of the way in which research can contribute. If this Army effort is successful, it will in my opinion result in a lowering of integrity in ORO . . . some compromise must be made.[250]

Johnson's solution was for the ORO research program to include a reasonable mix of projects proposed by the Army, projects proposed by the ORO, and short-term studies to satisfy the Army's immediate needs.

Ultimately, the efforts of some Army staff officers to restrict the ORO work program were unsuccessful. The growing Cold War with the Soviet Union soon made it clear that the Army could no longer confine its OR program to matters of a purely military nature, such as the design of weapons and the development of tactical doctrine. The new reality was that the Army found itself deeply enmeshed in issues of national policy and global strategy that could be addressed only by specialists in the fields of international relations, economics, psychology, and the other social sciences. Ellis Johnson and his associates had discerned this trend early on and had acted to align the efforts of the ORO to accommodate it. The wisdom of their actions would be borne out by the significant contributions made by the ORO to Army decision making in the 1950s.

Conclusion

The period between the end of World War II in September 1945 and the Communist invasion of the Republic of Korea at the end of June 1950 was a tumultuous time for the United States Army. The drastic postwar demobilization, lean budgets, restricted manpower ceilings, the reorganization required by the National Security Act of 1947, and the rapid growth of technology, particularly nuclear weapons, posed enormous challenges for the Army. These challenges required new methods and new insights. A small, but growing, part of the Army's ability to deal with those challenges successfully was the emerging application of operations research as a tool for decision making. As the newly appointed secretary of defense, James V. Forrestal, noted in his first report in 1948, "a salutary trend in military research and development is the extension and strengthening of operations analysis research which was begun in isolated fields during World War II."[251]

Operations research activities in the Army expanded dramatically with the creation of the Operations Research Office in the summer of 1948. Until that time, the Army's only OR capability had resided in the technical services and the test and evaluation boards, and it was focused primarily on weapons analysis. The ORO augmented that capability but soon moved on to broader studies of problems in the growing fields of peacetime research and development, international relations, defense economics, and national policy. Despite significant growing pains, the ORO proved to be a potentially valuable tool for determining priorities and designing the most effective and efficient weapons systems, organization, tactics, and strategy.

The first years of the ORO also provided important lessons regarding the conditions necessary for a successful OR organization. The three principal lessons learned were that the OR analyst should be free of any direct responsibility for the operation under study, the OR analyst should have sufficient time for research and not be harassed by day-to-day requirements, and the OR analyst should have the confidence of the military commander or staff responsible for the operation under study.[252] These were exactly the conclusions that had been reached regarding the World War II OR experience.

Despite a successful start to the ORO that greatly increased the Army's use of and benefit from operations research, several deficiencies remained in the Army's overall organization and program for OR Most notable were the lack of a single agency at the Department of the Army level charged with general staff supervision of all Army OR activities, and the lack of operations analysts on the Army Staff itself, other than the few in the technical services.[253] Neither deficiency would be corrected until the 1960s. In the meantime, the Army's operations analysts would face the challenge of a new hot war in Korea, an intensification of the Cold War with the Soviet Union, and the continued rapid growth in military technology.

CHAPTER TWO NOTES

[1]Lauriston S. Taylor, "Operations Analysis," *Military Review*, 26, 6 (1946): 25.

[2]Quoted in Irvin Stewart, *Organizing Scientific Research for War: The Administrative History of the Office of Scientific Research and Development* (Boston: Little, Brown, 1948), p. viii.

[3]Charles Alexander Holmes Thomson, *The Research Analysis Corporation: A History of a Federal Contract Research Center* (McLean, Va.: Research Analysis Corporation, 1975), p. 2.

[4]The proposals for a National Research Foundation included provisions for a successor to the OSRD OFS to provide technical and scientific assistance to the military forces in the field (see Lincoln R. Thiesmeyer and John E. Burchard, *Combat Scientists* [Boston: Little, Brown, 1947], p. 321).

[5]Thomson, *Research Analysis Corporation*, p. 2.

[6]Stewart, *Organizing Scientific Research*, p. 319.

[7]Ibid., pp. 319–20. Senate Bill 1297, introduced in the 79th Congress by Sen. Harley Kilgore of West Virginia, called for the creation of a National Science Foundation on the pattern advocated by Vannevar Bush. A similar bill (S.B. 1285) was introduced by Sen. Warren Magnuson of Washington. A compromise version (S.B. 1850) was worked out and passed the Senate, but it died in the House of Representatives.

[8]Ibid., p. 333. President Truman's decision to veto the bill was apparently based on cost considerations.

[9]James Phinney Baxter III, *Scientists Against Time* (Boston: Little, Brown, 1946), p. 450.

[10]Erik Peter Rau, "Combat Scientists: The Emergence of Operations Research in the United States during World War II" (Ph.D. diss., University of Pennsylvania, 1999), p. 338. The work of the National Research Council Committee on Operations Research led eventually to the creation of the Operations Research Society of America (ORSA) in 1952.

[11]Joseph F. McCloskey, "U.S. Operations Research in World War II," *Operations Research* 35, 6 (1987): 916; U.S. Congress, Office of Technology Assessment, *A History of the Department of Defense Federally Funded Research and Development Centers*, OTA-BP-ISS-157 (Washington: USGPO, 1995), p. 14 (hereafter cited as OTA History).

[12]Ltr, Fleet Admiral Ernest J. King (COMINCH/CNO) to James D. Forrestal (Sec Navy), Washington, 19 Aug 45, sub: Continuation of ORG, Provisions for (reproduced in ORG, HQ, COMINCH/CNO, , Summary Rpt to the OFS, OSRD, Washington, 1 Dec 45, Appendix C, pp. 38–39, located in College Park, Md., NARA II, RG 227, Entry 179, Box 301, Folder Summary Rpt to the OFS, OSRD (hereafter cited as ORG Summary Rpt).

[13]Ibid., p. 39.

[14]The history of the Navy's postwar OR program is covered admirably in Keith R. Tidman, *The Operations Evaluation Group: A History of Naval Operations Analysis* (Annapolis, Md.: Naval Institute Press, 1984), pp. 1–129. See also Joseph H. Engel, "Operations Research for the U.S. Navy since World War II," *Operations Research* 8, 6 (1960): 798–809.

[15]Tidman, *Operations Evaluation Group*, pp. 96–98.

[16]Ibid., p. 97. ONR was the official contracting agent for the Navy even though OEG was to report to the CNO. ONR's only real function was to manage OEG's funding levels.

[17]OTA History, p. 14.

[18]Tidman, *Operations Evaluation Group*, p. 100.

[19]Ibid., pp. 108–11.

[20]OTA History, p. 15. The OEG budget for FY 1949 reached $1 million (see Tidman, *Operations Evaluation Group*, Figure 1–1). The status of OEG as of October 1950 is summarized in J. L. Everett, "The Operations Evaluation Group, US Navy," in ORO, *The Second Tripartite Conference on Army Operations Research, 23–27 October 1950*, vol. II (Washington: JHU ORO, 1950), pp. 161–65 (located in College Park, Md., NARA II, RG 319, Entry 82, Box 2136, Folder JHU-ORO-Tripartite Conf) (hereafter cited as *Second Tripartite Conference*).

[21]Tidman, *Operations Evaluation Group*, pp. 109–10. The seven "desks" were Antisubmarine, Tactical and Doctrinal Publications Panel, Antiaircraft and Gunnery, Naval Air, Guided Missiles, Radar, and Atomic Energy Warfare.

[22]Ibid., p. 110. One OEG analyst was assigned to the Naval War College in the dual role of student and OEG liaison officer (see Everett, "Operations Evaluation Group," p. 162).

[23]U.S. Department of the Navy, Office of the Sec Navy, *Annual Report of the Secretary of the Navy for Fiscal Year 1949*, in U.S. DOD, Office of the Sec Def, *Second Report of the Secretary of Defense and the Annual Reports of the Secretary of the Army, Secretary of the Navy, and Secretary of the Air Force for the Fiscal Year 1949* (Washington: USGPO, 1950), pp. 213–14 (hereafter cited as *Second Rpt of the Sec Def*). At any given time, three to six OEG analysts were attached to ODF headquarters in Norfolk, Virginia (see Everett, "Operations Evaluation Group," p. 162).

[24]Tidman, *Operations Evaluation Group*, p. 110.

[25]Ibid., p. 98.

[26]Ibid.

[27]William T. Bradley, "Operations Research in the Armed Services," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1957, p. 19.

[28]Tidman, *Operations Evaluation Group*, pp. 102, 109–11.

[29]Engel, "OR for the U.S. Navy," p. 801. See also Tidman, *Operations Evaluation Group*, pp. 104–08, 116–28, for a discussion of the OEG research program, 1946–50.

[30]Florence N. Trefethen, "A History of Operations Research," in Joseph F. McCloskey and Florence N. Trefethen, eds., *Operations Research for Management* (Baltimore: Johns Hopkins University Press, 1954), p. 21. This work was originally prepared, under the same title, for presentation before the JHU-ORO Informal Seminar in Operations Research, 1952–53.

[31]Tidman, *Operations Evaluation Group*, pp. 102–04. *Methods of Operations Research* by Morse and Kimball has been published commercially, most recently by Dover Press (New York, 2003). Koopman's *Search and Screening* has been published by Pergamon (New York, 1980). Both works have also been reprinted in the Military Operations Research Society's Heritage Series.

[32]LeRoy A. Brothers, "Operations Analysis in the United States Air Force," Seminar Paper 1, 6 Oct 53, JHU-ORO Informal Seminar in Operations Research, 1953–54, Baltimore, p 13 (hereafter cited as Brothers, Seminar Paper 1). Although the Army Air Forces did not become a separate service until passage of the National Security Act in 1947, it was, for all intents and purposes, independent from the time of the Marshall reorganization of the Army in March 1942. For convenience, the term *Air Force* may be taken here to mean the Army Air Forces in the period before 1947.

[33]Ltr, Col. W. Barton Leach (chief, OAD, HQ AAF) to Harvey H. Bundy (special asst to the Sec War), Washington, 16 Jan 45, encl Memo,

sub: OA in the AAF for the Next War and Between Wars, RG 107, Entry 113, Box 68, Folder OA, 1943–45.

[34]Ibid., attached Memo, *passim*.

[35]Ibid., attached Memo, p. 6.

[36]Trefethen, "History of OR," pp. 21–22. It should be noted that most of what was designated as OR in the Army until the summer of 1948 was conducted under the auspices of the AAF.

[37]Taylor, "Operations Analysis," p. 25.

[38]USAF, *Air Force Regulation 20–7: Operations Analysis* (Washington: HQ, Dept of the Air Force, 6 May 53), para. 2. *AFR 20–7*, 11 October 1946, was superseded essentially unchanged by *AFR 20–7*, 5 July 1949, and then by *AFR 20–7*, 6 May 1953.

[39]Ibid., p. 4.

[40]I. B. Holley, Jr., "The Evolution of Operations Research and Its Impact on the Military Establishment; The Air Force Experience," in Monte D. Wright and Lawrence J. Paszek, eds., *Science, Technology, and Warfare: The Proceedings of the Third Military History Symposium, United States Air Force Academy, 8–9 May 1969* (Washington: USGPO for the Office of Air Force History, HQ USAF, and the U.S. Air Force Academy, 1983), p. 93. The status of OAD and OAO as of October 1950 is discussed in LeRoy Brothers, "The Office of the Assistant for Operations Analysis, US Air Force," in ORO, *Second Tripartite Conference*, vol. II, pp. 150–53.

[41]Ibid., pp. 93, 96–97.

[42]Brothers, Seminar Paper 1, pp. 9–12.

[43]Holley, "Evolution of OR," p. 92.

[44]Ibid., p. 96.

[45]Ibid., pp. 96–97.

[46]Participants in the 1 October 1945 meeting included Gen. Arnold, Edward Bowles, Donald Douglas (president of Douglas Aircraft Company), Arthur Raymond (chief engineer at Douglas Aircraft), and Franklin R. Collbohm (Raymond's assistant). See the history of the RAND Corporation at http://www.rand.org/about/history.

[47]OTA History, p. 16.

[48]Ibid., pp. 15–16. The history of Project RAND and the RAND Corporation is well documented. Perhaps the most comprehensive study is Bruce L. R. Smith, *The RAND Corporation: Case Study of a Nonprofit Advisory Corporation* (Cambridge, Mass.: Harvard University Press, 1966). See also Charles J. Hitch, *RAND: Its History, Organization and Character*. RAND B–200. Santa Monica, Calif.: RAND Corporation, 1960); RAND Corporation, *The RAND Corporation: The First Fifteen Years* (Santa Monica, Calif.: RAND Corporation, 1963); and the history of the RAND Corporation at http://www.rand.org/about/history.

[49]OTA History, p. 15.

[50]OTA History, p. 16; Hitch, *RAND*, p. 5. The status of Project RAND as of October 1950 is discussed in L. J. Henderson, Jr., "Outline of Research Analysis of the RAND Corporation," in ORO, *Second Tripartite Conference*, vol. II, pp. 154–60.

[51]OTA History, p. 16; Smith, *RAND Corporation*, p. 40. General Arnold's son, William B. Arnold, had married Donald Douglas' daughter in 1943.

[52]OTA History, p. 16. The RAND Corporation articles of incorporation were dated 14 May 1948, but the Project RAND contract was not formally transferred from the Douglas Aircraft Company to the RAND Corporation until 1 November 1948. See the history of the RAND Corporation at http://www.rand.org/about/history.

[53]History of the RAND Corporation, http://www.rand.org/about/history.

[54]OTA History, p. 16.

[55]USAF, *Air Force Regulation 20–9: Air Force Policy for the Conduct of Project RAND* (Washington: HQ, Dept of the Air Force, 22 Jan 54), pp. 1, 2.

[56]Ibid., p. 5.

[57]USAF, Office of the Sec Air Force, *Semiannual Report of the Secretary of the Air Force for the Period January 1 to June 30, 1950* (hereafter cited as *Semiannual Rpt of the Sec Air Force*), in U.S. DOD, Office of the Sec Def, *Semiannual Report of the Secretary of Defense and the Semiannual Reports of the Secretary of the Army, Secretary of the Navy, and Secretary of the Air Force, January 1 to June 30, 1950* (Washington: USGPO, 1950), p. 155.

[58]Lorna Jaffe, *Quantitative Analysis and Army Decision Making* (Alexandria, Va.: U.S. Army Materiel Development and Readiness Command Historical Office, 1984), p. 7; Bradley, "OR in the Armed Services," p. 27. Early on, RAND created a Nuclear Energy Division (later the Physics Division) that also did work on contract for the Atomic Energy Commission (see Hitch, *RAND*, p. 6).

[59]Lynn H. Rumbaugh, "A Look at US Army Operations Research—Past and Present," Combat Systems Technical Paper RAC–TP–102 (McLean, Va.: Research Analysis Corporation, Apr 1964), p. 5; OTA History, p. 16; and history of the RAND Corporation, http://www.rand.org/about/history.

[60]Smith, *RAND Corporation*, p. 51.

[61]Ibid., p. 53.

[62]William L. Whitson, "The History of Operations Research (I)," Seminar Paper 2, 15 Oct 52, JHU-ORO Informal Seminar in Operations Research, 1952–53, Baltimore, pp. 6–7 (hereafter cited as Whitson, Seminar Paper 2). For a discussion of the development of a role for the social sciences at RAND, see Smith, *RAND Corporation*, pp. 60–65.

[63]Smith, *RAND Corporation*, p. 61. General LeMay approved the concept with his usual decisiveness, saying, "Let's do it up right. If we're going to do this, do it on a meaningful scale" (Smith, *RAND Corporation*, p. 61 n. 35).

[64]Hitch, *RAND*, p. 8.

[65]NSA 1947 was enacted by the 1st Session of the 80th Congress on 24 July 1947 as Public Law 253.

[66]For a brief summary of the changes occasioned by NSA 1947 and NSA 1949, see Charles R. Shrader, ed., *Reference Guide to United States Military History, 1945 to the Present* (New York: Facts On File, 1995), pp. 6–8.

[67]Quoted in Jack Raymond, *Power at the Pentagon* (New York: Harper & Row, 1964), p. 278. As secretary of the Navy, Forrestal had led the opposition to unification of the armed forces. Forrestal resigned as secretary of defense in March 1949 and committed suicide on 22 May 1949. He thus did not live to see the correction of the situation. He was replaced by Louis A. Johnson, an advocate of greater centralization of power in DOD.

[68]The Commission on Organization of the Executive Branch of the Government, popularly known as the Hoover Commission, was set up under the chairmanship of former president Herbert Hoover in 1947 and delivered its reports and recommendations to President Harry Truman and Congress in 1949. The commission was an effort to improve the efficiency and effectiveness of government. A second Hoover Commission continued work on government reorganization during the Eisenhower Administration.

[69]A brief overview of the establishment, organization, and functions of RDB can be found in U.S. DOD, Office of the Sec Def, *First Report of the Secretary of Defense* (Washington: USGPO, 1948), pp. 121–24 (hereafter cited as *First Rpt of the Sec Def*). See also U.S. Army General Staff, Logistics Div, *Research and Development in the Department of the Army* (Washington: Logistics Div, General Staff, U.S. Army, 1948), pp. 11–12, and Office of the Sec Def, chart titled "Organization for National Security," dated 5 Nov 47, in Lowell R. Eklund, "Science and the Soldier: The Organization for Research and Development in the Army: Past,

Present, and Future" (MS thesis, Syracuse University, 1947, Tab 39). RDB replaced the Joint Research and Development Board established by the secretaries of War and the Navy on 6 June 1946. Vannevar Bush retired on 15 October 1948, and was replaced by Dr. Karl T. Compton, who had headed the wartime OFS in OSRD. Compton resigned from RDB on 10 November 1949 for reasons of health (see U.S. DOD, Office of the Sec Def, *Semiannual Report of the Secretary of Defense, July 1 to December 31, 1949* (hereafter cited as *Semiannual Rpt of the Sec Def*), in U.S. DOD, Office of the Sec Def, *Semiannual Report of the Secretary of Defense and the Semiannual Reports of the Secretary of the Army, Secretary of the Navy, and Secretary of the Air Force, July 1 to December 31, 1949* [Washington: USGPO, 1950], pp. 74–75).

[70]*Semiannual Rpt of the Sec Def, Jan 1–Jun 30, 1950*, p. 36. By the end of 1948, RDB had reviewed approximately eighteen thousand projects. Of those, some five thousand were completed, superseded, or canceled, leaving about thirteen thousand active and inactive projects to be coordinated (see *First Rpt of the Sec Def*, p. 15).

[71]Trefethen, "History of OR," p. 23.

[72]*Second Rpt of the Sec Def*, p. 16.

[73]Rpt, Philip M. Morse (director of research, WSEG), sub: Weapons Systems Evaluation Group Status, Washington, 1 Nov 49, p. 1, RG 319, Entry 153, Box 643, Folder P&O 334 Research and Development Board (hereafter cited as WSEG Status Rpt).

[74]Ibid. Morse, who had briefly directed the Navy's postwar OEG and was a member of the board of the RAND Corporation, resigned from WSEG in September 1950 to return to MIT. He was replaced by Howard P. Robertson, a veteran of the wartime Air Force OR program (see Tidman, *Operations Evaluation Group*, p. 100).

[75]Bradley, "OR in the Armed Services," p. 7. The original charter for WSEG provided that it should function under sponsorship of RDB until it should "have proved its worth," at which time it would become a component of the JCS. Staffing of WSEG with suitable scientific personnel proceeded slowly, and, in December 1949, the decision was made to retain WSEG under RDB sponsorship until at least 1 July 1950. See Memo, R. F. Rinehart (acting chairman, RDB) to JCS, Washington, 6 Dec 49, sub: Extension of RDB Sponsorship of WSEG (RDB 150/9.1; JCS 1812/24, 6 Dec 49, pp. 115–17 inclusive), in RG 319, Entry 153, Box 543, Folder 334 R&D B; Memo, Gen Omar N. Bradley (chairman, JCS) to Sec Def, Washington, 6 Jan 50, sub: Extension of Research and Development Board's Sponsorship of the WSEG, RG 319, Entry 153, Box 643, Folder 334 Munitions Board Petroleum Committee to R & D B.

[76]Bradley, "OR in the Armed Services," p. 8 (based on DOD Instruction No. 5128.8, 13 Apr 56, which reproduced earlier DOD instructions essentially unchanged).

[77]*Semiannual Rpt of the Sec Def, Jul 1–Dec 31, 1949*, pp. 79–80.

[78]Ibid., p. 80. One of the uniformed consultants was the noted Army military historian, Col. Vincent Esposito.

[79]Bradley, "OR in the Armed Forces," p. 8.

[80]Ibid.

[81]WSEG Status Rpt, p. 1.

[82]Ibid.

[83]*Second Rpt of the Sec Def*, p. 16.

[84]Ibid., pp. 43–44.

[85]Trefethen, "History of OR," p. 24.

[86]Ellis Johnson, JHU ORO, *Record of Proceedings—Social Science Conference, 19–21 Sep 49,* ORO–S–7. (Fort McNair, D.C.: JHU ORO, 10 Nov 49), p. 5, located in RG 319, Entry 153, Box 519, Folder P&O 020 ORO.

[87]For a brief summary of the measures taken to retain an operational research capability in the British armed forces after the war, see U.K. Air Ministry, *Origins and Development of Operational Research in the Royal Air Force*, Air Publication 3368 (London: Her Majesty's Stationery Office, 1963), pp. 186–88 (hereafter cited as *OR in RAF*).

[88]Trefethen, "History of OR," p. 20.

[89]Emmette Y. Burton, Jr., "The Role of Operations Research in the Army," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1955, p. 4.

[90]Trefethen, "History of OR," pp. 20, 24. See also G. Neville Gadsby, "The Army Operational Research Establishment," *Operational Research Quarterly* 16, 1 (1965): 5–18; and the papers by Dr. J. S. Hey and Dr. O. H. Wansborough-Jones presented at the Second Tripartite Conference on Army Operational Research, in ORO, *Second Tripartite Conference*, vol. II.

[91]J. W. Mayne, *History of Canadian Army Operational Research Establishment*, Defence Research Analysis Establishment Rpt 15, vol. 1 (Ottawa: Defence Research Establishment, Department of National Defence, 1970), p. 2.

[92]Joseph F. McCloskey, "Organization for Operations Research in the United States," in Max Davies and Michel Verhulst, eds., *Operational Research in Practice: Report of a NATO Conference* (New York: Pergamon Press for Advisory Group of Aeronautical Research and Development, NATO, 1958), pp. 169–70.

[93]The postwar history of the Canadian Army Operational Research Establishment (CAORE) to 1965 is covered in some detail in Mayne, *History of Canadian Army OR*. See also the paper by Maj. F. G. B. Maskell titled "The Canadian Defence Research Board and Its Operational Research Groups," in ORO, *Second Tripartite Conference*, vol. II, pp. 147–49.

[94]Mayne, *History of Canadian Army OR*, p. 6.

[95]Ibid. At first, the OEG analyst assigned to the office of the U.S. Naval Attaché in London filled the role (see Everett, "Operations Evaluation Group," in ORO, *Second Tripartite Conference*, vol. II, p. 163.

[96]Rumbaugh, "Look at US Army OR," p. 3. The agreement was later extended to include Australia.

[97]Ibid. The Tripartite Conferences were later renamed the ABC Discussions on Army Operational Research.

[98]The conference summary, remarks of invited guests, and conference papers were published in ORO, *Second Tripartite Conference*, vols. I, II.

[99]ORO, *Second Tripartite Conference*, vol. I, p. 21. The Tripartite Agreement as confirmed at the October 1950 conference in Washington is set forth in Appendix D of volume I, pp. 18–22.

[100]Inasmuch as a good working knowledge of the evolution of Army R&D is necessary to a thorough understanding of the development of Army OR after WWII, a brief outline of Army R&D history is provided in Appendix C of this volume. The history of Army R&D activities in the postwar period is well documented, although most of the sources have not been published commercially. Of particular value to this study are Eklund, *Science and the Soldier*; U.S. Army, *R&D in the Department of the Army*; U.S. DOD, Office of the Asst Sec Def for R&D, Resources Div, *The Growth of Scientific Research and Development,* RDB 114/34 (Washington: OASD [R&D], Resources Div, 1953); U.S. Department of the Army, Office of the Chief of Research and Development, *"Path of Progress": U.S. Army R&D Organizational Changes, 1924–1960* (Washington: OCRD, HQDA, 1960); L. Van Loan Naiswald, *The History of the Army R&D Organization and Program, Part I: Organization* (draft) (Washington: OCMH, DA, ca. 1963).

[101]The Research Section, General Headquarters, Southwest Pacific Area, was deactivated on 13 September 1945, and the OR section at Lt. Gen. Robert C. Richardson, Jr.'s, headquarters in the Pacific Ocean Area was closed down in September 1945.

[102]OR was also "embedded" in the work of the test and evaluation boards reporting to Headquarters, Army Ground Forces (later the Office of the Chief of Army Field Forces).

[103]Jaffe, *Quantitative Analysis*, pp. 7–8.

[104]For example, the Operational Analysis Branch in the Signal Section of Headquarters, European Theater of Operations, was deactivated on 20 May 1945, and the Operational Research Branch in the Office of the Chief Signal Officer, led by Dr. William L. Everitt, was deactivated on 1 April 1946.

[105]The major fields of R&D interest for each of the technical services are laid out in U.S. Army, *R&D in the Department of the Army*, pp. 14–17.

[106]ORO, *Record of Proceedings—Social Science Conference, 19–21 Sep 49*, p. 3.

[107]Oral history interview of Floyd Hill by Wilbur Payne, 7 Mar 89, conducted as part of the Office of the Deputy Under Secretary of the Army for Operations Research Oral History Project.

[108]Eugene P. Visco, "The Operations Research Office" (PB-20-96-3), *Army History* 38 (Summer 1996): 25; McCloskey, "Organization for OR," p. 165.

[109]Selwyn D. Smith, Jr., "An Evaluation of Army Operations Research," student individual study, U.S. War College, Carlisle Barracks, Penn., 1957, Annex 6, p. 59; and Seymour I. Gilman, "The Role of Operations Research in the Army," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1954, p. 20. The focal point of "embedded" OR activities at BRL was in what would become formally the Weapons Systems Laboratory in January 1953 with a staff of fourteen civilians and two military personnel and a budget of $435,000 for FY 1954. Only about 15 percent of its effort was devoted to OR analysis; the rest was experimental in nature (see Gilman, "Role of OR in the Army," Annex 2, p. 42).

[110]Oral history interview with George Schechter by Eugene Visco and James Williams, 15 May 93, conducted as part of the Office of the Deputy Under Secretary of the Army for Operations Research Oral History Project.

[111]U.S. Army, *R&D in the Department of the Army*, pp. 17–18. The division of responsibility for various types of equipment and the functions of the boards are laid out in that volume, pp. 18–20. In general, Board No. 1 at Fort Bragg, North Carolina, dealt with airborne and communications equipment and heavy weapons; Board No. 2 at Fort Knox, Kentucky, dealt with wheeled and tracked vehicles; Board No. 3 at Fort Benning, Georgia, dealt with small arms and individual equipment; and Board No. 4 at Fort Bliss, Texas, dealt with antiaircraft artillery and guided missiles.

[112]Gilman, "Role of OR in the Army," p. 20.

[113]Jaffe, *Quantitative Analysis*, p. 8; Thomson, *Research Analysis Corporation*, p. 7.

[114]Thomson, *Research Analysis Corporation*, p. 4; Trefethen, "History of OR," p. 15. See Memo, General of the Army Dwight D. Eisenhower (Army chief of staff) to directors and chiefs of War Dept General and Special Staff Divs and Bureaus and the commanding generals of the Major Commands, Washington, 30 Apr 46, sub: Scientific and Technological Resources as Military Assets, U.S. Army CMH, HRC–020—R&D, Fort Lesley J. McNair, Washington; also reproduced in Eklund, *Science and the Soldier*, Tab 18.

[115]Quoted in Memo, Maj Gen Anthony C. McAuliffe (deputy director for R&D, Logistics Div), Washington, probably Mar or Apr 48, sub: Department of the Army General Research Program, p. 2, JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR/ORO, May–Dec 1948.

[116]Perhaps best known as the acting commander of the 101st Airborne Division who delivered a notably curt reply to German demands for the surrender of Bastogne during the Battle of the Bulge, Maj. Gen. McAuliffe had long experience in Army R&D work. A 1919 graduate of West Point, McAuliffe served in the Developments Branch of G-4 at the beginning of WWII. He parachuted into Normandy on D-Day as commander of the 101st Airborne Division Artillery. Following the Battle of the Bulge, he commanded the 103d and 79th Infantry divisions. He then served in the Army section of the Joint Research and Development Board (Aug 1946–Dec 1947) and as the deputy director of logistics for R&D from January 1948 until his assignment as commander of the 24th Infantry Division in Japan. On 1 October 1949, McAuliffe became the chief of the Chemical Corps, in which position he served until 31 July 1951. He subsequently served as the assistant chief of staff, G-1, personnel, and deputy chief of staff for administration (1 August 1951–22 October 1953) before returning to Europe as commander of the Seventh United States Army and commander in chief, United States Army Europe (1 February 1955–1 May 1956). McAuliffe retired in 1956 and died on 11 August 1975.

[117]Gilman, "Role of OR in the Army," p. 14.

[118]Thomson, *Research Analysis Corporation*, p. 9.

[119]Seymour I. Gilman, "Operations Research in the Army," *Military Review* 26, 4 (1956): 60.

[120]Burton, "Role of OR," p. 23.

[121]Thomson, *Research Analysis Corporation*, p. 8; OTA History, pp. 16–17.

[122]Memo, Maj Gen McAuliffe, sub: Department of the Army General Research Program, p. 1–3, JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR/ORO, May–Dec 48.

[123]Ibid., p. 1.

[124]Ibid.

[125]Ibid., pp. 2–3.

[126]Ibid., p. 2.

[127]Trefethen, "History of OR," p. 23.

[128]Thomson, *Research Analysis Corporation*, p. 8. The advantages of JHU were also set forth in Memo, Dr Arthur E. Ruark (asst director, ICR, JHU) to Isaiah Bowman and P. S. Macaulay, Baltimore, 5 May 48, sub: Check Sheet for Discussion on May 6, p. 3, JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR/ORO, May–Dec 48.

[129]Memo, Dr Arthur E. Ruark (asst director, ICR, JHU) to Isaiah Bowman, Baltimore, 2 May 48, sub: Operations Research for the Army and the Navy, JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR/ORO, May–Dec 48.

[130]Memo, Ruark to Bowman and Macaulay, 5 May 48, pp. 1–9.

[131]Ibid., pp. 1–2.

[132]Ibid., p. 5.

[133]Ibid., pp. 8–9.

[134]To date, no copy of the original contract between the Army and JHU has been found in the National Archives, the JHU Archives, or other repository. That contract was apparently signed in June 1948 and covered a period of one year, expiring on 30 June 1949 (see Ltr, Dr. Detlev Bronk [president, JHU] to Archibald S. Alexander [asst sec Army], Baltimore, 29 Dec 49, p. 2, JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR/ORO, Jan–Dec 49).

[135]Memo, Dr Arthur E. Ruark (asst director, ICR JHU), Baltimore], 5 May 48(*?*), sub: Tentative Outline of Terms for Army Contract, pp. 1–5, JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR/ORO, May–Dec 48.

[136]Ibid., pp. 4–5.

[137]Gilman, "Role of OR in the Army," pp. 12–13.

[138]U.S. Department of the Army, *Memo No. 3–50–2: General Research Office* (Washington: DA, 20 Sep 48).

[139]Ibid., pp. 1, 2.

[140]Ibid., p. 4.

[141]Ibid., pp. 3, 6.

[142]U.S. Department of the Army, *Special Regulations No. 705–5–5: Research And Development—Operations Research Office* (Washington: DA, 13 Jan 49). *SR 705–5–5* underwent minor revisions on 24 October 1949 and was subsequently superseded by *Army Regulations No. 15–480: BOARDS, COMMISSIONS, AND COMMITTEES—Operations Research Office*, dated 30 Jun 1952.

[143]Ibid., pp. 1, 4.

[144]Ibid., p. 2.

[145]"Army Sets Up Johns Hopkins Research Unit," *Baltimore Evening Sun*, 21 Aug 48.

[146]Ibid.

[147]Thomson, *Research Analysis Corporation*, p. 10. Ellis Johnson was not the first GRO employee. That honor belongs to Dorothy Hoover, who served for many years as secretary to the director (see Visco, "The ORO," p. 26).

[148]Thornton L. Page, George S. Pettee, and William A. Wallace (assisted by Capt James Martin, USNR, and Alice L. Johnson), "Ellis A. Johnson, 1906–1973," *Operations Research* 22, 6 (1974), p. 1150.

[149]Smith, "Evaluation of Army OR," p. iv.

[150]Memo, Ruark to Bowman and Macaulay, 5 May 48, pp. 5–6. Ruark also assumed an annual expenditure of $15,000 for each technical or administrative position, including overhead, supporting personnel, travel, and so forth.

[151]ORO, "Administrative Operations Report for the Two Quarters Ending 30 June 1949," in *Quarterly Report*, vol. II, no. 1 and 2, 30 Jun 49 (Fort McNair, Washington: JHU ORO, 30 Jun 49), pp. 33, RG 319, Entry 82, Box 2129, Folder Quarterly Rpt.

[152]Ibid.

[153]Memo for Lt Gen Thomas B. Larkin (director of logistics, Army Staff), Washington, JHU ORO, 10 Aug 49, sub: Condensation of the Third and Fourth Quarterly Rpts of the JHU ORO, p. 1, RG 319, Entry 153, Box 519, Folder P&O 020 ORO.

[154]Page and others, "Ellis A. Johnson," p. 1150.

[155]Herbert Yahraes, "The Mysterious Mission of ORO," *Saturday Evening Post*, 23 Feb 52. Rumbaugh joined ORO as associate director in March 1950. Another distinguished alumnus of the wartime Navy mine warfare OR unit, Thornton L. Page, an astrophysicist, joined ORO in 1951. Herbert Yahraes was also an ORO employee, and E. B. Vandiver III (in 2006 the director of the Army Center for Army Analysis and a past president of the Military Operations Research Society) has told the anecdote about how reading Yahraes' article on ORO in the *Saturday Evening Post* as a child led him to a career in OR (related in Carl M. Harris and Andrew G. Loerch, "An Historical Perspective on U.S. Army Operations Research," *Military Operations Research* 4, 4 [1999]: 13).

[156]Visco, "The ORO," p. 27.

[157]Page and others, "Ellis A. Johnson," p. 1150. George S. Pettee was born on 29 October 1904, and was educated at Harvard University, where he received his Ph.D. in political science in 1937. From 1931 to 1941, he was an instructor at Harvard. During WWII, he served as a civilian on the War Production Board (1941–42), the Intelligence Division of the Office of War Information (1942–43), and the Foreign Economic Administration (1943–45). After the war, he taught at Amherst College (1945–47) and was a staff member for the Committee on Foreign Affairs of the U.S. House of Representatives. Pettee, who wrote extensively on national security and intelligence issues, joined ORO as an analyst in April 1949. He became deputy director in 1950, assistant director in 1954, and chairman of the Advanced Planning Group, RAC, in March 1962. He died at Bethesda, Maryland, on 17 November 1989.

[158]Yahraes, "Mysterious Mission," p. 7. Lester De Long Flory was born in 1899 and graduated from West Point in 1919. Commissioned as a Coast Artillery officer, he served with the American Expeditionary Forces in France in 1919 and in routine inter-war assignments at West Point, Fort Monroe (Va.), Washington, Panama, and Hawaii. During WWII, he commanded the 63d Antiaircraft Artillery Brigade (1943–44) and served with the Allied occupation forces in Austria (1945–46) as the principal organizer of the U.S. military government in Austria. He was deputy president of Army Field Forces Board No. 4 from November 1946 until his retirement from active duty on 1 July 1949. From October 1961 until his retirement in 1963, Flory was executive assistant to the president of the successor to ORO, the Research Analysis Corporation. He died at Walter Reed Army Hospital on 2 January 1990.

[159]McCloskey, "Organization for OR," p. 165.

[160]See the oral history interview with Margaret Emerson, the long-time ORO technical librarian, conducted by Eugene P. Visco on 7 Nov 99, as part of the Deputy Under Secretary of the Army for Operations Research Oral History Project.

[161]Thomson, *Research Analysis Corporation*, p. 10.

[162]Ibid.

[163]Memo, Dr Ellis A. Johnson (director, ORO) to director, ICR JHU, Fort McNair, Washington, 4 Mar 49, sub: Proposed Organization for the ORO, p. 1, JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR/ORO, Jan–Dec 49. It was anticipated that some projects would be carried out by subcontractors, at the choice of the project chairman.

[164]Ibid., p. 2. Each of the PSD groups would be headed by a senior ORO member who would report directly to the deputy director. In effect, PSD was a "general support" unit.

[165]ORO, *Quarterly Rpt 1949*, p. 31.

[166]Lester D. Flory, "Analysis of the ORO Research Program with Respect to Timeliness," ORO–TP–16, Bethesda, Md., ORO, Nov 60), p. 14, Table 5. Lt. Col. Farmer served from 1 July 1948 to 9 May 1949. He was succeeded, during the period under consideration here, by Lt. Col. Raymond Renola (9 May–15 August 1949) and Lt. Col. Vincent M. Elmore, Jr. (15 August 1949–21 November 1950).

[167]Memo, Dr Arthur E. Ruark (director, ICR JHU) to Isaiah Bowman, Baltimore, 24 May 48, sub: Overhead and Personnel Distribution on Proposed Contract, Army OR, pp. 1–4, JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR/ORO, May–Dec 48.

[168]Ibid., p. 4.

[169]U.S. Army General Staff, Plans and Operations Div, *Study on the Operations Research Office* (Washington: Plans and Operations Div, U.S. Army General Staff, 30 Sep 1949), Appendix A, p. 5, RG 319, Entry 153, Box 517, Folder P&O 020 ORO. The quartermaster general was assigned responsibility for the disbursement of funds allocated to the ORO-JHU contract.

[170]Ibid.

[171]U.S. Army, *Study on the ORO*, Appendix A, p. 2.

[172]Ibid.

[173]Ibid., Appendix A, Annex 3, p. 5.

[174]Ltr, Bronk to Alexander, 29 Dec 49, pp. 1–4.

[175]Ibid., p. 2.

[176]Ibid., p. 3.

[177]*DA Memo 3–50–2*, 20 Sep 48, para. 4 (superseded essentially unchanged by *Army Special Regulations 705–5–5* in 1949 and then *Army Regulations 15–480* in 1952). The first meeting of the Advisory Committee took place at Fort McNair on 21 September 1948 (see Memo, Brig Gen T. S. Timberman [chief, Operations Group, Plans and Operations Div] to Lt Gen Albert C. Wedemeyer [director, Plans and Operations Div], Washington, 28 Sep 48, sub: Ad Hoc Advisory Committee to the Dept of the Army GRO, p. 1, RG 319, Entry 153, Box 4, Folder P&O 000.8.

[178]Ibid., p. 3.

[179]See, for example, Ltr, Maj Gen C. G. Helmick (deputy director for R&D, Logistics Div) to Lt Col C. C. Noble (Plans and Operations Division), Washington, 1 Nov 49, sub: ORO Project Advisory Groups, RG 319, Entry 153, Box 517, Folder P&O 020 ORO. This letter established the PAG for Project ALCLAD, which dealt with the protection of the individual soldier on the battlefield. The Project ALCLAD PAG was chaired by a representative of the Logistics Division and included representatives of the Organization and Training and the Plans and Operations Divisions of the Army Staff, the chief of ordnance, the chief of engineers, the surgeon general, the chief of the Chemical Corps, the quartermaster general, and OCAFF.

[180]Ibid., p. 4.

[181]Ibid., p. 5.

[182]Burton, "Role of OR," p. 15; Smith, "Evaluation of Army OR," p. 29.

[183]Burton, "Role of OR," p. 25.

[184]Ltr, Dr Ellis A. Johnson (director, ORO) to Dr Detlev Bronk (president, JHU), Washington, 15 Nov 49, pp. 1–2, JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR-ORO, Jan–Dec 49.

[185]Ibid.

[186]JHU, Organization Chart, Baltimore, 1952, JHU Archives, Records of the Office of the President, Series I, Box 33, Folder ICR/ORO, Jul 52–Dec 53.

[187]Thomson, *Research Analysis Corporation*, p. 11.

[188]OTA History, p. 17.

[189]Gilman, "Role of OR in the Army," pp. 13–14.

[190]Ibid., p. 12.

[191]Thomson, *Research Analysis Corporation*, pp. 11–12. The extreme version of the ORO position was embodied in the comment by Ellis Johnson that " . . . we have . . . a fishing license to study everything that the Army does" (quoted in Burton, "Role of OR," p. 27).

[192]Flory, "Analysis of the ORO Research Program," p. 20.

[193]Smith, "Evaluation of Army OR," p. 13a. Ellis Johnson and other ORO staff members were agreed on the need for "basic research," that is, the development of OR theory and methods. Johnson himself believed that 10–15 percent of the overall ORO effort ought to be dedicated to such basic research (see Paul W. Ramee, "Operations Research and Army Problems," student thesis, U.S. Army War College, Carlisle Barracks, Penn., 1962, p. 12).

[194]Whitson, Seminar Paper 2, p. 7; John C. Schermerhorn, "The Role of Operations Research in the Army," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1956, p. 5; ORO, *ORO Today: Why the Operations Research Office Has Been Reorganized and What It Is Doing* (Chevy Chase, Md.: ORO, 1955), p. 1.

[195]Whitson (Seminar Paper 2, p. 7) pointed out that "in contrast to the rather specific problems which resulted in the organization of other groups, ORO was faced with a very broad phalanx of problems." Trefethen ("History of OR," pp. 26–27) noted that "the range of problems it has studied has been remarkably wide."

[196]ORO, *ORO Today*, p. 6. Project MAID was "one of the highlights of ORO's career." ORO project codes (ANALAA, EVANAL, MAID, POWOW, and so forth) are described below and in the Glossary to this volume.

[197]Thomson, *Research Analysis Corporation*, p. 4.

[198]Ibid.

[199]Ibid.

[200]Hugh M. Cole, "Selection and Training of Operational Research Scientists," in Max Davies and Michel Verhulst, eds., *Operational Research in Practice: Report of a NATO Conference* (New York: Pergamon Press for Advisory Group of Aeronautical Research and Development, NATO, 1958), p. 173.

[201]ORO, *Record of Proceedings—Social Science Conference, 19–21 Sep 49*, p. I.

[202]Ibid., p. ii.

[203]Thomson, *Research and Analysis Corporation*, p. 11; ORO, *ORO Today*, pp. 1, 4.

[204]The nature and status of approved and proposed ORO projects are described in the quarterly and semiannual ORO reports previously cited. A summary was included in U.S. Army, *Study on the ORO*, Annex 3. The most comprehensive summary is ORO, *Revised Summary of ORO Projects, Special Studies, and Field Operations to May 31, 1952, Volume I* (Chevy Chase, Md.: ORO, 28 Jul 52).

[205]On Project ANALAA, see ORO, *Revised Summary*, pp. 13–21; Memo for Lt Gen Larkin, 10 Aug 49, sub: Condensation of the Third and Fourth Quarterly Rpts of The Johns Hopkins University Operations Research Office, pp. 9–11; ORO, *Quarterly Rpt 1949*, vol. I, no. 2, pp. 8–15; ORO, *Semiannual Rpt 1950*, no. 1, pp. 13–27, 55; and U.S. Army, *Study on the ORO*, Annex 3, p. 1b.

[206]On Project EVANAL, see ORO, *Revised Summary*, pp. 61–63; Memo, Larkin 10 Aug 49, pp. 3–4; ORO, *Quarterly Rpt 1949*, vol. I, no. 2, pp. 16–17; U.S. Army, *Study on the ORO*, Annex 3, p. 1c.

[207]On Project MAID, see Yahraes, "Mysterious Mission," p. 8; Memo, Larkin, 10 Aug 49, pp. 12–14; ORO, *Quarterly Rpt 1949*, vol. 1, no. 2, pp. 19–22; U.S. Army, *Study on the ORO*, Annex 3, p. 1e.

[208]On Project ALCLAD, see Memo, Larkin, 10 Aug 49, pp. 5–6; ORO, *Quarterly Rpt 1949*, vol. I, no. 2, pp. 5–7; ORO, *Semiannual Rpt 1950*, no. 1, pp. 37–45, 56; and U.S. Army, *Study on the ORO*, Annex 3, p. 1a.

[209]On Project GUNFIRE, see ORO, *Revised Summary*, pp. 65–67; Memo, Larkin, 10 Aug 49, pp. 15–16; ORO, *Quarterly Rpt 1949*, vol. I, no. 2, p. 18; and ORO, *Semiannual Rpt 1950*, no. 1, pp. 47, 57.

[210]For Project POWOW, see ORO, *Revised Summary*, pp. 85–94; Memo, Larkin, 10 Aug 49, pp. 7–8; ORO, *Quarterly Rpt 1949*, vol. I, no. 2, pp. 23–30; ORO, *Semiannual Rpt 1950*, no. 1, pp. 49–54, 57; U.S. Army, *Study on the ORO*, Annex 3, p. 1f.

[211]U.S. Army, *Study on the ORO*, Annex 3, para. 2.

[212]ORO, *Revised Summary*, pp. 47–52. Project DONKEY was assigned on 8 December 1949, as Project No. 99–49–7 (see ORO, *Semiannual Rpt 1950*, no. 1, p. 57). Project participants included ORO employees W. G. Street, W. F. Druckenbrod, H. P. Griggs, and J. T. McIntyre, as well as five subcontractors (the Stanford Research Institute, the Battelle Memorial Institute, Booz Allen and Hamilton, the Columbia Research and Development Corporation, and the Cornell Aeronautical Laboratory).

[213]ORO, *Semiannual Rpt 1950*, no. 1, pp. 29–33, 56.

[214]Ibid., pp. 35–36, 56. Project ATTACK was assigned on 27 April 1950.

[215]Ibid., pp. 5–11, 55. Project ARMOR was assigned on 28 September 1950 as Project No. 99–50–10. There was also to be a Project FREVO, the subject of which can not now be determined. It was apparently never approved.

[216]The principal source for the details of Johnson's biography, insight into his character, and a list of his achievements is the retrospective by Page and others, "Ellis A. Johnson," which appeared in *Operations Research* 22, 6 (1974), pp. 1141–155. The following account is based primarily on that article. See also Yahraes, "Mysterious Mission," and Visco, "The ORO," pp. 24–25. The details of Ellis Johnson's life and career are contained in the brief biographical sketch in Appendix A of this volume.

[217]ORO, *Record of Proceedings—Social Science Conference, 19–21 Sep 49*, p. 3.

[218]Yahraes, "Mysterious Mission," p. 7.

[219]Page and others, "Ellis A. Johnson," p. 1149.

[220]Ibid.

[221]Harris and Loerch, "Historical Perspective," p. 5.

[222]"Remarks of Maj. Gen. Ward H. Maris, USA, Deputy Asst Chief of Staff, G4, Research and Development," in ORO, *Second Tripartite Conference*, vol. I, pp. 35–36.

[223]Page and others, "Ellis A. Johnson," p. 1148.

[224]Ibid., p. 1149; Thomson, *Research Analysis Corporation*, p. 9.

[225]Page and others, "Ellis A. Johnson," p. 1149.

[226]Ibid., pp. 1148–149.

[227]See Johnson's correspondence with JHU president Dr. Detlev Bronk in JHU Archives, Records of the Office of the President, Series I, Boxes 33 and 34.

[228]See Emerson interview, 7 Nov 99.

[229]Ibid.

[230]Ellis A. Johnson, "The Operations Research Office, US Army," in ORO, *Second Tripartite Conference*, vol. II, pp. 167–68.

[231]Gilman, "OR in the Army," p. 60.

[232]Smith, "Evaluation of Army OR," pp. 24–25; Gilman, "Role of OR in the Army," p. 1; Burton, "Role of OR," pp. 27–28.

[233]Gilman, "Role of OR in the Army," p. 1.

[234]Smith, "Evaluation of Army OR," p. 16.

[235]Gilman, "OR in the Army," p. 60.

[236]ORO, *Quarterly Rpt 1949*, vol. II, no. 1, 2, p. 3.

[237]Smith, "Evaluation of Army OR," p. 14.

[238]ORO, *Quarterly Rpt 1949*, vol. II, no. 1, 2, p. 1.

[239]Ibid., pp. 1–2.

[240]Ibid., p. 2.

[241]Ibid.

[242]U.S. Army, *Study on the ORO*.

[243]Ibid., pp. 1–2. The original paragraph numbers have been retained.

[244]ORO, *Record of Proceedings—Social Science Conference, 19–21 Sep 49*, p. 5.

[245]Ltr, Ellis A. Johnson (director, ORO) to Detlev Bronk (president, JHU), Fort Lesley J. McNair, 11 Nov 49, JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR-ORO, Jan–Dec 49.

[246]Ibid., p. 1.

[247]Ibid.

[248]Ibid.

[249]Ibid., p. 2.

[250]Ibid., pp. 2–3. Only four days later, on 15 November 1949, Johnson wrote another anxious letter to Bronk regarding Project MAID, the study of the military aid program that had evoked criticism by some Army officers for dealing with matters outside the traditional scope of military operations (see Ltr, Johnson to Bronk, 15 Nov 49, p. 1).

[251]*First Rpt of the Sec Def*, p. 133.

[252]Burton, "Role of OR," p. 21.

[253]Smith, "Evaluation of Army OR," pp. 32–33.

CHAPTER THREE

The Expansion of Army Operations Research, 1950–62

The 1930s and 1940s saw the infancy and childhood of military operations research (OR); the 1950s and early 1960s saw its adolescence and young adulthood, characterized by rapid and extensive growth and increasing maturity as well as occasional missteps and attempts to define its boundaries. By 1950, many of the basic problems of military operations research had been successfully resolved. Most commanders and staff officers had come to trust and value the support they received from OR analysts, and the analysts had learned to understand the requirements of the military and to communicate their findings effectively to the commanders and staff officers who needed them.[1] A successful partnership had been achieved, and, although spots of friction remained, the soldier and the scientist were able to work well together for common goals.[2] Close cooperation between soldiers and scientists had grown more important than ever, for, as Secretary of Defense Thomas S. Gates, Jr., noted in his 1959 report to the president, scientific advances were occurring rapidly, and "the timely application of new inventions and technological improvements to military use has become a matter of national survival."[3]

Between 1950 and 1962, the Operations Research Office (ORO) remained the Army's principal operations research establishment. ORO—and, after 1961, its successor, the Research Analysis Corporation (RAC), expanded, took on new and more-complex studies, and interacted in a positive manner with OR organizations in the other services, both abroad and in the civilian community. The period also saw the creation of several new, independent organizations focused on specific problem areas, such as human performance, special operations, and wargaming, all of which relied heavily on OR techniques.

The expansion of OR in the armed services between 1950 and 1962 was reflected in the steady growth of Department of Defense (DOD) expenditures on OR and in the number of OR analysts employed by the U.S. armed services. In 1951, DOD spending on OR in all the services amounted to more than $10 million; by 1954 that figure had doubled to approximately $20 million, and it continued to grow over the next ten years.[4] The number of scientific personnel engaged in DOD OR work also expanded exponentially during the period. In 1941, only some twenty-five OR professionals worked for the armed services, but by 1945 their number had grown to around four hundred.[5] That number grew to approximately eight hundred to one thousand by 1954, distributed among the services in the following proportion: DOD (Weapons Systems Evaluation Group [WSEG]) 1, Navy 2, Army 10, and Air Force 20.[6] The number rose to between fifteen hundred and two thousand by 1957, and reached a total of five thousand to eight thousand by 1959, with every indication of continued rapid growth, particularly in the technical services and the combat developments field.[7]

The tremendous expansion of Army OR organizations between 1950 and 1962 resulted in large part from the demonstrated usefulness of OR in helping Army leaders make the key decisions regarding the complex problems arising from the hot war in Korea, the Cold War with the Soviet Union, the rapid development of military technology, and the increasing emphasis on economy. The doctrine of massive retaliation and the Army search for a role on the nuclear battlefield, as well as the intense intraservice competition for scarce resources of men and money, demanded ever more sophisticated decision-making tools, and OR was recognized as one such important tool. As the techniques of OR grew more sophisticated, the problems that OR analysts could address became larger and more complex. The emergence of electronic digital computers and computer-assisted wargaming as important means for assessing weapons, organization, and doctrine further enhanced the ability of OR to provide the information needed for effective and efficient decisions. By 1962, OR had reached young adulthood. It was no long-

er merely a useful tool for military decision makers—it had become an essential one.

The Operations Research Office, 1950–61

In 1950, the Operations Research Office, headed by Dr. Ellis A. Johnson, was the Army's principal OR organization and was fully engaged in a number of studies of interest to the Army. The outbreak of war in Korea in June 1950 presented an opportunity for contributing directly to the solution of problems encountered in Korea, gathering field data for ongoing studies, and promoting the use of OR in the Army. Johnson seized the opportunity, and, by the time of the cease-fire in July 1953, more than 150 ORO-connected men and women had served in Korea and had prepared several hundred reports and technical memoranda, some of which had a profound effect on the Army.

Meanwhile at home, ORO continued to grow and produced a stream of studies on problems of continuing concern to the Army. ORO field offices were established in Japan and Germany, and at the Office of the Chief of Army Field Forces (OCAFF) at Fort Monroe, Virginia. The ORO research program took on ever more complex problems, but with mixed results in terms of pertinence and timeliness. Johnson continued to advocate the expansion of ORO studies into non-Army and nongovernmental fields. By the early 1960s, the Army began to have doubts about Johnson's leadership of ORO. When The Johns Hopkins University (JHU) refused to replace him, the Army and JHU mutually agreed to sever their relationship and an independent research organization, the Research Analysis Corporation, took over in September 1961. Thus, Ellis Johnson, who had built ORO from scratch, was ultimately the principal agent of its demise. However, ORO had established a recognized place for operations research in the Army and had contributed handsomely to the solution of Army problems.

ORO in Korea, 1950–53

The North Korean invasion of South Korea on 25 June 1950, and the ensuing effort by U.S. and United Nations (UN) forces to repel the North Koreans and their Chinese Communist allies led to a hard-fought conflict that raged up and down the Korean peninsula until a cease-fire was arranged in July 1953. Ellis Johnson immediately recognized that the hot war in Korea offered ORO the opportunity to achieve three goals: to contribute directly to the solution of problems encountered by UN forces in the field, to obtain actual field data for ongoing projects, and to promote better understanding by the Army of the capabilities of OR.[8] Accordingly, he proposed that a large part of the available ORO staff go to Japan and Korea to support the Army in the field.[9] The Department of the Army (DA) and the Far East Command (FEC) quickly approved the plan, and Johnson and a team of four ORO analysts arrived in Korea in early September 1950, just before the breakout from the Pusan perimeter.[10] Johnson's personal task was to establish the ground rules and administrative structures needed to support ORO teams working in the theater, and, by the end of 1950, eight ORO teams consisting of the bulk of ORO's technical personnel—some forty scientists, social scientists, historians, and engineers in all—as well as several key members of its administrative staff were at work in Korea and Japan in support of the Far East Command.[11] The main group was attached to the Office of the G-3, Headquarters, Eighth United States Army, Korea (HQ EUSAK), and in June 1951 ORO formally established a field office at Headquarters, Far East Command, in Tokyo to supervise the work of ORO personnel in the theater.[12]

By the time of the Korean cease-fire in July 1953, more than 50 percent of the entire ORO professional staff had served in the combat zone.[13] In all, more than 150 ORO employees, subcontractors, and consultants served in Korea and Japan between September 1950 and July 1953, and 113 of them earned the right to wear the UN Service Medal.[14] Some ORO analysts came under enemy fire, and at least one was rescued after having been shot down behind enemy lines.[15] Ellis Johnson himself qualified for the UN Service Medal by organizing ORO support in the Pusan, Taegu, and Seoul areas for 58 days in 1950–51.[16]

The work of ORO analysts during the Korean War fell into two main categories: studies and recommendations concerning current operations, and the collection of data for later and broader studies.[17] Some of the problems faced by ORO analysts in Korea were new and had not been encountered during World War II, but for the most part the ORO studies conducted in FEC were of the familiar weapons-analysis type or dealt with concrete practical problems such as the design and use of winter clothing and equipment.[18] However, the range of ORO studies was in fact quite broad and included such major topics as the tactical use of atomic bombs, close air support of ground forces, armor operations, infantry weapons and tactics, airborne operations, mobilization and use of South Korean manpower, combat service support, counterguerrilla operations, and psychological warfare operations.[19]

By the end of December 1950, ORO analysts had already produced a dozen memoranda and were at work on another two dozen.[20] In all, ORO analysts, subcontractors, and consultants produced several hundred technical memoranda and completed studies on operations in Korea. Among the more notable studies conducted by ORO analysts there was a study of close air support of ground forces that recommended, surprisingly, that the Air Force could

make effective use of the heavy B–29 strategic bomber for tactical bombing at night.[21] ORO analysts also studied the possible use of tactical nuclear weapons in Korea and worked out the organization and procedures that would be necessary for their use.[22] The data, conclusions, and recommendations assembled by ORO analysts provided the basis for all subsequent exercises and simulations for the use of tactical nuclear weapons.

Also, ORO researchers systematically collected data on every tank destroyed in Korea, thereby providing an invaluable database for later studies on tank vulnerabilities. The results of the tank studies led by James W. Johnson showed that fewer than half of the destroyed North Korean tanks were destroyed by aircraft; ground weapons such as artillery, bazookas, and tanks accounted for most of the remainder, except those lost to rough terrain, lack of fuel, and breakdowns.[23] By far the best "tank killer" was shown to be napalm.

A considerable amount of the ORO research effort in the Far East Command was devoted to the study of psychological warfare and its effects on Communist morale and fighting power. ORO research on psychological warfare operations in Korea began during the first months of the war and quickly demonstrated that psychological operations at a relatively low cost accounted for a large number of enemy surrenders.[24] Several ORO psychological warfare analysts working for the Special Projects Office of the HQ FEC G-2 under the direction of J. W. Green in Tokyo and at interrogation centers in Korea conducted extensive interviews with North Korean and Chinese Communist prisoners of war.[25] The analysts substantially improved the effectiveness of UN psychological warfare efforts by recommending a tighter focus on "the enemy soldier's immediate problems of survival and safety" and the greater use of pictures and loudspeakers.[26] As a result of ORO efforts, the Army sharpened its psychological warfare efforts; psychological operations in EUSAK were reorganized; and other important changes were made in the organization, scale, and orientation of the overall Army psychological warfare program.[27]

Many of the ORO studies conducted in Korea dealt with practical matters of operations at low levels. One of the best-known of the ORO consultants in Korea was the military analyst and historian, S. L. A. Marshall. Marshall studied small-unit infantry tactics and weapons and produced a primer of Chinese tactics that was widely distributed to United Nations Command units.[28] Data on infantry operations and weapons use collected by Marshall from interviews with combat troops in Korea in the winter of 1950–51 provided the basis for his critique of infantry tactics, weapons, unit cohesion, and combat stress and led to changes in weapons design, organization, training, and supply economy.[29] His popular books on the war in Korea, notably *The River and the Gauntlet* and *Pork Chop Hill*, were based on work he did for ORO in Korea.

In a little less than three years, ORO analysts made many important contributions to the UN effort in Korea and developed a bank of important new data on combat operations for use in further studies at home after the war ended. Moreover, the bulk of the ORO professional staff, which no longer included a large proportion of OR analysts with World War II experience, gained practical experience in the field. Then, too, as one historian has noted, "ORO's work during the Korean War thus demonstrated that operations research could be successfully applied to land warfare just as it had been applied to naval and air warfare in World War II."[30]

ORO at Home, 1950–61

The demand for ORO services in the Far East Command during the hot war in Korea absorbed a good deal of the available ORO manpower and effort, but at home ORO continued to grow and to take on an increasingly diverse work program. The number of professional personnel increased substantially between 1950 and 1961, as did the ORO budget. The "balanced" work program introduced in 1950 involved ORO analysts in a broad range of projects of interest to the Army, and ORO produced several hundred reports, technical memoranda, and other publications. At the same time, ORO played a key role in efforts to coordinate projects and exchange information among the various service OR programs, among the OR establishments of the principal U.S. allies, and with the civilian OR community.

Despite significant changes in the scope and magnitude of the ORO research program and the growth of its peripheral activities, its basic mission as assigned in *Army Regulations No. 15–480* did not change between 1951 and 1961, but remained

> to undertake such analytical studies of military problems as may be of interest to the Army in order to provide responsible commanders and staff agencies with a scientific basis for decision on action to improve military operations.[31]

On the whole, ORO successfully fulfilled the tasks set for it by the Army, but not without some criticism of the focus and timeliness of its studies. Then, too, by 1961 the somewhat imperious personality of Ellis Johnson, as well as his continued efforts to expand ORO studies into nonmilitary areas, provoked a loss of confidence in his leadership among Army leaders. As a result, in August 1961, the Army did not renew the ORO contract with The Johns Hopkins University, preferring instead to place the contract with a newly formed private corporation, the Research Analysis Corporation, which took over the ORO work program along with most of its personnel and physical plant.

Organization

During its first five years there was a substantial increase in ORO's workload and a gradual change in the character of its work with a shift from weapons systems analyses toward strategic and tactical studies. These changes reflected the growing acceptance of OR as a key decision-making tool and of the office itself as the Army's principal OR establishment.

Until 1954, ORO was organized on the basis of projects authorized by the Army, essentially along the lines of the various weapons systems under study. The broadening of the scope of ORO work to include more tactical and strategic studies necessitated a reorganization. Accordingly, on 1 April 1954, the office was reorganized on a functional, or mission, basis to provide "an effective organizational pattern for the required comprehensive approach to problems of operational research in tactics and strategy."[32] The reorganization created five new research divisions (Tactics, Strategic, Logistics, Intelligence, and Home Defense), as shown in Figure 3–1; gave each division "a mission broad enough to accommodate special studies likely to be assigned"; and increased the autonomy of every division.[33] Each new division was subdivided into several groups that were further broken down into "studies," and the Committees on Wargaming and Atomic Warfare coordinated work that crossed divisional lines. In addition, the April 1954 reorganization also created a Field Division to oversee ORO branch offices in Tokyo, Heidelberg, and Fort Monroe, as well as an Editorial Division and a Business Administration Division to carry out necessary administrative tasks. Two new leadership positions—associate director and assistant director—were also created to improve communications with the Army and to conduct program planning. Above all, the reorganization reflected an intention to integrate the study of weapons, tactics, and strategy by providing for greater emphasis on tactical and strategic studies.

BRAND, a special staff section that reported to the director, was set up in April 1954 to conduct a continuous evaluation of the Army's research and development (R&D) program and to make recommendations for the most efficient use of available R&D funds, the stepped elimination of obsolete weapons systems, and the gradual introduction of new equipment and methods.[34] By 1958, BRAND had been replaced by the Management Systems Division, which included a chief, eleven analysts, and six research aides organized as shown in Figure 3–2. The primary mission of the new division was "to examine Army management problems in a framework of limited budget funds and accelerated impact of R&D on the useful service life of equipment, and to concentrate on those types of decisions which are becoming much more complicated than they were in the past."[35]

Under the April 1954 reorganization, the Office of the Director consisted of the director, the associate director, the assistant director, the executive director, one or more staff assistants to the director, such other assistants as might be assigned, and the secretarial staff.[36] The associate director was responsible for the research program and chaired the Technical Council.[37] The assistant director managed the system of research management reports and oversaw the process by which ORO publications were reviewed. The assistant director also planned the assignment of personnel in accordance with the research program, although Johnson himself played a key role in assigning analysts. The executive director was responsible for the administrative activities of ORO and its field offices, and provided liaison between the ORO director and JHU on such matters. He also was responsible for staff coordination between divisions and executed the policy decisions of the director. A staff assistant to the director for training and personnel recruited, counseled, and assisted in the assignment of new professional personnel, coordinated their orientation and training, and conducted personnel studies regarding the professional staff.[38]

The heart of ORO was in the five research divisions that actually conducted studies and made recommendations. Each division chief directed the work of his division, supervised his subordinate group chairmen, transmitted technical memoranda and reports to Army authorities, and oversaw personnel and budgetary matters. Each group chairman planned and directed the work of his group and was responsible for the technical quality of papers prepared by group members. He also steered the day-to-day administration of his group.

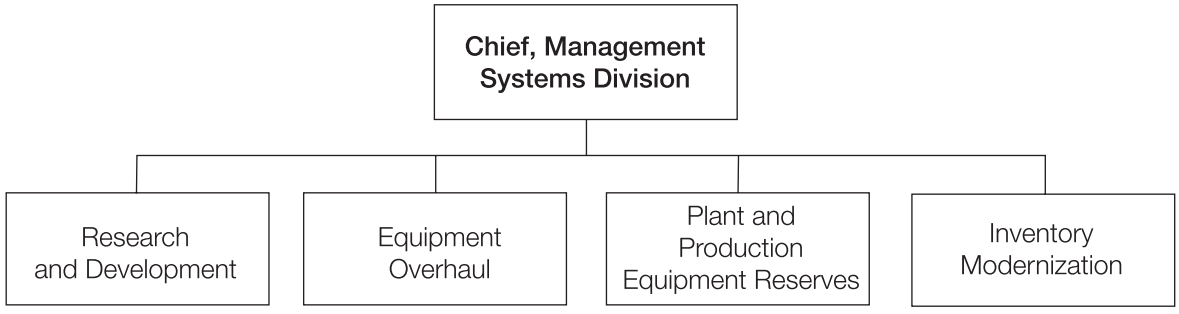
The mission of the Tactics Division was "to study combat operations with the aim of finding new methods for increasing the effectiveness of combined arms in ground combat."[39] Such methods encompassed not only improving the physical capabilities of weapons systems but doctrinal, organizational, and tactical matters as well. The studies carried out by the Tactics Division fell into three general areas: the physical characteristics and dynamics of our own and enemy combat systems, the relative worth of fire and movement in characteristic military situations, and communications for command and control. The division was initially subdivided into five groups. The Infantry Group sought ways to improve infantry weapons, organization, and tactics; the Armor Group studied the probable role of armor in a future war; the Support Weapons Group studied the organization and use of artillery, guided missiles, aircraft, and other supporting weapons systems; the TACSPIEL Group tested and synthesized the findings of the other groups and gave special attention to the use of high-speed computer techniques for simulating battles; and the Cost Group developed methods for measuring mili-

FIGURE 3–1—ORO ORGANIZATION: 1957

Note: ORO organization remained essentially unchanged from April 1954 to 1957.

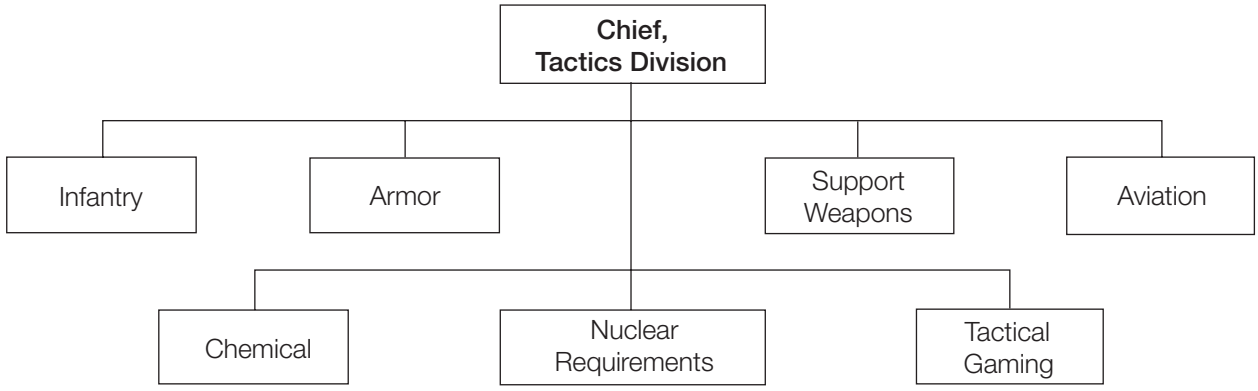
Source: William T. Bradley, "Operations Research in the Armed Services," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1957, p. 59, Annex 5; John C. Schermerhorn, "The Role of Operations Research in the Army," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1956, p. 54.

FIGURE 3–2—ORO MANAGEMENT SYSTEMS DIVISION: 1958



Source: Thomas D. Scriggins, "Management Systems Division," in ORO, "A Discussion of the ORO Work Program," ORO–SP–71, ORO, Chevy Chase, Md., October 1958, p. 57.

FIGURE 3–3—ORO TACTICS DIVISION: 1958



Source: Philip H. Lowry, "Tactics Division," in ORO, "A Discussion of the ORO Work Program," ORO–SP–71, ORO, Chevy Chase, Md., October 1958, p. 19.

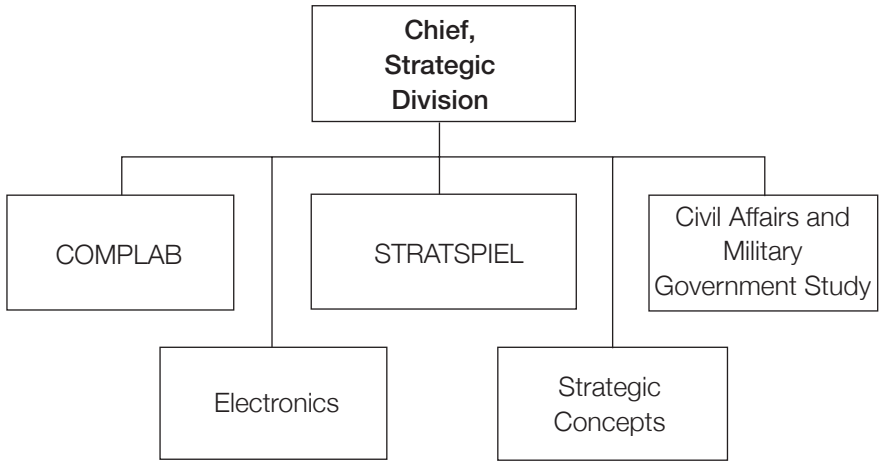
tary value in terms of dollars, lives, critical resources, or other criteria and assisted in comparative studies throughout the division. By 1958, the Cost Group had been dropped and the TACSPIEL Group had been renamed the Tactical Gaming Group. A new Aviation Group had also been added as had two short-term groups: a Chemical Group and a Nuclear Requirements Group.[40] The Tactics Division then had a chief, 35 analysts, 9 research aides, and 2 active-duty military advisors, organized as shown in Figure 3–3.

The mission of the Strategic Division was: "(1) to conduct operations research on strategic problems of interest to the Army; (2) to carry out research in the methodology of operations analysis in general, with special emphasis on methodology at the strategic level; (3) to provide analytical and computational support to the entire ORO staff."[41] To conduct its mission, the Strategic Division was initially organized in five groups. The STRATSPIEL Group worked on the development of strategic wargame techniques. The OPSEARCH Group worked on basic OR methods and techniques, and supported other ORO studies by applying OR methods and techniques. The COMPLAB Group operated the computer laboratory that provided computer and gaming facilities for all ORO divisions. The Electronics Group operated an electronics laboratory supporting all the divisions by constructing data-gathering devices, computer accessories, and control and display devices, including those for field experiments. The COMPASS Group continued an old ORO effort: the study of psychological warfare missions that would fall to the Army in time of war. By 1958, the OPSEARCH Group had achieved independent status and the COMPASS Group had been replaced by a Civil Affairs and Military Government Study Group. At that time, the Strategic Division had a chief, twenty analysts, and seven research aides, organized as shown in Figure 3–4.

The initial mission of the Logistics Division was "to seek solutions to problems of Army interest concerning the systems by which military forces are logistically operated."[42] The division was concerned primarily with the strategic aspects of logistics, and was subdivided initially into four groups. The Mobilization Group studied ways of improving the mobilization of personnel, supplies, and equipment. The Lines of Communications Group investigated the transportability of Army materiel and the capabilities and vulnerabilities of Army transportation systems, maintenance, and the improvement of Army participation in civil affairs and military government.[43] The Interdiction Group studied the use of unconventional warfare to deny goods and transportation facilities to the enemy, and the vulnerability of road and rail nets in western Europe to interdiction by a balanced weapons system. The LOGSPIEL Group developed analytical methods and gaming techniques for testing logistics systems and introducing logistical considerations into ORO tactical and strategic wargames. The Logistics Division also continued work on a special study, POWER, concerned with the use of atomic energy. By 1958, the Logistics Division had been renamed the Operations Division; had a chief, twenty-five analysts, three research aides, a full-time active-duty military advisor, and a full-time Transportation Corps liaison officer; and was organized with five new groups, as shown in Figure 3–5.

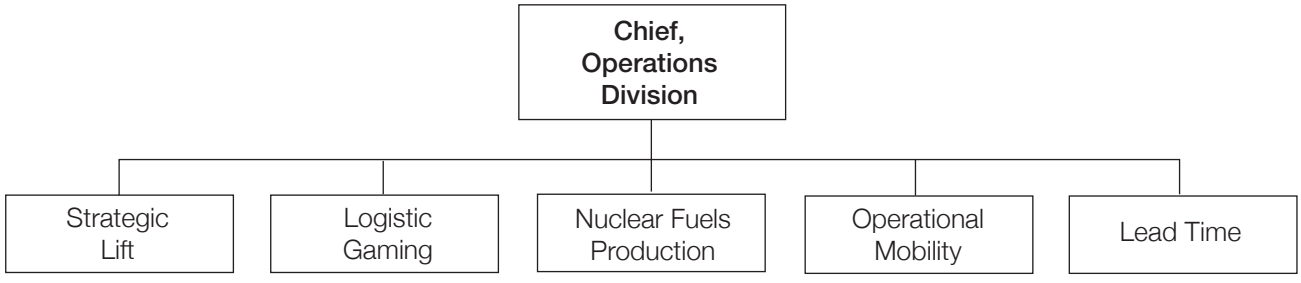
The mission of the Intelligence Division was "to study problems associated with battlefield intelligence as related to both conventional and atomic weapons, with the aim of improving intelligence devices, techniques, and procedures."[44] To conduct its work, the division was subdivided into four groups. The Acquisition Group studied the problem of obtaining accurate, timely information on enemy and friendly dispositions, movements, and capabilities. The Communications Group investigated problems related to the flow of in-

FIGURE 3–4—ORO Strategic Division: 1958



Source: Nicholas M. Smith, "Strategic Division," in ORO, "A Discussion of the ORO Work Program," ORO–SP–71, ORO, Chevy Chase, Md., October 1958, p. 71.

FIGURE 3–5—ORO OPERATIONS DIVISION: 1958



Source: Hugh M. Cole, "Operations Division," in ORO, "A Discussion of the ORO Work Program," ORO–SP–71, ORO, Chevy Chase, Md., October 1958, p. 41.

formation. The Decision Procedures Group was concerned with the information needed by each echelon to make correct decisions and how that information should be transmitted and presented. The TELLSPIEL Group applied gaming techniques to the solution of intelligence problems.

The mission of the Home Defense Division was "to obtain the best possible solutions to the problem of defending the North American continent against air attack."[45] The division studied what we could buy in the way of defense, when, and at what cost, and included consideration of Air Force weapons systems, civil defense procedures, and the psychological effects of air attack. Initially, the division was organized with four groups. The Weapons Group analyzed the effectiveness of various defensive weapons systems, including early warning systems and interceptors as well as ground weapons. The Costs Group determined the costs of various defensive systems at various levels and times. The Targets Group studied the possible effects of damage on war potential; the vulnerability of various types of targets by type of attack and munitions used; and the optimum distribution of Army active defenses, taking into account the effectiveness of other agencies such as the Air Force, Civil Defense Administration, and the Office of Defense Mobilization, among others. The ZIGSPIEL Group evaluated the enemy threat and possible enemy tactics and developed wargaming techniques to test the effectiveness of various proposed defense systems. By 1958, the Air Defense Division had replaced the Home Defense Division, and it included a chief, five analysts, and one research aide.[46]

The Field Division was created as part of the April 1954 reorganization to "coordinate the planning, administration, and conduct of operations research in the field"—that is, to oversee the operations of the three ORO field offices then in existence.[47] The most senior of the three offices was ORO-USAFFE, established in June 1951 at Headquarters, United States Army Forces Far East in Tokyo, to oversee ORO operations in Japan and Korea during the Korean War. Fol-

lowing that war, the Tokyo field office was concerned mainly with assisting HQ USAFFE with simulations and wargaming and with completing two major projects: a study of the tactical employment of atomic weapons in the Far East and a study of the Korean War experience to determine the need for revisions in Army logistics doctrine.[48]

A similar office, ORO-USAREUR, was established at Headquarters, United States Army Europe in Heidelberg, Germany, in 1952. Its purpose was to perform similar functions with respect to simulations and wargaming and to conduct a critical analysis of the Army Group weapons system for defense of a main line of resistance.[49] Problems arose with the conduct of some of the ORO civilian employees initially assigned to the USAREUR office, and the military historian Hugh M. Cole was brought in to run the office. Cole brought with him his own team of distinguished historians, including Forrest C. Pogue (the biographer of George C. Marshall), Roland Ruppenthal (the author of volumes on logistics in the official Army history of World War II), and Marcel Vigneras, a former French Army officer who had seen service in World War I and with the *maquis* in the French Resistance movement during World War II.[50] Another very distinguished military historian, Charles B. Macdonald, joined the team later. Although the others eventually left to pursue other interests, Cole remained for some time as the senior manager of ORO, and later served as president for its successor, the Research Analysis Corporation.

As of 1955, ORO-USAFFE and ORO-USAREUR each employed four to six analysts to assist their respective G-3 sections with the preparation of war plans and exercises and to collect data and provide advice.[51] Their work was coordinated with the overall ORO work program but was designed to meet the needs of the theater commander who controlled them. The main ORO office in Washington, D.C., retained responsibility for selecting and rotating ORO analysts to the field offices.

The third field office, ORO-OCAFF, was established in late 1952 at the Office of the Chief of Army Field Forces, at Fort Monroe, Virginia. It's primary mission was to assist that headquarters with the design of field tests and exercises and to conduct simulations and wargames.[52] Among the projects undertaken by ORO-OCAFF were the design of field tests to determine the effect of atomic weapons on tactics and, in collaboration with the Tactics Division, the development and application of wargaming methods to specific tactical problems.

In addition to overseeing the ORO field offices in Tokyo, Heidelberg, and Fort Monroe, the Field Division had a Maneuver and Exercise Group and a THEATERSPIEL Group. The Maneuver and Exercise Group planned, coordinated, and supervised ORO participation in maneuvers and exercises. The THEATERSPIEL Group developed methods and techniques for the use of wargames as a means of analyzing theater-scale operations.

The general organization of ORO changed over time in response to the changes in the scope and number of tasks assigned by the Army. By 1960, the Home Defense and Logistics divisions had been replaced by the Air Defense and Operations divisions, respectively; BRAND had been supplanted by the Management Systems Division; the Field Division had been eliminated; and a Special Studies Division had been added. The resulting organization of ORO is shown in Figure 3–6.

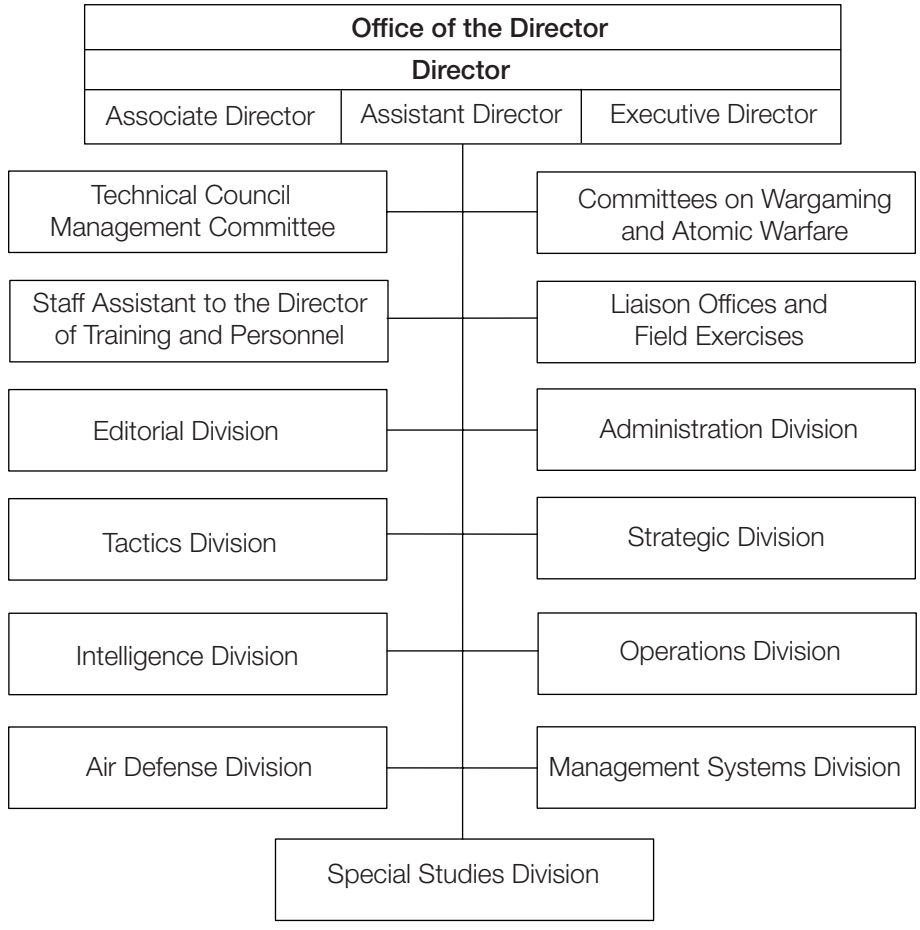
ORO's Relationship with The Johns Hopkins University

Until 1 July 1951, ORO was administered by The Johns Hopkins University through its Institute for Cooperative Research (ICR). On 1 July 1951, action by the JHU Board of Trustees made ORO a separate division of the university on the normal pattern.[53] The plan for establishing ORO as a separate JHU division included provisions for two university groups to oversee ORO activities, as shown in Figure 3–7.[54]

On 24 October 1951, the JHU president, Dr. Detlev Bronk, formed a JHU advisory board for ORO "to discuss ORO policies in their relationship to the University."[55] The advisory board was composed of the president and provost of JHU; three JHU faculty members; the director, associate director, assistant director, and executive director of ORO; three ORO staff members; and the chief of ORO's Administrative Division who acted as secretary of the board. On 3 December 1951, the executive committee of the JHU Board of Trustees appointed a trustees committee for ORO to meet with ORO management at regular intervals to consider germane policy matters.[56] The trustees committee included Robert W. Williams (chairman), Thomas S. Nichols, and Stuart S. Janney; the president of the JHU Board of Trustees, Carlyle Barton, was an ex-officio member. The committee advised the JHU Board of Trustees as to whether ORO work was up to university standards.[57]

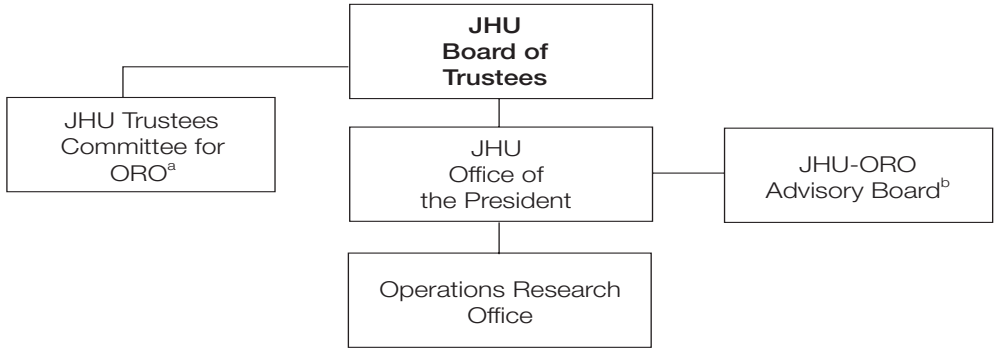
There is little evidence that either the JHU–ORO Advisory Board or the JHU Trustees Committee for ORO became involved in routine administrative, personnel, and fiscal matters. Substantive issues, such as the quality and direction of the ORO work program and the relationship of ORO with the Army, were no doubt discussed in both bodies and their advice was provided to the president of JHU who dealt directly with Ellis Johnson and Army officials. For example, at its first meeting, held at the ORO offices in Chevy Chase, Maryland, on 12 June 1952, the advisory board discussed the establishment of a seminar on operations research to be held on the JHU campus, and recommended that ORO obtain an unclassified contract for OR work and then conduct

Figure 3–6—ORO Organization: 1960



Source: William L. Whitson, "The Growth of the Operations Research Office in the U.S. Army," *Operations Research* 8, 6 (1960): 818, Figure 7.

Figure 3–7—ORO Relationship to JHU: After 1 July 1951



a. Appointed by the president of the JHU Board of Trustees.

b. Appointed by the president of JHU.

Source: William L. Whitson, "The Growth of the Operations Research Office in the U.S. Army," Operations Research 8, 6 (1960): 811, Figure 2. See also the organization chart in JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR/ORO, Jul 52–Dec 53.

that work on the JHU campus, partly to train OR candidates and partly to develop OR as a science.[58] Other issues taken up by the two groups were the acquisition of property for the building of ORO offices, pay and benefits for ORO employees, and the appointment of senior ORO managers.

Army Oversight of ORO

Throughout ORO's existence, the chief of research and development (CRD) on the Army Staff was responsible for overseeing its research program.[59] The Office of the Chief of Research and Development (OCRD) itself underwent several reorganizations between 1950 and 1965, notably the transfer of responsibility for R&D from the Office of the Assistant Chief of Staff (ACS) G-4, Logistics, to the Office of the ACS G-3, Operations, on 22 January 1952, and from the ACS G-3 to the CRD on 1 July 1956. The successive offices within the Army Staff responsible for oversight of ORO are shown in Table 3–1.

The CRD exercised his responsibilities for oversight of the ORO research program through three agents: the Department of the Army Advisory Committee for the Operations Research Office, the Department of the Army Project Advisory Groups for the Operations Research Office, and the active-duty military advisors assigned to ORO. *AR 15–480* prescribed the composition and functions of the Department of the Army Advisory Committee for the Operations Research Office, which was chaired by the CRD and included as members representatives of the ACS G-1, ACS G-2, ACS G-3, deputy chief of staff for logistics, the comptroller of the Army, and the chief of Army field forces (later the commanding general, United States Continental Army Command [CONARC]).[60] The committee met periodically to review current and proposed ORO work programs to ensure they met Army needs, to establish priorities for specific studies and projects as necessary, and to review the ORO budget estimates.

A Department of the Army project advisory group (PAG) was established for each ORO project or research area.[61] Every PAG included representatives from each of the staff agencies that had an interest in a particular study, and they met periodically—at least quarterly—to review the current and future ORO work, to advise ORO, and to inform the CRD on the progress of the project in question.

As prescribed by *AR 15–480*, the CRD assigned one or more active-duty military officers to ORO for the purposes of advising the ORO director on the tactical applications of ORO research, interpreting Army policy and procedures, and making pertinent recommendations to the ORO director and the CRD. As of the end of 1960, nine Army officers were assigned to ORO.[62] The senior of the assigned officers was designated as the senior military advisor. All assigned officers were trained in OR methods and participated actively in the ORO research program as mutually agreed by the Director, ORO, and the senior military advisor. The officers who served as the senior military advisor to ORO from 1948 to 1960 are listed in Table 3–2.

Although the principal Army contact with ORO was through OCRD, ORO relied on a number of other government agencies for various services. For example, ORO contract between the Department of the Army and JHU was administered by a contracting officer in the Office of the Quartermaster General at Cameron Station, Virginia; the Navy provided auditing services; Walter Reed Army Medical Center supplied motor transport and quarters for Army enlisted personnel assigned to ORO; and the Military District of Washington provided some security services.[63]

Personnel

In response to a constantly increasing workload, the ORO professional technical staff grew steadily from 1948 to the office's demise in August 1961. As the nature of the ORO work program expanded into areas that were not "hard science"—political science, economics, and psychology—the academic disciplines represented by the ORO staff increased in scope as well. Many ORO analysts continued to be drawn from the traditional hard sciences, but "life scientists," "social scientists," retired military officers, and people trained in other disciplines played an increasingly important role.[64] Throughout the period, the selection, retention, and training of technical personnel remained one of the most difficult problems facing the ORO leadership. Nevertheless, many ORO analysts and consultants were distinguished men and women in their own right and brought special skills and abilities to the operations research program.

In general, personnel strength grew at an average rate of fewer than two analysts per month between 1948 and 1954.[65] In 1951, ORO had roughly sixty professional staff members and an equal number of administrative employees.[66] By 31 May 1952, the number of professional staff members had increased to approximately one hundred.[67] The number again increased slightly to 111 in 1953.[68] The following year the total reached 158.[69] The number of ORO technical personnel, both analysts and research aides, as of 31 December of each year from 1955 to 1960 is shown in Table 3–3. By 1963, two years after RAC had taken over, the number of professional staff members had reached 169—and a significant number were women.[70]

As of 1956, roughly 70 percent of the ORO technical staff had served in uniform, and a few others had served as civilian OR analysts with Army units in the field.[71] Ellis Johnson was convinced of the need for interaction between mature civilian OR analysts and the professional soldiers

Table 3–1—Army Staff Responsibility for ORO Research Programs: July 1948–August 1961

Office	*Dates*
Deputy Director for R&D, Logistics Division	1 July 1948–1 July 1950
Deputy Assistant Chief of Staff G-4, for R&D	1 July 1950–22 January 1952
Assistant Chief of Staff G-3, Operations	22 January 1952–23 December 1954
Chief of R&D, Office of the Deputy Chief of Staff for Plans and Research	23 December 1954–1 November 1955
Chief of R&D, Office of the Chief of Staff	1 November 1955–29 December 1958
Chief of R&D	29 December 1958–31 August 1961

Source: Lester D. Flory, "Analysis of the ORO Research Program with Respect to Timeliness," ORO–TP–16, ORO, Bethesda, Md., November 1960, p. 14, Table 4.

Table 3–2—Department of the Army ORO Senior Military Advisors: 1948–61

Name	*Dates*
Lt. Col. William C. Farmer	1 July 1948–9 May 1949
Lt. Col. Raymond Renola	9 May 1949–15 August 1949
Lt. Col. Vincent M. Elmore, Jr.	15 August 1949–21 November 1950
Lt. Col. William P. Brooks	21 November 1950–21 July 1952
Col. M. W. Schewe	21 July 1952–1 June 1954
Col. Selwyn D. Smith	1 June 1954–1 July 1956
Col. Roland P. Carlson	1 July 1956–15 April 1958
Lt. Col. J. M. Gaustad (acting)	15 April 1958–9 June 1958
Col. John V. Roddy	9 June 1958–1 February 1960
Lt. Col. J. M. Gaustad	1 February 1960–29 July 1960
Lt. Col. Oran K. Henderson	29 July 1960–15 August 1960
Col. Charles B. Hazeltine	15 August 1960–31 August 1961

Source: Lester D. Flory, "Analysis of the ORO Research Program with Respect to Timeliness," ORO–TP–16, ORO, Bethesda, Md., November 1960, p. 14, Table 5.

Table 3–3—ORO Analysts and Research Aides: 1955–60

Year	*Analysts*	*Research Aides*	*Total*
1955	133	11	144
1956	115	18	133
1957	114	30	144
1958	119	31	150
1959	118	19	137
1960	143	20	163

Source: Lester D. Flory, "Analysis of the ORO Research Program with Respect to Timeliness," ORO–TP–16, ORO, Bethesda, Md., November 1960, pp. 11 (Table 2), 23.

whom they served.[72] Accordingly, he hired a number of retired military officers as analysts and consultants and encouraged the Army to assign active-duty officers to the ORO staff.[73] As part of the Army's oversight of ORO, the chief of research and development was authorized to assign three active Army officers, normally three combat arms officers, to ORO for full-time duty.[74] That number expanded to nine by 1960, and both the Signal Corps and the Transportation Corps maintained a full-time liaison officer at the operations research offices.[75] During and following the Korean War, eighteen Army enlisted men, most with advanced degrees in mathematics or the sciences, were also assigned to ORO and were integrated into the work program as analysts.[76]

Recruiting and training adequate numbers of suitable OR analysts was a continuing problem. As the demand for both military and civilian analysts increased during the 1950s, the number of suitable candidates for ORO employment declined, and it became more and more difficult to recruit experienced analysts.[77] At the same time, OR itself grew more complex and required greater training. The average annual turnover in the ORO technical staff was approximately 20 percent, and it took at least eighteen months for a new analyst to become productive and as much as four years before he or she could be rated "superior."[78] By 1957, principally because of rising costs and stringent security requirements, ORO was struggling to overcome the loss of trained personnel and the difficulty of recruiting competent replacements necessitated by the ever-growing ORO research program.[79] For the most part, ORO had to select promising candidates from various disciplines and conduct its own on-the-job training with some assistance from the academic community.[80]

There has long been intense debate about the qualities required in a good operations research analyst. In January 1959, a questionnaire was sent to all ORO analysts asking them to rate the desirable characteristics of ORO candidates. The results were published in ORO-SP-124, *Fields of Knowledge and Operations Research*, along with statements about the contributions to OR that could be made by people in the various disciplines.[81] The following list of eight qualifications that a prospective ORO analyst should have was gleaned from the questionnaires. He or she should:

1. be fairly mature, with five or more years of professional experience in his or her field;
2. have a genuine interest in OR;
3. be able to get to the heart of a problem;
4. have better-than-average mathematics skill and the ability to show results in quantitative form;
5. be able to get along well with the client's representatives;
6. be resourceful and able to get along with a minimum of support;
7. be willing to go anywhere, at any time, and do anything ethical; and
8. have a strong sense of loyalty to country, employer, and client.[82]

In general, ORO tried to form a "true mixed team" of both physical and social scientists, and, in 1960, the technical staff of more than 125 analysts represented some twenty-five different disciplines and professions.[83] In general, the analysts who prospered at ORO were trained as chemists, physicists, biologists, philosophers, mathematicians, engineers, historians, economists, political scientists, and psychologists, in that order.[84] But as Ellis Johnson himself stated:

> we have found no correlation between competence in operational research and previous research experience in the traditional sciences. The only correlation is with years of experience at ORO and the amount of education. Possession of a doctorate doubles the probability of being in the first quartile at ORO.[85]

As the scope of OR applications increased and the proportion of the ORO work program devoted to pure weapons analysis declined, the traditional reliance on candidates from the hard sciences was diluted by the need to find analysts competent in such non-scientific fields as history, economics, political science, psychology, sociology, and military science. As one leading ORO analyst has noted, "there is reason to believe that the lawyer, social scientist or historian is better equipped professionally to evaluate evidence which is derived from the mind and experience of the human species."[86] Nevertheless, the proportion of the various disciplines represented by the technical staff remained relatively stable, as shown in Table 3–4.

Many ORO employees and consultants had distinguished careers and an amazingly wide range of interests before, during, and after their service with ORO in the 1950s and early 1960s.[87] As already noted, Ellis Johnson had served with distinction in the Navy OR program during World War II and had designed the strategic mining campaign against Japan. Dr. Richard Parmenter was the coordinator of research at Cornell University when he was appointed associate director of ORO in April 1951. He had led the Austin Sub-Arctic Expedition to Baffin Bay in 1927 and had served with distinction as a Navy antisubmarine warfare officer in World War II.[88] George S. Pettee, who had earned a doctorate in political science from Harvard University in 1937, enjoyed a distinguished academic and government service career and published several books before joining the ORO staff in 1949 and becoming assistant director in 1954.[89] The executive director, Brig. Gen. Lester D. Flory, United States Army (ret.), was a 1919 graduate of the United States Military Academy and earned a 1930 master of science degree

Table 3–4—Distribution of ORO/RAC Personnel, by Discipline: 1953 and 1963

Discipline	*1953 Percentage*	*1963 Percentage*
Mathematics, engineering, and sciences	56.8	59.4
Social sciences, history, business, literature, and law	43.2	40.6

Source: Based on Lynn H. Rumbaugh, "A Look at US Army Operations Research—Past and Present," RAC–TP–102, RAC, McLean, Va., April 1964, p. 8, Table 1.

in electrical engineering from the Massachusetts Institute of Technology (MIT) before serving with distinction in World War II and as the deputy commissioner and chief of section, U.S. Element, Allied Commission in Austria, from 1945 to 1946.[90] Brig. Gen. Flory became executive director of ORO in August 1949.

Dr. Wilbur B. Payne, a 1955 Louisiana State University Ph.D. in physics, joined the office in 1955 and later became the first deputy under secretary of the Army for operations research before moving on to head the U.S. Army Training and Doctrine Command (TRADOC) Systems Analysis Agency at White Sands Missile Range, New Mexico. He subsequently established the TRADOC Operations Research Organization (now the TRADOC Analysis Center).[91] The annual prize awarded by the secretary of the Army for excellence in Army OR is "The Wilbur B. Payne Memorial Award for Excellence in Analysis" in honor of his many contributions to Army operations research.

Gen. Thomas Handy, USA (ret.), a 1914 graduate of the Virginia Military Institute, was the righthand man to Army chief of staff Gen. George C. Marshall, and served as the chief of the Operations Division of the Army General Staff during most of World War II. Handy retired from active duty in 1954 and became an ORO consultant in 1955.[92] He joined the ORO staff full-time in January 1959.

Other notable "OROns" include Dr. Hugh M. Cole, the author of the official U.S. Army histories of the World War II campaigns in Lorraine and the Ardennes, who joined ORO in 1952 and became its resident expert in logistics; Dr. Dorothy Kneeland Clark, a 1937 Radcliffe Ph.D., who did groundbreaking analysis on the effects of casualties on combat unit performance; James W. Johnson, a 1948 Harvard bachelor of arts in economics, who was responsible for analysis leading to the design of the pentomic and pentagonal division structure in the mid-1950s; and Richard E. Zimmerman, a 1950 Purdue University master of science graduate, who wrote the seminal paper on Monte Carlo simulation and who is considered the father of Army combat modeling.[93] One ORO luminary, the astronomer Thornton L. Page, became embroiled in the controversy over unidentified flying objects (UFOs) after serving briefly on a Central Intelligence Agency–sponsored committee of scientists assembled in Washington, D.C., on 14–18 January 1953 to study the available evidence on UFOs.[94] Among the many distinguished ORO consultants was Dr. Henry A. Kissinger, who served briefly in 1951, before going on to fame as a presidential advisor, U.S. secretary of state, and Nobel Prize laureate.[95]

Physical Facilities

As ORO tasks and staff size increased, new quarters were needed. In mid-June 1951, ORO moved from Fort McNair to a new home at 7100 Connecticut Ave. in Chevy Chase, Maryland.[96] The National 4-H Club owned the site (a former junior college for young women) and it was persuaded to lease the facility to ORO. The campus had three buildings. The director's office, administrative offices, the library, and many of the analysts were located in the former classroom building. One of the major study project groups was accommodated in the former president's house, and the so-called science building was used by analysts.[97] More space was required, and ORO leased additional office space at Chevy Chase Circle and near Wisconsin Avenue and East-West Highway in Bethesda, Maryland. When ORO acquired its first computer, it was housed in a former plumbing supply warehouse, a Quonset hut–like building near the railroad tracks in Bethesda that was known as the Pearl Street building. The building had no central air conditioning, and the heat generated by the vacuum tubes in the primitive Sperry-Rand 1103A computer was so great that the computer had to be shut down frequently during the summer months. Eventually, in June 1957, the National 4-H Club reclaimed its facilities, and ORO leased a four-story office building on Arlington Road in Bethesda, where it remained until it went out of business in August 1961.

From 1954 until August 1961, Ellis Johnson and other ORO leaders struggled in vain to patch together a deal between the Army and The Johns Hopkins University for the construction of a purpose-built facility for ORO.[98] The university purchased land for the proposed ORO building near

Shady Grove, Maryland, on the east side of what is now Interstate 270.[99] However, the Army and the university were never able to come to an agreement on cost sharing for the proposed facility, and it was never constructed. For a short time in the summers of 1960 and 1961, the ORO staff used the land for vegetable gardening.[100]

Budget

During the Korean War period, the ORO budget quadrupled—from about $1 million in FY 1949 to just more than $4 million in FY 1954—and remained relatively stable thereafter.[101] In May 1953, ORO budgets for FY 1955 and FY 1956 were projected at $4.4 and $4.0 million, respectively.[102] The actual annual appropriation for ORO as well as the amounts paid to consultants and subcontractors from FY 1956 to FY 1960 are shown in Table 3–5. During the period covered in Table 3–5, the cost per project undertaken declined steadily from $106,000 per study in FY 1956 to just $68,000 per study in FY 1960.[103] By 1960 the Department of the Army chief of research and development was spending about $11 million per year on OR contracts with some twenty-five to thirty companies; about half that amount was paid to ORO.[104]

ORO Work Program, 1950–61

Despite generous fiscal allocations, ORO took three or four years from its creation to reach full production, and it took even longer to develop a good feel for what kind of studies were useful to the Army and to develop adequate quality control measures.[105] During the entire course of its existence, ORO produced 632 publications based on 1,666 studies (or study phases), which addressed 98 problems of interest to the Army, including the defense of the continental United States against strategic nuclear attack, the role of nuclear weapons in ground warfare, the racial integration of the armed forces, the concept of cost effectiveness in evaluating weapons systems, the application of computers to OR, the use of wargaming, psychological and guerrilla warfare, technological forecasting, the concept of air mobility, and the performance and reliability of weapons and supporting equipment.[106]

Until 1951, the projects undertaken by ORO were limited in number and unbalanced in scope.[107] Each project had to be approved by the Army in advance, and changes in the work program were cumbersome. As a result, there were a number of problems related to policy and finance as well as difficulties in ensuring that analysts with the requisite skills were on hand to begin newly assigned projects promptly. On 22 May 1950, Ellis Johnson proposed to the Army deputy assistant chief of staff, G-4, for research and development, Maj. Gen. Ward H. Maris, what came to be called the balanced program, a slate of projects or research areas covering all the fields in which the Army was likely to require OR support. Johnson argued that the balanced program would permit the recruitment of a balanced staff, realistic budgeting and cost accounting, and flexibility in the research effort. Detailing planning and direction of research would be the responsibility of ORO, and each project, as well as the overall work program, would be reviewed annually to ascertain the suitability of its scope, progress, and costs and to ensure a proper balance among the various projects in accordance with the Army's needs. It was also intended that the list of projects in the balanced program would change as Army needs changed.

The proposed balanced program was approved by the Army in principle in 1950. The original list of projects in the balanced program was based on 5 projects then authorized, 3 projects that were pending, and 12 new projects proposed by ORO—a total of 20 projects. In February 1951, the Army approved eight of the twelve proposed projects. Two additional projects added later brought the total number of projects in the balanced program to seventeen (one of the original eight projects having been completed).[108] The seventeen subject areas/projects in the balanced program from 1951 through 1954 were these[109]:

- air defense (ANALAA)
- armored warfare (ARMOR)
- atomic weapons (ATTACK)
- balance of weapons systems (BALANCE)
- cost effectiveness (CAPWAR)
- chemical, biological, and radiobiological warfare (COBRA)
- guided missiles (DONKEY)
- infantry weapons (DOUGHBOY)
- military government (LEGATE)
- OR methodology (OPSEARCH)
- guerrilla warfare (PARABEL)
- psychological warfare (POWOW)
- artillery (REDLEG)
- human factors (SHOP)
- intelligence (TACIT)
- air support of ground operations (TEAR)
- logistics and mobility (TREMABASE)

Each project was divided into a number of separate tasks, and priorities were set for each task based on a four-level scheme. Group I tasks addressed operations considered *immediately* critical to the successful prosecution of a major war. Group II tasks addressed operations considered critical to the successful prosecution of a major war. Group III tasks addressed operations considered of lesser importance than those in Groups I or II. Group IV tasks addressed matters that could be dealt with at leisure.

Table 3–5—ORO Appropriations and Expenditures: FY 1956–FY 1960

Fiscal Year	*ORO Appropriation ($)*	*Paid to Consultants ($)*	*Paid to Subcontractors ($)*
1956	4,470,000	58,652	513,004
1957	4,800,000	94,689	187,595
1958	5,226,500	92,030	383,373
1959	4,994,344	42,865	217,873
1960[a]	4,662,054	6,534	99,627

a. Figures are through 30 June 1960.

Source: Lester D. Flory, "Analysis of the ORO Research Program with Respect to Timeliness," ORO–TP–16, ORO, Bethesda, Md., November 1960, p. 11, Table 2.

The new demands on ORO caused by the Korean War sidetracked the balanced program aimed at long-term Army problems, but progress continued on all fronts.[110] Over time, the shift away from weapons-evaluation studies toward more-comprehensive studies of tactics and strategy made the balanced program obsolete, and in April 1954 ORO was reorganized into five major research divisions (Tactics, Strategic, Logistics, Intelligence, and Home Defense) and the special BRAND section described previously.[111] In effect, the balanced program was abandoned with the approval of the FY55 ORO work program, but the principles on which it was based (standing areas of interest; ORO responsibility for details of project planning; and annual Army reviews of scope, costs, and progress) were retained.[112] The ensuing number of ORO research projects and their topical distribution is shown in Table 3–6.

In fact, the topic areas addressed by the ORO research program changed very little over the thirteen years of its existence. There was a gradual shift from pure weapons analysis studies toward more-comprehensive tactical and strategic studies, but generally the research program exhibited stability of focus, as shown in Table 3–7.[113] As Lynn Rumbaugh, one of the ORO analysts, has pointed out:

> The principal trends were: (a) a gradual decrease from 47 to 39 percent in publications on combat operations; (b) a corresponding increase from 21 to 29 percent in publications on logistics and costs; and (c) a modest increase from 2 to 7 percent in publications on methodology. The decrease in publications on troop training and psychological warfare is due, of course, to the entry of HUMRRO [the Human Resources Research Office] and SORO [the Special Operations Research Office] into these fields.[114]

The determination of what projects to pursue was made on the basis of a number of inputs. The ORO work program was reviewed annually at the time the ORO contract was renewed.[115] Ongoing projects were reviewed, new proposals were considered, and work effort was reallocated as necessary. Before the annual review, both the Army and ORO worked up lists of proposed studies that were then reviewed by a committee comprising both ORO and Army representatives. Those projects agreed on by both sides, up to approximately 60 percent of the available funding, became the official ORO work program. About 10 percent of the available funding was reserved to support projects wanted by the Army for which ORO saw little value, and another 10 percent was reserved to support projects that ORO wanted but for which the Army saw no need.[116] Another 10–20 percent of the ORO effort was reserved for unprogrammed studies, and the remainder, if any, was set aside for studies aimed at furthering OR techniques.[117]

Beginning in 1952, ORO instituted a series of so-called search studies that went by the name "PISGAH" conferences.[118] From 1952 ORO hosted lengthy meetings (as long as two months) of selected military and civilian experts at some remote location (usually in Maine) to discuss current trends and ways in which ORO could meet the Army's emerging needs. The results of the PISGAH conferences were fed into the process for developing the annual ORO work program. The first PISGAH conference, in 1952, led to the important decision to make a concerted effort to use wargaming as a method for solving major problems.[119]

Most of the 1,666 studies and 632 publications completed by ORO between September 1948 and August 1961 were of only average quality and had minimal impact on Army equipment, organization, or doctrine.[120] However, a few studies were of substantial quality, broke new ground, and had a significant effect. As Secretary of the Army Frank Pace, Jr., noted in his semiannual report for the period January–July 1952, "The Operations Research Office studies have provided the Army with candid self-criticism which has led to corrective action and improvement in complex areas of Army operations."[121] Among the most prominent of the "successful" ORO studies were those on nuclear warfare, desegregation, psychological operations, cost effectiveness, marksmanship training, and the selection of the M16 rifle as the standard Army rifle.

Table 3–6—Distribution of ORO Projects, by Division or Topic Area: FY 1956–FY 1960

ORO Division/Project	*FY 1956*	*FY 1957*	*FY 1958*	*FY 1959*	*FY 1960*
Tactics	11	7	9	8	7
Operations	4	7	7	6	8
Strategic	3	5	5	4	3
Intelligence	8	6	6	4	4
Air defense	1	3	4	6	5
Management systems	2	2	5	5	5
Basic research	0	0	0	1	6
TOTAL	28	30	36	34	38

Note: One additional project, identified only as SANDY but not otherwise described, was undertaken in FY 1959 and FY 1960. The figures do not include projects undertaken by ORO field offices or special studies.

Source: Lester D. Flory, "Analysis of the ORO Research Program with Respect to Timeliness," ORO–TP–16, ORO, Bethesda, Md., November 1960, p. 22, Table A1.

Table 3–7—Distribution of ORO Studies, by Topic: July 1948–June 1961

Study Topic	*July 1948–June 1951*	*July 1951–June 1954*	*July 1954–June 1958*	*July 1958–June 1961*	*Weighted Thirteen-Year Average*
Combat operations: weapons and equipment; intelligence; organization, tactics, and doctrine	47	41	45	39	43
Logistics and costs	21	17	24	29	23
Background studies: social, cultural, and civil affairs environment; international strategy, economics, and politics	12	11	6	10	9
General studies: personnel selection, training, and performance; psychological warfare; special warfare and counterinsurgency	14	21	10	3	12
Special studies: R&D management; OR methodology; miscellaneous	6	10	15	19	13

Source: Lynn H. Rumbaugh, "A Look at US Army Operations Research—Past and Present," RAC–TP–102, RAC, McLean, Va., April 1964, p. 9, Table 2.

Beginning in 1949, ORO conducted a number of groundbreaking in-depth studies of nuclear warfare. The major ORO study on the defense of the continental United States against nuclear attack was published in August 1957 as ORO-R-17, *Defense of the US Against Attack by Aircraft and Missiles*.[122] The 718-page study addressed all aspects of such an attack and the possible defensive measures to be taken to prevent or attenuate it. The study evoked a formal critique by the RAND Corporation, against which ORO's George S. Pettee made a spirited defense.[123] Having been vetted in open debate, ORO-R-17 proved a valuable aid to U.S. leaders in working through some of the very difficult problems and trade-offs involved in protecting the nation against Soviet nuclear attack. Beginning in 1949 and continuing through the Korean War and later in Germany, ORO completed a number of studies on the tactical use of nuclear weapons.[124] These studies delineated for the Army an important role in nuclear warfare and contributed significantly to the develop-

ment of the Army's pentomic organization and doctrine for nuclear warfare operations.[125] ORO also did the first study on the use of atomic warheads for air defense missiles, as well as several studies on nuclear powerplants.[126]

In every major conflict since the Civil War, the United States Army has turned to black soldiers to supplement the available numbers of white soldiers. In July 1948, President Harry Truman issued two executive orders prohibiting racial discrimination in the executive branch and the armed forces, and the Army Reorganization Act of 1950 subsequently removed the requirement for segregated units in the Army.[127] The retreat of UN forces from the Yalu River in late 1950 was followed by a scarcity of white replacements for U.S. units, and the Army began to assign black soldiers to previously all-white units. Based on the request of Army chief of staff Gen. J. Lawton Collins in March 1951, ORO was tasked to study the question of the utilization of Negro manpower in the Army.[128] The study was assigned to a team of five ORO analysts led by Dr. Alfred H. Hausrath and aided by a number of other ORO personnel, consultants, and subcontractors who used demographic analysis, opinion and attitude surveys, content analysis, critical incidents technique, statistical analysis, and community surveys to gather and analyze data.[129] ORO submitted interim reports on 1 July and 1 November 1951, and the full, final report was published in three volumes in April 1955, titled *Utilization of Negro Manpower in the Army*.[130] The study, focused on combat units in Korea, concluded that

> first, integrated units allow more effective use of the manpower available through a more even distribution of aptitudes than is possible in segregated units; second, that performance of integrated units is satisfactory; and third, that the resistance to integration is greatly reduced as experience is gained.[131]

The ORO study on desegregation was widely circulated and, by providing objective arguments in favor of integration, had a significant effect on the decision to integrate the armed forces after 1952 and on the way that integration was carried out—a process that had important positive effects on the efficiency of Army units and racial relations in the United States.

From 1949 until 1957, when responsibility for studies on psychological warfare was transferred to the newly established Special Operations Research Office, ORO played an important role in the development of psychological warfare in the U.S. Army. Between 1949 and 1954 alone, ORO published sixty-three technical memoranda (5,613 pages) on the subject of psychological warfare.[132] In 1957 the Army's chief of psychological warfare made an audit of ORO studies on the topic and found that 55 percent of the studies had been accepted as doctrine and for study, 10 percent had been accepted in principle, 4 percent were deferred for additional study, 2 percent were rejected, and the remainder (approximately 29 percent) were not considered.[133]

ORO studies addressed psychological warfare at both strategic and tactical levels, and the effect of those studies was noteworthy.[134] As a result of Project POWOW, which included studies conducted on the frontlines in Korea, the Army recognized psychological operations (PSYOPS) as an important aspect of modern warfare; shifted responsibility for psychological warfare from G-2 (intelligence) to G-3 (operations); and, on 15 January 1951, created an Office of the Chief of Psychological Warfare as a special staff division of the Army Staff.[135] At the tactical level, ORO was responsible for the concept of tailoring the psychological operations message to its intended audience and, among other innovations, the introduction of airborne loudspeakers for such operations.[136]

ORO was among the first to apply operations research to the study of methods for determining the costs of future military equipment and operations, and its costing methods subsequently became the standard for the Department of Defense.[137] This was important because applying a standard method for arriving at a reasonably accurate assessment of relative costs is key to making rational choices among alternatives.

Finally, ORO played a prominent role in the development of a new program of marksmanship training for the Army and in the development and selection of the M16 rifle.[138] Beginning in 1948 with Project ALCLAD (a study on the protection of the individual soldier from missile weapons on the battlefield), ORO conducted a number of important studies on the effects of various small arms and their use by soldiers in battle.[139] From those studies arose two interesting concepts. The first was the duplex rifle projectile—in effect, two bullets contained in the same cartridge and propelled by the same powder charge. The idea was to increase the probability of a hit on a man-size target at the usual range of infantry combat.[140] Although the Army accepted the results of the studies and standardized a duplex projectile for the 7.62-mm. M14 rifle, the concept never really caught on. The second concept developed by ORO was much more successful. It involved an attempt to improve Army marksmanship training by using an array of simulated battlefield targets, man-size cardboard cut-outs placed at various distances on the firing range. The targets were rigged to pop up unexpectedly at various ranges, thereby testing the soldier's reaction time and accuracy. The details of the new training method were subsequently worked out by the Human Resources Research Office and adopted by the Army as the TRAINFIRE system.[141] TRAINFIRE was a significant improvement over the old known-distance firing range as a means of providing realistic infantry training, and

it was used very successfully to train several generations of Army personnel in rifle marksmanship.

ORO studies on casualties caused by small-arms fire, small-arms design and characteristics, and marksmanship led to several conclusions: (1) Accurately aimed rifle fire was no more effective in producing enemy casualties than was the volume of fire, (2) the rifle was seldom used at ranges beyond 300 meters, and (3) most rifle "kills" were made at less than 100 meters. ORO analysts thus found that what the Army needed was a low-recoil weapon firing a number of small projectiles. In 1957 the CONARC asked various arms manufacturers to help design a new 5.56-mm. military rifle capable of high-velocity fire in both full- and semiautomatic modes. Studies conducted by ORO and several subcontractors under Project SALVO eventually determined that the AR15, designed by the Armalite Division of the Fairchild Engine and Airplane Corporation of Costa Mesa, California, was the best design. The AR15 weighed only 6.7 pounds, used a .223-caliber (5.56-mm.) cartridge firing a 55-grain projectile at 3,300 feet per second, incorporated many of the best features of existing designs, and was relatively cheap to manufacture. The Armalite AR15 was subsequently adopted with a few modifications as the M16 rifle, the standard U.S. infantry weapon from the mid-1960s to the present.

Although many ORO studies were well received and made major contributions to the stated goal of improving Army weapons, organization, and doctrine, Army users of ORO products had some complaints. Those complaints generally fell into five main categories: the failure to address problems of immediate interest and usefulness to the Army; the lack of quality; the inability of ORO authors to communicate their results to Army decision makers in a clear, concise, and tactful manner; the lack of timeliness; and the personal conduct and attitude of individual ORO researchers who sometimes ignored Army custom and were disrespectful to senior officers. Such shortcomings remained a challenge for ORO leaders throughout the organization's existence despite gallant efforts to correct them.

Complaints about ORO products and the conduct of ORO personnel must be seen in the context of the time. As one Army War College student observed in 1957:

> Criticism of Army operations research, as typified by the Operations Research Office, is not entirely without foundation. However, criticism is traceable primarily to the comparative newness of operations research and the attendant problems of management and supervision, both of which have shown marked improvement.[142]

In fairness to ORO it must be pointed out that the studies undertaken in the 1950s and early 1960s were much broader in scope and complexity than the simpler analytical studies of World War II; moreover, there were no accurate, generally accepted means for measuring ORO performance precisely.[143] Then, too, throughout its existence ORO was inadequately staffed and funded for the workload the Army imposed on it. ORO also faced many administrative challenges that affected the quality and timeliness of its research program. The difficulties of administering a staff of some three hundred people in various disciplines scattered in half a dozen inadequate facilities while safeguarding an enormous collection of classified documents were sometimes overwhelming.[144]

Many of the early ORO studies failed to address matters of immediate interest to the Army and were criticized accordingly. In part, that problem can be attributed to the Army's failure to provide adequate guidance and to articulate its needs. In the end, the real test of the usefulness of a given ORO study was how many of its recommendations were actually adopted by the Army. One Army chief of research and development, Lt. Gen. James M. Gavin, stated that most ORO recommendations were adopted within a few years of publication, and ORO's own estimate was that about 80 percent of all recommendations were adopted eventually.[145]

Ellis Johnson and other ORO leaders were acutely aware of the criticisms regarding the usefulness and quality of ORO studies. In the early days, some of the studies produced were quite poor and represented "work that may not be correct or is of no use to the Army and is scientifically of low quality."[146] The quality of about 80 percent of ORO studies produced between 1951 and 1954 was rated "excellent" or "good," but the remaining 20 percent—"fair" and "poor" reports—caused significant problems with the customer.[147] In an effort to increase the quality of studies, in 1954 Johnson introduced a system of "murder boards" and a post-publication review board to review ORO work. The murder boards, one for each study, comprised ORO staff members who conscientiously evaluated and criticized the ongoing work of their colleagues. Each completed study went to the post-publication review board at the same time it was sent to the Army, and the board independently evaluated the quality of the study and reported its results to the director, who could then take internal corrective action as necessary. The murder boards and the review board were successful in significantly reducing the number of studies rated "fair" or "poor." By 1957 almost 100 percent of ORO studies were rated "excellent" or "good."[148]

It was not necessary only to produce quality studies; the results of the studies also had to be conveyed to the Army in a clear, concise, and tactful manner. In 1958 Johnson confronted head-on the problem of effectively providing Army decision makers with study results. He did so in a pamphlet directed to ORO managers and analysts.[149]

Noting that "even though our work is excellent we need to communicate it *in time* much better than we do now," Johnson set forth a number of measures to be taken by ORO supervisors and authors to improve the quality and effectiveness of both published and oral ORO presentations to the Army.[150] He instructed the research staff members to ensure that their recommendations were practical and to accompany their studies with a draft "directive," using "Army language," for consideration by the Army executive responsible for decisions about the study's recommendations. The purpose of the draft directive, which in every case was to be vetted by the senior military advisor at ORO, was to facilitate adoption of the recommendations included in the study by making them stand out "loud and clear" and by identifying in advance those people who had the authority to take action. Johnson recognized the risk in seeming to dictate to the Army what should be done with any given set of ORO recommendations, but he was convinced that "there will be no serious resentment at any level in the Army if ORO results are well substantiated and are presented without bias or emotion."[151] Furthermore, he insisted that each study and its draft directive be sent forward under a well-composed letter of transmittal.

Johnson also prescribed certain measures to improve oral briefings presented by the ORO staff. He prescribed that all research staff members be trained in effective briefing techniques, that only the best briefers be used to present study findings, and that all briefings be "well-practiced, simple, direct, and devoid of extraneous technical detail."[152] ORO staff members presenting papers or briefings at meetings and symposia as well as speeches were enjoined to have a "prepared, practiced, and good presentation."[153] Finally, Johnson encouraged all staff members to "make a special effort to present ORO research results on a personal basis to Army officers and civilians."[154] Doing so, he noted, involved "making a real effort to meet and become friendly with our colleagues in the Army who might be able to make use of ORO research results."[155]

The problem of voluminous, overly academic studies couched in dense quantitative formats and academic jargon was compounded by the frequently "uncompromising and forthright tone of some of the ORO's reporting."[156] Not only did some authors lack tact in the presentation of their results, but there also was dissatisfaction in the Army regarding the tendency of some ORO leaders to report major findings first to top officials and only then to the lower-level staffs. As one historian wrote, "If ORO reports dealt with issues already controversial within the Army, one side or another was almost certain to question the findings, and counterattacks were launched not only against ORO's work but its concept as an organization as well."[157] Ellis Johnson's assertion that "the canons of scientific procedures" justified the widespread, simultaneous distribution of ORO findings and recommendations met with little acceptance among some Army personnel.[158]

The most persistent criticism of the studies was that they took too much time to produce and often appeared long after they were needed. As the Army's chief of research and development, Lt. Gen. Arthur G. Trudeau, wrote to Johnson on 30 July 1958:

> Lack of timeliness is the most common criticism of ORO studies. ORO studies have made many important contributions to the Army, but these contributions would be greatly enhanced if the substance of ORO findings were made available to the Army more quickly. It appears that timeliness of ORO studies might be improved by the following measures:
>
> a. Early publication and distribution of draft research reports.
>
> b. Reduction of extensive editorial and art work on publication of final reports.
>
> c. Fuller use of briefings for dissemination of research findings.
>
> d. Terminating research when there is an obviously low probability of uncovering significant additional data.
>
> I realize that getting research results quickly is always a critical problem to the researcher, but it has been the Army's experience that study cycles of two or more years result in greatly reduced payoff to the Army.[159]

Continued criticism of the timeliness of ORO studies prompted Johnson to assign to the ORO executive director, retired Brig. Gen. Lester D. Flory, the task of conducting a thorough analysis of the timeliness of all ORO studies published between 1 November 1955 and 31 October 1960. The results of Flory's in-depth analysis were published in November 1960 as ORO-TP-16, *Analysis of the ORO Research Program with Respect to Timeliness*. Flory expressed the opinion that the "ORO feels the criticism leveled at it has not always been justifiable and has been made without an examination of the whole operation."[160] He pointed to a number of factors causing delays in the ORO research program, including the

> effect of special and crash studies, difficulty of problem, insufficient personnel assigned, specific skills not available, delays encountered in getting data, diversions of personnel on other assignments, delays in improving quality and validity of the study, lack of supervision or direction, changes in scope or objectives, and a host of other factors.[161]

As Flory pointed out, "even with a full complement of analysts and no diversions there will always be a normal slippage, inherent in any research in a long-range research study, which will be reflected in changes of the estimated completion date."[162]

The problem for ORO was that a study rated "excellent" not only had to be timely; it also had to meet high standards of scien-

tific quality and effective communication.[163] With respect to the timeliness of ORO studies, Johnson himself noted that

> we could cut down the number of projects and get each one done more quickly. In doing that we would lose balance in the program. . . . Planning the ORO work program is the problem of an optimum and balanced synthesis vs a quicker but incomplete and narrow set of piecemeal solutions arrived at without proper consideration of their interactions.[164]

In a letter to the Army chief of research and development, Brig. Gen. Andrew P. O'Meara, on 31 August 1955, Johnson attempted to justify the practice of not assigning an estimated completion date to each project on the grounds that hastily done studies only had to be reworked at an even greater loss of time.[165] Unconvinced, Brig. Gen. O'Meara replied:

> The usefulness of ORO studies to the Army staff depends to some extent on the knowledge that a particular phase of a study will probably be available on a certain date. Such knowledge increases the assurance that the ORO studies will be used in the decision process. Conservative estimates of completion dates may somewhat alleviate your problem which I recognize.[166]

Given high-quality, pertinent, and timely studies presented in a clear and tactful manner, there remained some aspects of ORO operations that constituted an irritant to some Army personnel. In the early days, some of the ORO personnel were inexperienced in dealing with the Army and some of their actions were contrary to accepted behavior and interfered unnecessarily with urgent ongoing Army staff work.[167] Other ORO researchers were particularly cavalier about the handling of classified material, ignored the chain of command, or flouted Army procedures and thus caused considerable consternation among their military contacts. The solution, of course, was to thoroughly indoctrinate new ORO personnel in Army procedures and mores before turning them loose.[168] Even so, with an annual personnel turnover of roughly 20 percent, it was a constant struggle for Johnson and his subordinate managers to ensure that overeager and inexperienced researchers did not offend the sensibilities and break the established rules of their Army customers.

As noted previously, the shortcomings of studies were not entirely the fault of ORO. The Army failed to provide timely evaluation of ORO products and maintained a persistent ignorance of the purposes, capabilities, and limitations of operations research. The Army's advisory committee system for ORO oversight proved weak, in part because the military members of both the ORO advisory committee and the project advisory groups had other pressing duties and devoted only intermittent attention to their supervisory functions.[169] For one thing, Department of the Army letters of evaluation of ORO studies tended to be "too general in nature and too long in preparation."[170]

Despite almost a decade of attempts to inform and indoctrinate Army officers about the benefits of operations research, ignorance persisted and resulted in rejection of OR recommendations and in opposition to the use of such research in general. In 1957, one Army War College student concluded, "There is not present among the officers of the Army an appreciation of OR to the degree required for the most effective functioning of OR."[171] To solve the problem, he made the following five recommendations:

> (1) The Department of the Army should establish, in conjunction with ORO, a course in "Appreciation of Operations Research." This course should initially be given officers having the following assignments: ORO duty designees; Project Advisory Groups; Appropriate sections of the offices of: The Director of Research and Development, Technical Services R&D, Combat Development in D/A, CONARC, Technical Services, and Service Schools; Other field grade officers as time and space permit.
>
> (2) A lecture, or lectures, on the purpose, capabilities and limitations of OR be included in the curriculums of the Army War College and the Command and General Staff College.
>
> (3) A moderate, dignified program of Army-wide recognition of ORO be initiated in service affiliated publications such as *Army*, *Military Review*, *Army Digest*, and the *Military Engineer*.
>
> (4) The Department of the Army authorize ORO to detail annually one analyst as a student at the Army War College, and one at the Command and General Staff College.
>
> (5) There be established at the headquarters of the Seventh and Eighth armies, small detachments of ORO to provide OR services at the field army level. That continued consideration be given toward the establishment of similar detachments in other agencies.[172]

To some degree the problem was that Army personnel held a general expectation of quick results and instant gratification coupled with a lack of understanding of the time required to produce an accurate and thorough operations research study. The result was a tension between sound, thorough scientific research and limited, short-term projects that could easily be completed on schedule and within budget.[173]

One shortcoming that could only be placed at the feet of the Army was the lack of provisions for General Staff supervision and coordination of all Army operations research matters, either in the staff or throughout the Army as a whole.[174] The ORO chain was relatively clear, but there was no oversight or coordination of the OR work program, organizations, or budgets in the Army Staff, field commands, or technical services. One recommended solution was that OR analysts be assigned to the various Army general and special staff sections as required and that the authority of the Army chief of research and development be extended to cover all Army OR establishments.[175]

Other ORO Activities, 1950–61

In addition to its approved annual program of research and publication, ORO conducted a wide variety of other activities, including a number of innovative in-house programs.[176] ORO personnel were loaned to the Executive Office of the President, the Department of Defense, and other Army agencies to participate in special studies, scientific advisory groups, and high-level joint panels. Personnel also served as lecturers in service schools and war colleges, reviewed studies prepared by other Army agencies or subcontractors, and aided other organizations in the United States and abroad in setting up OR establishments. Ellis Johnson and his senior staff played a major role in the exchange of information and coordination among the OR organizations of the various services, with OR establishments in allied countries, and with OR elements in academia and business. The office also sponsored, chaired sessions at, and presented papers at conferences, symposia, and professional meetings, both in the United States and abroad.

Internal Programs

ORO conducted a number of innovative internal programs to stimulate its personnel and promote an interest in operations research among various constituencies. For most of the office's existence, a weekly internal seminar was conducted, and in 1952 Ellis Johnson convinced the dean of the Engineering School at The Johns Hopkins University to initiate a graduate operations research seminar led by ORO personnel.[177] One of the most successful programs initiated to stimulate interest in such research was a program of summer internships at ORO for high school students. The program was supervised by Jean G. Taylor, an ORO analyst and a psychologist by training.[178] Each year, students at local high schools were interviewed and selected for the internship program. Rather than performing routine administrative tasks, the student interns were organized into teams and set to work on "meaningful analytic programs, generally as part of a larger ORO study underway for the Army."[179] The Army was amazed to learn that, properly guided, the young students were capable of preparing such viable studies as a civil defense plan for the Washington, D.C., metropolitan area.[180] During the five years of its existence, the internship program was extraordinarily successful, and approximately 75 high school students participated, some of whom joined the staff as full-fledged analysts after attending college.[181]

ORO Relationships with Other DOD OR Agencies

ORO took the lead in supporting the development of OR organizations in the technical services and elsewhere in the Army, actively participated in conferences on OR organized by the Ordnance Corps, and hosted a number of conferences for Army operations researchers. ORO also played a major role in assisting the Army chief of research and development in defining the Army's R&D needs by bringing together ORO specialists, military personnel, consultants, and operations research analysts from the other services in the series of so-called PISGAH conferences already mentioned.[182]

As ORO grew and matured, so too did the operations research programs in the Department of Defense and the other services. Johnson intended that ORO should take the lead informally in coordinating the various military OR programs. To that end, the office participated actively in liaison visits, meetings, conferences, and other methods of contact that included representatives of OR groups in the technical services, the Department of Defense WSEG, the Navy Operations Evaluation Group (OEG), the Air Force Operations Analysis Division (OAD) and major command Operations Analysis Offices, and the RAND Corporation. For a time in the 1950s, the directors of the various Department of Defense OR organizations met regularly to discuss mutual problems and to effect informal coordination of their research programs.[183] As ORO's director, Ellis Johnson was an active participant, along with the directors of WSEG, OEG, OAD, and RAND.

International Relationships

Since World War II, American military operations research organizations had cooperated closely with their counterparts in Britain and Canada. ORO personnel worked closely with British and Canadian operations analysts in Korea, and the office maintained a full-time liaison officer with the British Army Operational Research Establishment (AORE).[184] Another important means of maintaining contact with the British and Canadian OR organizations was the series of annual Tripartite (later Quadripartite, with the addition of the Australians) Conferences on Army Operations Research, the first of which was held in London in April 1949 and the second of which was hosted by ORO in Washington in October 1950.[185] Each conference concentrated on a specific major topic and was attended by representatives from ORO, AORE, and the Canadian Army Operational Research Establishment (CAORE), as well as representatives from the OR organizations of the other services in all three countries.

The British and Canadians also frequently participated in conferences sponsored by other U.S. Army agencies, such as the annual Army OR symposium sponsored by the Ordnance Corps Army Research Office (Durham). At the second such symposium in March 1962, G. Neville Gadsby of AORE explained that his organization included a small element with the director of operational science and research in the War Office and the main AORE, located at West Byfleet a few miles outside London, which included

an integrated staff of military and civilian analysts divided into subelements covering weapons, tactics, field studies, general studies (logistics, economics, communications, and so forth), human factors, and clothing and equipment physiology.[186] As Gadsby explained, AORE was on a level with two other British Army OR groups, one in Germany (Operational Research Section, British Army of the Rhine) and one in southeast Asia (Operational Research Unit, Far East). At the same symposium, Henry H. Watson discussed the CAORE, which then was physically located at Canadian Army Headquarters in Ottawa and reported directly to the scientific advisor to the chief of the General Staff.[187] Watson also explained that the entire staff of CAORE, which included military personnel, was in Ottawa and that CAORE conducted a program of research projects (10–15 percent of which were self generated) that fell into two main groups: tactical studies and systems studies.[188]

In the 1950s, the other nations of the North Atlantic Treaty Organization (NATO) also began to set up OR organizations, as did NATO itself.[189] In the mid-1950s, an international OR group composed primarily of the British and the Canadians was established under Headquarters, Allied Air Forces Central Europe, at Fontainebleau, France, and a group led by Dr. H. F. Robertson was organized at Supreme Headquarters Allied Powers Europe (SHAPE).[190] From 1953 the NATO Advisory Group on Aeronautical Research and Development (AGARD) (and later the OR group at SHAPE) was active in promoting lectures on operations research and helping interested nations form their own OR groups.[191] Robertson's team at SHAPE also organized a number of conferences on OR in the various NATO member nations. The first conference, in 1955, had 30 participants from only four nations, but the third gathering, held in November 1956, had 120 participants representing all but two of the NATO countries.[192] In April 1957, the four-day NATO conference on operational research sponsored by AGARD was held at the Palais de Chaillot in Paris.[193] The chief aims of the conference were to interest high-level NATO administrators in the need for OR and to familiarize NATO technical and operating personnel with the latest research methods.[194] As the supreme allied commander in Europe, U.S. Air Force General Lauris Norstad, told attendees at the conference:

> Operational research, by revealing methods for more effective utilization of our manpower, our skills, our material and our resources, is making a significant contribution to the military potential of the Atlantic Alliance. This is of utmost importance, for our strength depends not alone on what we have but to a large extent on what we do with what we have.[195]

The attendees at the second SHAPE operations research conference, held at HQ SHAPE on 14–15 February 1956, noted that most NATO OR groups were in the central geographical area, with few in the NATO "flank" countries.[196] In March 1956 AGARD organized a three-man team—Thornton Page (from the ORO field office in Heidelberg), Tony Sargeaunt (from the SHAPE scientific advisory staff), and Glen D. Camp (from Melpar, Inc.)—to conduct a two-week trip to Italy, Greece, and Turkey to promote OR and help organize OR groups.[197] The Italian General Staff expressed interest and asked for a followup visit, and, on 1 June 1956, the Turks established an OR group within the Turkish General Staff Scientific Advisory Board comprising ten reserve officers with mathematics and scientific training under the direction of Turkish Air Force Col. Fuat Ulug.[198]

As of 1956, allied OR groups in NATO included those at the headquarters of the British Army of the Rhine, the Second Allied Tactical Air Force, and the Canadian Infantry Brigade Group (all near Dusseldorf); a RAND representative and elements of the Office of Operations Analysis at Headquarters, United States Air Forces Europe, in Wiesbaden; the ORO field office at Headquarters, United States Army Europe; Headquarters, Twelfth U.S. Air Force at Ramstein; Headquarters Allied Air Forces Central Europe at Fontainebleau; two Navy analysts at Headquarters, Commander SOUTH near Naples; the Air Defense Technical Center in The Hague; SHAPE near Paris; and the Turkish OR group under Col. Ulug.[199] By 1963, Norway had an OR group of approximately 450 people concentrated in the Norwegian Defence Research Establishment (NDRE).[200] By that time, operations research in NATO was focused in the SHAPE Air Defence Technical Center (SADTC), roughly 40 percent of whose scientific staff (thirty-five analysts) were assigned to OR tasks.[201] The SADTC analysts generated 70–80 percent of their own projects, and, as with the NDRE, military officers were seconded to participate in specific projects.[202]

Industry and Academia

The use of OR in industry and the study of it as a separate discipline in American universities took off in the 1950s. As one historian wrote:

> By the mid-1950s, OR was becoming increasingly popular among managers of private firms, some—but not all—of which were military contractors. . . . It would be difficult to overstate the importance of government support in the postwar growth of operations research.[203]

Ellis Johnson closely monitored the trends in both industry and academia and maintained close contacts with the leaders in both sectors. He also encouraged experienced military analysts to move into the industrial operations research field and newly established industrial OR groups to become involved in military operations research.

The use of OR in industry spread most rapidly in Britain after World War II, perhaps because British industry continued to suffer from severe shortages of manpower and raw materials and thus had to operate on a most-efficient basis if it were to survive at all.[204] American industry also adopted OR in the late 1940s. By 1953, 75 percent of all industrial R&D expenditures were for OR, and 65 percent of industrial OR in the United States was concentrated in six industries: aircraft, electrical machinery, chemicals, instruments, machinery, and petroleum.[205] By May 1954, following a spurt of growth on the order of 50 percent in fifteen months, there were twenty to twenty-three American industrial firms with operational research sections.[206]

The study and teaching of OR as a separate, formal discipline in American universities also expanded rapidly in the late 1940s and early 1950s. Ellis Johnson's efforts to promote the discipline at The Johns Hopkins University have already been noted. MIT, also long involved in the management of military OR organizations, established in 1948 (in conjunction with the Navy) a course in the nonmilitary applications of OR.[207] In November 1951, the Case Institute of Technology held a conference on the applications of OR in business and industry and subsequently became the first American university to offer the degree of master of science in operations research.[208] Columbia University offered its first course in OR in the spring of 1952, and Johns Hopkins began a graduate OR seminar in the fall of that year.[209] By 1954, twelve American universities were presenting seminars in the discipline: Case Institute, Johns Hopkins, MIT, Columbia, University of California–Los Angeles (UCLA), Penn State, Illinois Institute of Technology, Stevens Institute of Technology, Tufts, American, the Naval Postgraduate School, and the Wright Field Air Development Center.[210] MIT and Johns Hopkins awarded the first doctorates in OR in 1955, and the Case Institute admitted a number of doctoral candidates in the discipline the following year.[211]

Operations Research Societies

Meeting at the Athenaeum Club in London in the fall of 1947, several of the distinguished scientists who had been active in the wartime British OR program—including Sir Charles Goodeve, Prof. P. M. S. Blackett, Dr. C. Gordon, and Sir Charles Tizard—formed the Operational Research Club.[212] The club was formally established in April 1948, with an initial membership of fifty, and it met periodically in the rooms of the Royal Society in London.[213] In March 1950 the club began to publish the *Operational Research Quarterly*, edited by Max Davies and Roger T. Eddison; the first article was Blackett's "Operational Research."[214] In 1953 the Operational Research Club was renamed the Operational Research Society and it defined qualification standards for new members. By 1964 it had approximately 1,250 members.[215] The society now runs a comprehensive training program; holds an annual conference and a series of meetings for young operations research workers; publishes *OR Insight*, which contains readable accounts of OR in action; and sponsors other activities for people interested in the field.[216]

In the United States, the National Research Council in 1948 created the Committee on Operations Research, with Dr. Horace C. Levinson as chairman, to foster interest in nonmilitary OR and to disseminate information about it.[217] In January 1952, ten people interested in the topic met in Cambridge, Massachusetts, and a somewhat larger group assembled the following March.[218] From these preliminary meetings the Operations Research Society of America (ORSA) was formed on 26 May 1952 at Columbia University's Harriman House in Arden, New York. Dr. Philip M. Morse was its first president.[219] In November 1952, ORSA began regular monthly meetings and published the first issue of its quarterly *Journal of the Operations Research Society of America (JORSA)*, which quickly became the preeminent journal of OR in the United States.[220]

Ellis Johnson and other ORO personnel played prominent roles in the founding of the society. Of the seventy-one people who attended the founding meeting in May 1952, nine were from ORO, and numerous "OROns" subsequently served on the various ORSA committees.[221] An ORO division chief, Thornton Page, was the first editor of *JORSA*, and the ORO editorial staff provided support.[222] When Page was assigned to the ORO facility in Heidelberg, Charles P. Chadsey, the ORO managing editor, took over as the editor of *JORSA*. Johnson also played an important role in funding the annual Lanchester Prize, established in the early 1950s, to honor the best operations research work published in the previous year.[223]

The first national meeting of ORSA was held at the National Bureau of Standards in Washington, D.C., on 17–18 November 1952, with more than four hundred members and guests attending.[224] Within two years, ORSA had 870 members and was growing at the rate of 40 new members per month, drawn from the military OR organizations, industry, and academia.[225] Of the 870 members in 1954, more than one third were engaged directly in operations research for the military services: 48 military personnel; 74 with the ORO; 41 with OEG; 30 with OAD; 20 with RAND; 5 with WSEG; 40 in research laboratories; 3 at the Naval Postgraduate School; 7 at Scientific Research, Inc.; 7 with other government agencies; 15 individual consultants; 14 foreign members; and 33 others.[226] Following the first joint national meeting of ORSA and The Institute of Management Sciences (TIMS) in November 1961, re-

lations between the two groups grew closer, and, in 1995, ORSA merged with TIMS to form the Institute for Operations Research and Management Sciences (INFORMS), an international scientific society with more than ten thousand members in 2002.[227]

The needs of professional operations researchers working in the military OR field were unique. By 1963 more than five thousand professional scientists were working full-time in military OR.[228] Of those five thousand, only about one third were members of ORSA, the principal deterrent to membership being the fact that 75–85 percent of all military OR studies were classified, and thus the work of most military analysts could not be discussed in an open forum.[229] To meet the special needs of military OR analysts, in August 1957 the Office of Naval Research branch office in Pasadena, California, began a series of military operations research symposia (MORS), which subsequently became important venues for the exchange of ideas among military OR managers and analysts.[230] The first symposium was a one-day meeting held on 14 August 1957 at the Naval Ordnance Laboratory in Corona, California. Four invited papers and panel discussions on the theme of air defense were presented to eighty-three attendees.[231] The ninth MORS, hosted by the U.S. Continental Army Command at Fort Monroe, Virginia, in April 1962, was the first truly national meeting. With the eleventh MORS, held at the United States Naval Academy in April 1963, sponsorship of the symposia was transferred to the Office of Naval Research in Washington, D.C., and the MORS Executive Committee was joined by Operational Logic Corporation, which provided the workforce essential for preparing and running the symposia.[232] Following the seventeenth MORS, the executive committee was phased out and the Military Operations Research Society, incorporated in Virginia, took responsibility for achieving the objectives of MORS:

1. To provide media for professional expression of both clasfied and unclassified military OR;
2. To improve the quality of military OR through exchange of information and other interaction among professionals;
3. To increase the effectiveness of military OR by stimulating interaction between OR professional and military officers and civilians whose duties bear upon the conduct of OR;
4. To foster the development of the students of military OR.[233]

New Organizations Using Operations Research, 1950–62

The early work of the Operations Research Office in such areas as troop motivation, training, and performance; psychological operations; and political, economic, and social conditions in foreign nations stirred interest in such fields within the Army and prompted the creation of several new research organizations to deal specifically with such fields of emerging interest. Chief among the new research organizations created by the Army in the early to mid-1950s were the Human Resources Research Office and the Special Operations Research Office. ORO continued to conduct studies in the areas assigned primarily to the new organizations, but it cooperated actively with them.

Human Resources Research Office

Several ORO projects conducted during the late 1940s and early 1950s both reflected the growing interest within the Army and stimulated additional Army interest in improving troop motivation, training, and performance.[234] For some time, the Army had recognized the need to "concentrate responsibility for operationally diverse activities of human resources research and to create additional research units capable of fulfilling requirements not currently met by existing research activities."[235] Accordingly, a Human Resources Research Section was established in the Research and Development Division of G-4 on the Army Staff, and a staff study titled "An Integrated Program in Human Resources Research" was prepared.[236] The staff study recommended that the Army contract with a recognized educational institution to set up a Human Resources Research Office with primary responsibility for research in training methods, troop motivation and morale, and psychological warfare. The proposed organization would conduct studies, grant and monitor contracts for studies, and provide civilian staff and technical supervision for research units at selected Army installations. The study was presented to Army chief of staff Gen. J. Lawton Collins on 21 June 1951, and to Secretary of the Army Frank Pace, Jr., the following day, and it was approved.[237] The Army then persuaded George Washington University to form the new HumRRO, and a contract was signed on 27 July 1951. A distinguished psychologist, Dr. Meredith P. Crawford, was appointed director on 2 August 1951.[238] In July 1951, Army Staff supervision of HumRRO was lodged in the Research Section of the Research and Development Division, Office of the ACS, G-4 Logistics. With later changes in the Army Staff, responsibility for HumRRO migrated with the Office of the CRD. HumRRO was charged with four main functions: research planning and analysis, supervision of contract research, provision of staff members to conduct human factors research at various Army installations as needed, and technical supervision and support for the human factors research units at various Army installations.[239] As Director Crawford explained, the dominant theme of HumRRO research efforts was the "improvement, primarily through training and education, of

the performance of individuals and units," and the office had two general goals:

> *First*, to establish productive working relations between HumRRO and the Army, at appropriate echelons and at locations where research skills could be applied to practical problems.
>
> *Second*, to foster the growth of a strongly integrated, though geographically dispersed, organization that would promote professional development and a high quality of research capability in our assigned area.[240]

The office supplemented the existing Army human resources research efforts of ORO; the Personnel Research Section of the Adjutant General's Office; the Army element in the Navy Special Devices Center; the Office of the Quartermaster General and research units at the Quartermaster Climatic Research Laboratory and Food and Container Institute; the Medical Department Field Laboratory at Fort Knox, Kentucky; and the Ordnance and Signal Corps.[241]

HumRRO was initially organized with a central office composed of an administrative section and three research sections (Training Methods; Motivation, Morale, and Leadership; and Psychological Warfare and Intelligence), all located on the campus of George Washington University in Washington, D.C.[242] Provision was also made for establishing three field research laboratories located at various Army installations, but that plan soon changed. The Training Methods Section in Washington became HumRRO Division No. 1, and during FY 1952 two new elements, called Army human research units, were activated, at Fort Knox, Kentucky, and at the Presidio of Monterey, California. Division No. 1 subsequently provided small detachments of civilian scientists to form additional Army human research units. All of the Army human research units were later redesignated as HumRRO divisions. In 1954, the responsibilities of the HumRRO Motivation, Morale, and Leadership Section were spread over the other existing divisions. The following year, responsibility for psychological warfare studies was transferred from HumRRO to the newly created Special Operations Research Office, and the Psychological Warfare and Intelligence Division was phased out.

An initial $500,000 was provided from held-over FY51 funds for the support of HumRRO at its founding on 30 July 1951, and a request was made later for an additional $700,000 from FY52 emergency funds.[243] The FY53 HumRRO budget request was for $2,900,000, of which $700,000 was to be for research in psychological warfare and intelligence with the remainder divided about evenly between training methods research and research in motivation, morale, and leadership. Approximately 50 percent of the FY52 and FY53 HumRRO budgets was allocated to contract research and the remainder to in-house projects, with the intention that the percentage distribution would shift toward in-house research as the HumRRO staff was built up. Subsequently, the total HumRRO annual budget hovered at approximately $3.5 million per year.[244]

Because HumRRO was established less than six weeks before the beginning of the 1951/52 academic year, there was some difficulty in recruiting qualified staff, but as of 1 November 1951, eleven scientists had been hired. It was anticipated that full strength would be reached by January 1954.[245] The subsequent growth in the HumRRO staff during the 1950s is shown in Table 3–8.

HumRRO was a combined military–civilian agency. The majority of the professional civilian staff—originally envisioned to be approximately one hundred scientists—were psychologists, and a relatively high proportion of them held doctoral degrees.[246] Specialists in sociology, anthropology, linguistics, military science, engineering, computer technology, and publications/graphics were also represented. All HumRRO civilian personnel were members of the sponsored-research staff of George Washington University. They participated in the university's retirement, benefits, and leave programs, but their salary scales were set by an annex to the Army–George Washington University contract from FY 1959 onward.[247] As Director Crawford acknowledged, it was "the professional competence, vision, and dedication of the staff that is the key ingredient for solving practical problems in the improvement of human performance—HumRRO's broad objective."[248]

HumRRO's in-house and contract research work programs were governed by *AR 70–8: RESEARCH AND DEVELOPMENT—Human Factors and Social Science Research*, and the primary document used to disseminate the results of HumRRO research was the Technical Report, prepared in compliance with *AR 70–31*. HumRRO also produced two kinds of special reports (interim reports and consulting reports), quarterly status reports, research and technology résumés (DD Form 1498), bibliographies of publications, and research bulletins. The HumRRO work program originally consisted of a set of so-called work units (or tasks) organized and presented in sections, with each section representing the work planned for a division. The first full-scale research project undertaken by HumRRO was planning and coordinating the psychological evaluation of troop behavior in Project DESERT ROCK, an atomic bomb test conducted in Nevada in November 1951.

Thereafter, HumRRO production grew rapidly. In FY 1952 just 1 presentation was produced, but in FY 1962 HumRRO produced 93 separate items, including 8 technical reports, 2 research reports, 1 research bulletin, 20 research memoranda, 28 journal articles (plus 1 reported else-

Table 3–8—HumRRO Personnel Strength: FY 1952–FY 1961

End of FY	*Strength*	*End of FY*	*Strength*
1952	66	1957	237
1953	198	1958	260
1954	224	1959	263
1955	236	1960	270
1956	205	1961	278

Source: Meredith P. Crawford, *A Perspective on the Development of HumRRO* (Alexandria, Va.: George Washington University HumRRO, 1968), p. 6.

where), 30 presentations (including 7 reported elsewhere), and 4 other items.[249]

It was not until 1957 that the Army developed a system for commands and agencies to submit their requirements for human factors research annually. Before FY 1956 each HumRRO research proposal and Army approval was handled individually, but, when supervision of HumRRO passed from the ACS, G-1, to the Office of the Chief of Research and Development in January 1955, an annual work program cycle was established, and the Army Human Factors Research Advisory Committee was set up.[250] To regulate the HumRRO research program, key staff members of the director's office and the directors of the research divisions met twice a year to establish general policy, discuss the development of procedures, plan the annual work program, and conduct long-range planning.[251]

HumRRO's influence on the Army has been called "deep and fundamental" and "the major catalyst in changing traditional training and task assignment procedures from those in effect during World War II" to new ones based on the concept of the soldier as part of an overall system.[252] Many of the personnel, training, and leadership programs and procedures familiar to those who have served in the Army since the mid-1950s had their origins in HumRRO studies. Included in that group are the TRAINFIRE I and II marksmanship training programs, the Noncommissioned Officer Leader Preparation schools conducted at Army training centers, the techniques for teaching land navigation, and procedures and miniature devices for armor training.[253]

Special Operations Research Office

The global responsibilities assumed by the United States in the postwar period, stemming from the Cold War with the Soviet Union and, particularly, the emergence of Communist-inspired "wars of national liberation" in the late 1940s and early 1950s, spurred U.S. Army interest in area studies, guerrilla warfare and counterinsurgency techniques, and psychological operations. That interest led directly to the establishment in the Army Staff of the Office of the Chief of Psychological Warfare on 17 January 1951.[254] The chief in turn led efforts to establish a research organization to study psychological warfare and special operations.[255]

Early ORO work, such as Project MAID (which included political, economic, and social assessments of various potential candidates for U.S. military aid) and Project POWOW (on psychological warfare), demonstrated the utility of systematic studies of foreign countries and psychological operations, but there was a growing sentiment in the Army Staff that such studies should not have to compete for funding with the more-elaborate studies of weapons systems. That view was reinforced by the Harlow Committee appointed by Secretary of the Army Robert T. Stevens in 1955.[256] The Harlow Committee recommended that a separate agency designed for the purpose address psychological warfare and special operations research.

Already in 1954 the Department of the Army had contracted with the Human Relations Area Files (HRAF) of New Haven, Connecticut, to prepare area handbooks to support special warfare operations, but HRAF could not meet Army needs and the contract was canceled.[257] At the request of the Army, in 1956 The American University (AU) in Washington, D.C., established the nonprofit SORO to support the Army's psychological and unconventional warfare operations. SORO was managed by AU under the terms of contracts with the Army that called for SORO to "conduct non-materiel research in support of the Department of the Army's missions in such fields as counterinsurgency, unconventional warfare, psyops, and military assistance programs."[258]

The SORO was an integral part of AU, and its director reported to the president of the university through the dean of faculties for everything except business matters, which were handled by the AU treasurer and business manager.[259] All SORO employees were considered AU staff members and participated in the university's insurance, pension, and medical programs.[260] SORO professional staff members were eligible for faculty rank without tenure at AU.[261]

Initially, SORO was organized with the usual supervisory, administrative, and support elements and two techni-

cal divisions—the Research Division and the Foreign Area Studies Division (FASD)—each of which was governed by a separate contract and reported to a different agency of the Army Staff. As of 1 March 1962, the Research Division was organized with a director, two branch chiefs, and six interdisciplinary research teams, and was responsible for conducting research on a broad range of topics, including psychological operations and guerrilla/counter-guerrilla warfare.[262] The activities of this division were overseen by the Office of the Chief of Research and Development on the Army Staff, in accordance with *AR 70–32: Special Warfare Non-Materiel Research*, dated 3 April 1957.[263] Support for the division came from the Army Research and Development/Test and Evaluation funds under Contract DA–49–092–ARO–7, amounting to $225,000 in FY 1957, $300,000 in FY 1958, $380,000 in FY 1959, $400,000 in FY 1960, and $350,000 in FY 1961.[264]

The Research Division work program was based on requirements submitted by Department of the Army agencies and approved by the chief of research and development (later by the director of the Army Research Office). By 1964, the SORO Research Division had produced some fifty research reports and a wide range of "quick response" studies and advisory services.[265] Among the SORO projects were the development of tested appeals and symbols for communicating propaganda messages to specific audiences in selected countries (Project PROSYMS), a study of word-of-mouth communications in selected countries (Project PROPIN), a study of the psychological operations vulnerabilities of the Soviet Union (Project EXPLOIT-USSR), and publication of *A Casebook on Revolutionary Warfare* and *A Selected Bibliography on Counter-Unconventional Warfare*.[266]

The Foreign Area Studies Division became part of SORO on 1 July 1958.[267] FASD was organized with a division chief, two deputy chiefs, and four interdisciplinary research teams, plus several historians and geographers and an editorial staff.[268] The division was responsible for the preparation of country and regional studies that included material on political, economic, sociological, and military matters. In accordance with *AR 70–8*, FASD activities were overseen by the chief of psychological warfare (later the chief of special warfare, and after 1958, the director of special warfare in the Office of the Deputy Chief of Staff for Military Operations). Funding for FASD was provided from Operations and Maintenance–Army funds under Contract DA–49–083–OSA–2427, and it amounted to $430,000 in FY 1958, $340,000 in FY 1959, $400,000 in FY 1960, and $420,000 in FY 1961.[269] The FASD goal was to produce six to eight new or revised area handbooks each year, and, as of 1 March 1962, it had completed forty-seven special warfare area handbooks.[270]

Computers and Wargaming

The increased interest in operations research and the tremendous growth in Army OR organizations in the 1950s and early 1960s were accompanied by significant advances in both the theory and the techniques of OR. New mathematical formulae were developed, new applications of OR were created and tested, and new ways of looking at old problems flourished. But no development in OR during the period was more significant than the invention of the high-speed electronic digital computer and its application to wargaming as a means of testing and evaluating weapons systems, organization, and tactical and strategic doctrine. As one participant in the events wrote in 1964:

> It has enabled us to plunge into areas, e.g., data processing, linear and nonlinear programming, simulation, and operational gaming on a scale where sheer size and complexity would have swamped us several years back.[271]

The Development of High-Speed Electronic Digital Computers

The history of the high-speed electronic digital computer goes back at least to the work of Charles Babbage in the early nineteenth century.[272] Babbage's "analytical engine," completed in 1835, is generally recognized as the first general-purpose computer. Although it was steam powered, it incorporated most of the aspects of modern electronic computers, including a calculating unit, a memory, an input device, a control section, and a printer.[273] A version of Babbage's analytical engine was actually used by the British government from 1859 to 1864 to compute actuarial tables for predicting life expectancy.[274] But, for almost eighty years thereafter, development of the computer progressed very little.

Interest in high-speed mechanical calculation was revived by the World War II demand for such complex and time-consuming processes as computing ballistics tables, inventory control, and cryptoanalysis. In response, Howard Aiken of Harvard University, with the sponsorship of the International Business Machines Corporation (IBM), designed the first successful electromechanical computer, the Harvard Mark I, completed in 1943. The Mark I was controlled by instructions on paper tape, and the addition or subtraction of two numbers took three tenths of a second.[275] A few months later, the first all-electronic computer, the "Colossus," began operation at Bletchley Park in England. Colossus was a special-purpose computer specifically designed to aid in the code-breaking work at Bletchley Park. It had some two thousand "valves" (vacuum tubes) and was fed by a paper tape run through a photoelectric reader.[276]

Meanwhile, in the United States, work went forward on what was to be the first general-purpose electronic com-

puter, the "Electronic Numerical Integrator and Calculator" (ENIAC).[277] Not completed until 1946, ENIAC was designed by Dr. John W. Mauchly and Dr. J. Presper Eckert, Jr., at the Moore School of Electrical Engineering at the University of Pennsylvania to meet the needs of the U.S. Army Ordnance Corps Ballistic Research Laboratories (BRL) at Aberdeen Proving Ground, Maryland. BRL was charged with the preparation of ballistic firing and bombing tables for the Army and Army Air Corps—tedious and time-consuming work that was done using various mechanical computation devices.[278] On 5 June 1943, the Army awarded a contract to the University of Pennsylvania for "six months of research and development of an electronic numerical integrator" and delivery of a report thereon.[279] ENIAC was formally dedicated at the University of Pennsylvania on 15 February 1946 and was accepted by the Army in July. It was then disassembled and rebuilt at Aberdeen Proving Ground and became operational there in August 1947, subsequently undergoing numerous modifications.[280]

Although designed primarily to do the calculations necessary to produce ballistics tables, ENIAC had a number of other applications including weather prediction, atomic energy calculations, cosmic ray studies, thermal ignition, random number studies, wind tunnel design, and other scientific uses.[281] ENIAC, which worked in decimal rather than binary mode, weighed 30 tons, had some nineteen thousand vacuum tubes and fifteen thousand relays, consumed enormous amounts of power (around 200 kilowatts), and ran very hot.[282] On the positive side, ENIAC greatly increased the speed of calculating such problems as ballistic trajectories. A skilled human "computer" using a mechanical desk calculator could compute a 60-second trajectory in about 20 hours. The same task using an analog differential analyzer took 15 minutes. ENIAC required only 30 seconds to complete the same set of calculations.[283]

The principal drawback to ENIAC was that it was necessary to rewire the computer to switch "programs." Dr. John von Neumann of the Institute for Advanced Study at Princeton University, who had worked with the ENIAC team, solved that problem by coming up with the idea of storing programs in the computer itself.[284] This concept was used in the construction of EDVAC (ENIAC's replacement), which was completed in 1951, as well as in all later electronic computers.

Having played a significant role in the development of electronic computers during World War II, the U.S. armed forces continued to foster their development and use in the postwar period. In fact, it was only in 1951 that the use of computers in business and industry began to develop. The first business computer, LEO, was developed in Great Britain in 1951 by John Pinkerton for the food giant, J. Lyons, and was soon followed in the United States by the first commercially successful computer system, UNIVAC I, designed by ENIAC designers Mauchly and Eckert.[285]

The development of computers for business and scientific applications progressed rapidly in the 1950s, with a number of computer manufacturers competing for dominance, a competition eventually won by IBM. In the early 1950s, Remington Rand was the principal rival of IBM for the emerging market in electronic computers. The Remington Rand UNIVAC 1103, a commercial version of the ATLAS II computer designed for the Armed Forces Security Agency (a predecessor of the National Security Agency), became available in the summer of 1952, and an improved version, the UNIVAC 1103A, came out in September 1956.

Computers built in the 1950s were generally of the large mainframe type and required expansive, air-conditioned spaces and a multitude of well-trained operators and repairmen. Such machines were expensive and had to be carefully scheduled for maximum efficient use. Time sharing became common, and eventually remote entry and then online services were developed.

In the 1960s, developments in transistors generated a revolution in computer design, with the production of smaller but much more powerful computers. By the 1970s, the cost of such computers had been reduced to the point that even medium-sized organizations were able to own one.[286] Ultimately, the microcomputer, then the personal computer (PC), emerged at a price and size such that even the individual scientist or operations research analyst could own and operate it.

By 1960, the use of high-speed electronic computers in operations research had become commonplace. The two areas in which computers proved most useful for OR work were linear programming and simulation.[287] Until 1952, most linear programming had been done using punch-card calculators, but, beginning in 1952, W. Orchard-Hays and George Dantzig developed linear programming computer code, which enabled linear programming to become a practical OR tool.[288] By the late 1950s it was possible to solve sizable linear programming problems by computer, and attention shifted to the development of matrix generators for improving data input and report writers for producing understandable output.[289] By the mid-1970s such items had been perfected and it was possible to solve larger, more-complex problems more easily.

The effect of the high-speed electronic digital computer on simulation—in particular, the military wargame—was even more profound. By orders-of-magnitude increases in the speed at which the effects of multiple variables could be calculated, the computer enabled the design and use of much more sophisticated wargames in which a multitude of factors could be considered. The quick turnaround times achievable

with a computer made it possible to play such games in reasonable time frames and eliminated the delays and "downtime" associated with manually or mechanically computed game moves.

Early History of Wargames

The use of games to evaluate and predict the performance of military organizations in battle has a long history.[290] The game of chess is believed to be the oldest form of wargame, although the Chinese sage Sun Tzu is said to have created a wargame called "Wei Hei" around 1,000 B.C.E. In this game, each player maneuvered colored stones on a painted surface with the object of outflanking his opponent.[291] In the West, however, games of the chess variety, such as the "King's Game," developed by Christopher Weikhmann at Ulm in 1664, were the dominant form until the late eighteenth century.[292] By the late eighteenth century, the scientific revolution and the Enlightenment had produced increasing interest in warfare as an exact science, the rules of which could be expressed precisely using mathematics. This interest was manifested in the development of wargames—still played on chess-like boards with pieces representing various military formations—of increasing complexity with detailed and lengthy rules. One such game was invented in 1780 by Helwig, the Master of Pages at the Court of Brunswick, and was played on a modified chessboard with 1,666 squares tinted to represent varying terrain.[293] The game was played by two opponents, each of whom had his "Fortification," which replaced the traditional "King." Another, even more complex game, the "New Kriegsspiel," was published in 1798 by Georg Vinturinus, a military writer and tactician from Schleswig.[294] Vinturinus' game used a board with 3,600 squares and had some sixty pages of rules.

The revolution in warfare effected by Napoleon at the beginning of the nineteenth century made earlier concepts of warfare obsolete, and interest in the older wargames declined. However, in 1811, the Prussian Baron von Reisswitz developed a new wargame played on a sand table rather than a game board, and in 1824 his son, von Reisswitz the Younger, a lieutenant in the Prussian Guard Artillery, came up with a new type of wargame based on actual military operations and played on a realistic map-like chart with a scale of 1:8,000.[295] Troop units were represented by movable pieces, a director or umpire provided a starting situation and made decisions regarding movements, and losses and outcomes were determined by a throw of the dice. Von Reisswitz the Younger's *Instructions for the Representation of Tactical Maneuvers under the Guise of a War Game* attracted the attention of Field Marshal Meffling and King Wilhelm III of Prussia, and was prescribed for play in the Prussian army.[296] However, von Reisswitz's game was difficult to learn and tedious to play, and there was considerable opposition to it in the Prussian army, although one of its enthusiasts was Count von Moltke the Elder, the chief of the Prussian General Staff in the mid-nineteenth century.[297]

A major change in wargaming came with the publication in 1876 of a booklet titled *A Contribution to the War Game* by Col. von Verdy du Vernois, the chief of staff of the First Army Corps of the Imperial German Army.[298] Von Verdy du Vernois greatly simplified the rules for wargaming and introduced what came to be called "Free Kriegsspiel," which largely dispensed with set rules and detailed calculations, relying instead on the experience and acumen of a director who made decisions regarding movement rates, combat power, casualties, and so forth. A further important development—the use of a "standard" based on collected data but modified by a "multiplier" to account for variations in conditions—came with the publication of Naumann's *Das Regiments-Kriegsspiel* in 1877.[299]

Because Von Verdy du Vernois' Free Kriegsspiel was relatively easy to learn and to play, and proceeded at a relatively fast pace, it became popular. The older, more-elaborate form of the wargame involving abundant and complex rules, tables, and data based on actual historical battles, which came to be called "Rigid Kriegsspiel," fell out of favor.[300] The Germans were particularly enthusiastic proponents of Free Kriegsspiel, and it became a staple of German military instruction and war planning from the late nineteenth century through World War II.[301] The famous "Schlieffen Plan" of World War I was thoroughly "gamed," as were the 1940 German Ardennes offensive, the abortive amphibious invasion of Britain (Operation SEALION), and the invasion of Russia in 1941 (Operation BARBAROSSA), and when the Allies attacked in Lorraine and around Aachen in November 1944, Field Marshal Walther Model used the results of an ongoing wargame to direct his countermoves.[302]

The Japanese were also enthusiastic wargamers, and the Japanese Total War Research Institute, created in October 1940, conducted a series of in-depth games beginning in August 1941 that assumed a United States–Japanese war beginning in mid-December of that year.[303] The most important games, involving nearly all the top Japanese naval officers, began on 2 September 1941 and covered two general problems: a surprise raid on the U.S. fleet at Pearl Harbor; and the schedule for Japanese forces occupying Malaya, Burma, the Dutch East Indies, the Philippines, the Solomon Islands, and the islands of the central Pacific, including Hawaii.[304]

American army officers in the late nineteenth century were ardent admirers of all things Prussian, and Free Kriegsspiel became popular along with such Prussian Army accouterments as the *Pickelhaube*, or spiked dress helmet.[305] A number of U.S. Army officers published wargames, the

most important of which was probably *The American Kriegsspiel,* designed by Maj. W. L. Livermore of the U.S. Army Corps of Engineers in 1883.[306] Using data from actual Civil War battles as well as from the Prussian campaigns of 1866 and 1870–71, Livermore designed a game with extensive rules and planning factors covering the minute details of the effects of fire; the training, fatigue, and morale of the troops; and the effect of variations in terrain.[307] Livermore's contemporary, Lt. C. A. L. Totten of the 4th Cavalry, also designed a game, called "Strategos," played on a board with blocks representing the troops and with messages and orders issued by a director.[308] A notable feature of Strategos was that it came in two versions—a "battle game" for beginners and an "advanced game" for more-seasoned players.

The games of Livermore and Totten were essentially Rigid Kriegsspiel, and, being difficult to learn and play, did not arouse much enthusiasm, although the Naval War College codified the rules for an "American Kriegsspiel" in 1884, and wargaming was integrated into the Naval War College curriculum from 1887.[309] However, in 1897, Maj. Eben Swift of the 5th Cavalry (and a leading instructor at the Army School of the Line and Staff College at Fort Leavenworth) translated von Verdy du Vernois' *A Simplified War Game,* and thus introduced Free Kriegsspiel to the U.S. Army.[310] Free Kriegsspiel was played at the Staff College at Fort Leavenworth from 1904 and at the Army School of the Line from 1907, but, although wargaming became commonly used for instructional purposes, it had little real influence until the 1930s when the Army War College used wargaming techniques to evaluate strategic war plans.[311]

Free Kriegsspiel remained the most popular form of wargaming in both Europe and America until the development of operations research during World War II and the subsequent development of the high-speed electronic digital computer.[312] Both OR and the computer revived interest in Rigid Kriegsspiel by providing an adequate means for handling the massive amounts of data and computations required to make a complex Rigid Kriegsspiel exercise practicable. So much time was required to complete each cycle of play and the number of game variables was limited by the difficulty of computing the necessary values and effects quickly and accurately in the era of "the stubby pencil." Operations research, however, led to matrix mathematics by which the many variables and interrelationships in a given situation could be defined, and the high-speed electronic digital computer made it possible to store, relate, and compute the effects of those variables quickly.[313] Thus, by the early 1950s it was possible to design and play a complex Rigid Kriegsspiel with numerous variables based on data derived from actual operations with reasonable accuracy and speed. By the early 1960s, the use of computers in wargaming had been further enhanced by the development of new electronic display devices that made it possible for players to visualize the ongoing action more clearly.[314] As a consequence, OR analysts turned increasingly to sophisticated computerized simulation as the principal tool for the study of weapons systems, organization, and tactics.[315]

Computers and Wargaming at ORO, 1950–61

As in so many other areas of Army OR, the Operations Research Office under Ellis Johnson took the lead in the use of wargaming supported by high-speed electronic digital computers. ORO was among the first military OR organizations to make full-time use of a high-speed electronic computer and to develop wargaming as a method for studying military situations.[316] Even before the advent of the high-speed electronic digital computer, ORO used the latest data handling and mechanical computation devices, principally programmable IBM punch-card machines.[317] When high-speed electronic computers became available to government offices in the early 1950s, ORO rented time on the UNIVAC I computers operated by various government agencies, particularly the Bureau of the Census.[318]

In May 1955, ORO contracted for its own computer, an ERA (UNIVAC) 1103 chosen over its competitor, the IBM 701, on the basis of cost and early delivery date.[319] ORO leased the 1103 on a single-shift, 40-hours-per-week basis, with any downtime on one day being made up by extending time on another.[320] The 1103 was used primarily for wargame simulations. The wargames usually had long periods between inputs while the gamers determined their next move, and the interrupt feature on the 1103 made it possible to run other batch work between wargaming iterations.[321] In 1957, ORO replaced the 1103 with a UNIVAC 1103A having 4,096 words of core memory and added six Uniservo tape drives to the system, for a total monthly rental fee of $24,838.[322] ORO was still using the UNIVAC 1103A at the time of ORO's demise in August 1961.

Computer operations at ORO were focused in the Computing Laboratory (COMPLAB) that was part of the Strategic Division. COMPLAB was a service organization that assisted all the ORO divisions with matters pertaining to computers. Its prescribed mission was to "provide service and assistance to other projects through equipment operation, instruction in the use of facilities, and the development of applications to OR problems."[323] The associated Electronics Laboratory also provided support services, including the design, construction, installation, operation, and maintenance of instrumentation for wargames, both map and computer types, and for field experiments.

COMPLAB consumed a sizable proportion of the ORO resources, and Ellis Johnson monitored it closely to

ensure that there was an adequate balance between research analysts and computer staff and machines.[324] ORO computer operations grew from a staff of eight, some 1,000 hours of operation, and an annual machine rental cost of $100,000 in 1955 to a staff of nineteen, an estimated 3,500 hours of operation, and an estimated machine rental cost of $425,000 in 1958.[325] Counting COMPLAB personnel costs, ORO computing services consumed $650,000 in 1957, which was 18–20 percent of the total ORO budget.[326] By 1960, the direct cost of the Computing Laboratory was about 7 percent of ORO's gross income.[327]

Although all ORO analysts were required to attend a short course on computers and learn to write a simple program, by 1960 about 90 percent of the computing time available to ORO was used for simulations and validation of mathematical models rather than straight analysis.[328] Of eighteen major computing programs completed in the period 1958–60, only three were straight analysis, reduction of data from field experiments, or the solution of mathematical equations.[329]

Wargaming was a major part of the ORO work program throughout the 1950s. Each ORO division had its own set of games, designed primarily as research tools, and ORO participated actively in wargames conducted by other government agencies, from the National Security Council on down, as well as in Japan, Korea, and Germany.[330] The players of ORO wargames were mostly military personnel, which helped the office achieve necessary military insights, but ORO analysts also played active roles.[331] As Ellis Johnson noted in 1958:

> War games are used to give us insight. This allows us to design practical combat models that we can usually solve on a digital computer to find the best combination of organization, weapons, materiel, and tactics. This usually leads to a need for more detailed operations analysis and field experiments, which lead to revision of the war games. The results go continuously to the Army, which in turn provides continuous guidance.[332]

The purpose of the STRATSPIEL Group in the Strategic Division was to develop wargaming at the strategic level and integrate the gaming materials produced by the other divisions into a comprehensive theater-level game.[333] The STRATSPIEL Group first attempted to adapt the RAND Corporation's strategic game, SAWSPIEL, to ORO requirements by placing more emphasis on the ground war and by introducing sociological considerations.[334] The group then passed on to the development of STRATSPIEL I, a strategic generalization of the air defense game ZIGSPIEL, which explored the Army role, including air defense measures, during and after a strategic nuclear attack.[335] The Strategic Division also controlled COMPLAB, which supported wargaming by the other ORO divisions, and the division's OPSEARCH Group undertook studies on OR methodology related to wargaming, published several papers on the application of high-speed computers to wargaming, and developed a value theory as a component of decision theory.[336]

The Tactics Division's TACSPIEL Group focused on tactical battle simulation using high-speed computer techniques, the quantification of the tactical effects of terrain and weather, and battle decision criteria.[337] The TACSPIEL Group had two main games: FAME, a hand-played game, and Carmonette, a computerized game.[338] FAME was designed to enable the ORO tactical gamers to get a feel for the situation and to suggest approaches to the gaming of a limited war in the Middle East, specifically Jordan.[339] Two questions that the ORO gamers hoped to answer with FAME were "To what extent can nuclear weapons compensate for conventional inferiority?" and "Can an air-lifted division, such as the 101st Airborne Division, stand up against a current [1958] Soviet mechanized division?"

Carmonette was arguably the premier tactical game to appear in the 1950s and 1960s.[340] The game, a Monte Carlo simulation, integrated the simulated effects of various weapons systems and military actions (such as firing and moving) to produce a combat result. As originally designed in the mid-1950s, Carmonette dealt with a company-level attack against a defending Soviet rifle company.[341] The initial runs involved a counterattacking Blue Force consisting of a medium tank company (seventeen tanks) and three squads of infantry mounted in armored personnel carriers with a battery of 4.2-inch mortars in support, and a defending Red Force consisting of a company of ten medium tanks, a company of five self-propelled guns, and nine squads of dismounted infantry. In the 1960s Carmonette was extended to represent battalion-level operations with forty to fifty systems on the defender's side and three times as many for the attacking forces.

The Intelligence Division's TELLSPIEL Group concerned itself with developing and applying mathematical models and gaming techniques to the problems of intelligence collection, analysis, and dissemination.[342] The principal TELLSPIEL Group wargame was INDIGO, a two-sided wargame played by experienced military officers.[343] In INDIGO, the emphasis was on "the solution of intelligence-type problems, one of which is the measuring of the relative utility and effectiveness of various proposed acquisition devices."[344] INDIGO was a hand-played game, but there were plans to computerize it. The Intelligence Division also studied ways in which the high-speed electronic digital computer could be used "to simulate and calculate the effects of varying the major components of an intelligence system."[345]

The LOGSPIEL Group in the Logistics (later Operations) Division developed "gaming methods for comparing the capabilities of various logistics systems and for evaluating the effects of changes in the logistic situation on strategic and tactical plans and operations."[346] An ORO technical

memorandum titled *Gaming Strategic Logistics Studies* was published in March 1959.[347]

The ZIGSPIEL Group of the Home Defense (later Air Defense) Division assessed the Soviet threat and then developed gaming methods "for estimating the effectiveness of various defense systems in a realistic framework" and integrated the air defense of the continental United States into the strategic wargaming work of the Strategic Division.[348] The Air Defense Division also undertook operational simulations of various air defense missiles, such as the Nike, Talos, and Hawk systems.[349]

The Strategy and Tactics Analysis Group

The rapid and substantial growth in the use of digital computers and wargaming techniques to test and evaluate Army weapons, organization, and doctrine prompted the establishment in 1960 of a separate in-house Army agency to develop and apply simulation techniques. Following concept approval by the Army vice chief of staff, Gen. George H. Decker, on 28 July 1960, the United States Army Strategy and Tactics Analysis Group (STAG) was established as a Class II field activity under the staff supervision of the deputy chief of staff for military operations (DCSOPS) on 11 August 1960, pursuant to Department of the Army General Order No. 19.[350] Col. Alfred W. DeQuoy was appointed as chief of STAG effective 1 September 1960, but productive operations did not begin for some time.[351]

The mission of STAG as prescribed in *Army Regulations No. 15–14* was "to support Department of the Army operational planning and evaluation activities by wargaming and allied techniques."[352] The tasks and functions associated with that mission were to

a. Develop a land combat wargaming model for testing Army plans. To the extent feasible, the model will be developed for application to a large scale computer.

b. Conduct studies of Department of the Army problems using wargaming and allied techniques as feasible.

c. Advise and provide technical assistance to other Army and Army-supported agencies in wargaming matters on request.

d. Provide Army participation, to include wargaming models, in joint wargames as required.

e. Maintain liaison with other agencies engaged in wargaming activities as required in furtherance of STAG's mission.

f. Perform other duties as directed.[353]

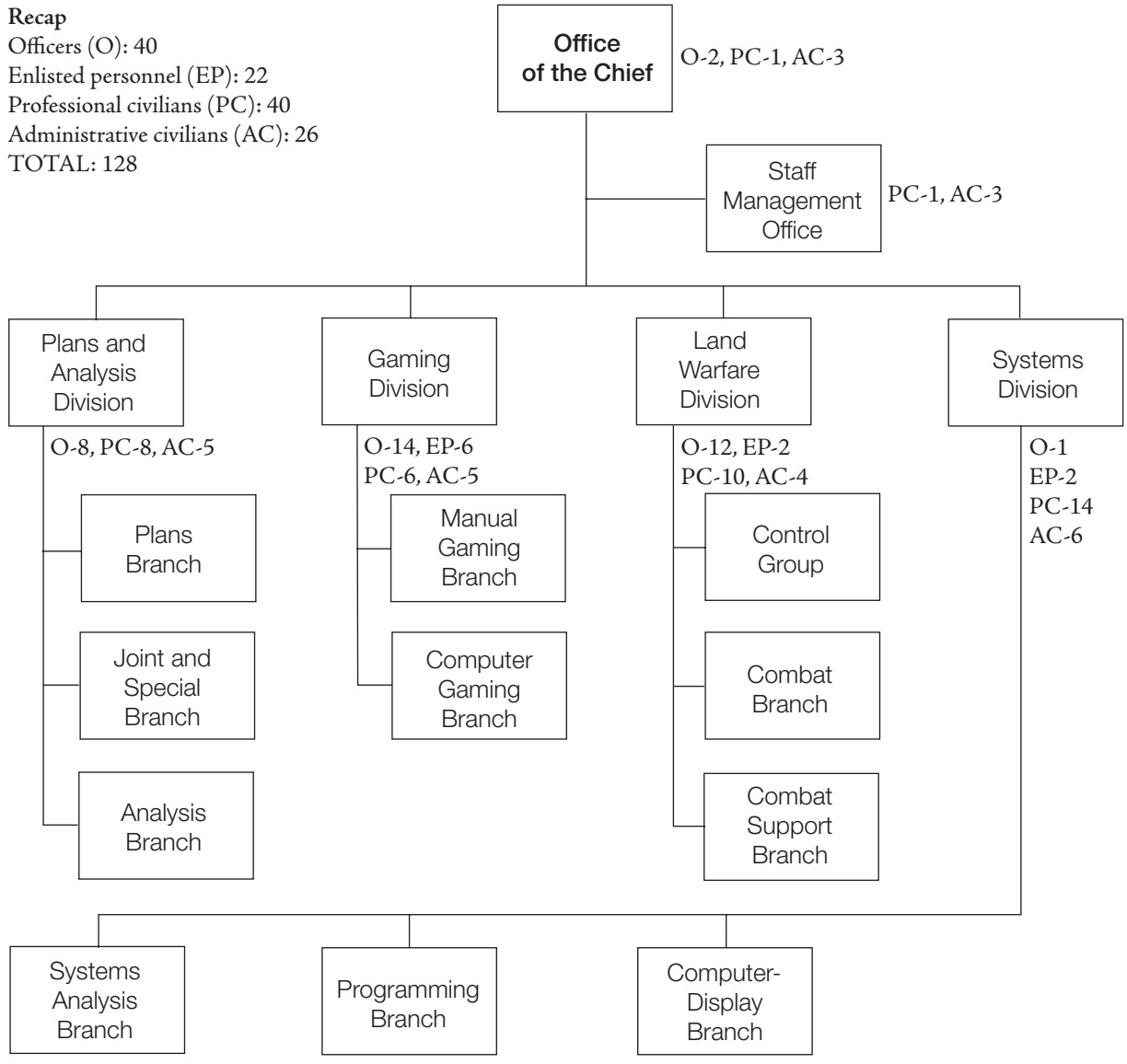
STAG was organized functionally "to provide the military, scientific, and computer integration necessary for the solving of complex problems through gaming and other techniques."[354] The organization of STAG evolved quickly, and, by the end of the first quarter of FY 1963, STAG was organized as shown in Figure 3–8.

The Office of the Chief provided command, supervision, and technical direction, and the Staff Management Office was responsible for all support and coordination functions normally accomplished by an installation staff such as operations and security, administrative services, drafting and reproduction services, supply, and transportation.[355] The Plans and Analysis Division was organized with three branches (Plans, Joint and Special, and Analysis) and undertook long-range planning for STAG itself; conducted studies of Army problems to determine the feasibility and applicability of using wargaming or allied techniques for their solution; provided advice and technical assistance to other Army and Army-supported agencies in wargaming matters; provided Army participation in joint wargames; and analyzed, evaluated, interpreted, and prepared technical reports of wargames, wargaming methodologies, OR studies, and other technical procedures.[356]

The Land Warfare Division, which performed the primary task of STAG, was organized with three branches (Combat, Combat Support, and Control Group), and was responsible for planning and developing a mathematical land wargaming model of sufficient size, scope, and flexibility to make possible the computerized wargaming of any and all phases of combat and combat support operations.[357] The Gaming Division was organized with a Manual Gaming Branch and a Computer Gaming Branch, each with a Control Team, a Blue Team, and a Red Team; the division conducted manual, computer-assisted, and computerized wargames to test Army operational plans using models developed by the Land Warfare Division or other STAG elements.[358] The Systems Division, consisting of a Systems Analysis Branch, Programming Branch, and Computer-Display Branch, designed, developed, modified, and implemented high-speed computational systems to be used for simulating or wargaming ground combat and for solving related Army problems for which mathematical models had been prepared.[359]

It was envisioned that the orderly development of STAG would take place over a period of three years by gradually increasing its personnel strength.[360] The authorized STAG personnel strength for FY 1961 was set at 74 (21 officers, 14 enlisted personnel, 26 professional civilians, and 13 administrative civilians).[361] However, as late as 4 May 1961, STAG had only three officers and seven professional civilians assigned.[362] Difficulties were encountered in hiring qualified civilian OR analysts at civil service grade GS–13, and STAG had to pursue a vigorous nationwide effort to find qualified personnel.[363] Additional personnel were found, but many of them had no background in OR or wargaming, and a long training program was necessary.

FIGURE 3–8—STAG ORGANIZATION: END OF FIRST QUARTER, FY 1963



Source: U.S. Army STAG, Fact Sheet, Bethesda, Md., ca. 1962, RG 319, Entry 100, Box 3, Folder 203–04 OPPR Program Rpt Files, 1962, Fact Sheets.

It was soon determined that the proposed staffing for FY 1963 (105 people) was inadequate, and STAG leaders recommended a substantial increase in the FY63–FY67 period.[364] *Army Table of Distribution No. 89–9826*, dated 1 August 1962, increased the STAG personnel authorization for the first quarter of FY 1962 to 128 (40 officers, 22 enlisted personnel, and 66 civilians), and the Personnel Increase Justification Plan for FY 1963, approved by the Acting Chief of Staff of the Army, provided for a strength of 162 people at the end of FY 1963.[365] The STAG personnel status, FY 1961–FY 1963, is shown in Table 3–9.

The initial plans for STAG included awarding a civilian contract for technical support and physical facilities, and funds for that purpose were included in the FY61 STAG budget, which totaled $500,000.[366] Booz-Allen Applied Research, Inc., was awarded the contract, effective 1 October 1960, for three professional personnel and temporary facilities for STAG at 4921 Auburn Ave. in Bethesda, Maryland.[367] STAG occupied the temporary site on Auburn Avenue until 19 June 1961, when it moved to a leased office building at 4815 Rugby Ave. in Bethesda.[368]

During its first year, STAG established contact with other agencies in the OR and wargaming fields ,including ORO; Headquarters, United States Army Continental Army Command; Headquarters, United States Army Pacific; and Headquarters, Eighth United States Army in

Table 3–9—STAG Personnel Status: FY 1961–FY 1963

Type Personnel	*Authorized FY 1961*	*Authorized FY 1962*	*Actual, 8 June 1962*	*Proposed FY 1963*
Officer	21	27	24	49
Enlisted	14	14	13	25
Professional civilian	26	34		
Administrative civilian	13	17	35	88
TOTAL	74	92	72	162

Source: U.S. Army STAG, Organization and Functions Manual (Bethesda, Md.: STAG, 1962), p. 1-1; Memo, DeQuoy to Fisher and others, 14 Sep 61, sub: Proposed Reorganization for FY 63–67, p. 2, RG 319, Entry 100, Box 1, Folder 201–22 DA Mobilization Program Planning Files, 1961; Col. Alfred W. DeQuoy (chief, STAG), Fact Sheet for Director, Strategic Plans and Policy, Office of the Deputy Chief of Staff for Operations, Bethesda, Md., 8 Jun 62, sub: Mission, Organization, and Personnel Status, STAG, RG 319, Entry 100, Box 3, Folder 203–04 OPPR Program Report Files, 1962, Tactics Analysis Group

Korea. STAG representatives also participated in a variety of professional meetings, including the Seventh Tripartite Conference on Operational Research in London on 29 May–6 June 1961. To secure the assistance of eminent scientists, STAG established an Advisory Council, which met for the first time on 19 July 1961.[369] The initial members of the council included Dr. L. T. E. Thompson (Navy Special Projects Office), Dr. F. E. Bothwell (director, Laboratories for Applied Sciences, University of Chicago), Dr. Richard A. Leibler (deputy director, Institute for Defense Analyses), Dr. H. A. Wilcox (director of research and engineering, Defense Systems Division, General Motors Corporation), and Julian N. West (director, Military Systems Engineering, Bell Telephone Laboratories).[370]

It was intended that STAG should have the best and latest computer equipment with which to carry out its mission, and the FY61 STAG budget included funds for the rental of an electronic computer. After studying the available high-speed computers, in October 1960 STAG arranged to lease an IBM 7090 system for delivery on 1 August 1961.[371] During FY 1961, STAG also received proposals from civilian firms for supplying STAG with a large-screen display system for use with the IBM 7090 computer, and in June 1961 STAG contracted with IBM for installation of a $1.3 million automatic display system by 1 May 1962.[372] The new electronic visual display system used color symbology and alphanumeric characters projected on background reference maps.[373]

In March 1961, Col. DeQuoy, the chief of STAG, exchanged letters with Ellis Johnson regarding the possibility of ORO sharing the cost and use of STAG's IBM 7090.[374] By letter of 20 March 1961, however, Johnson declined the offer, although ORO subsequently did lease time on the STAG IBM 7090 on an hourly basis as did its successor, RAC.[375] In July 1962, Philip H. Lowry, the acting director, Combat Systems, RAC, wrote to the DCSOPS noting "the splendid cooperation given RAC by the STAG computing staff. The results obtained from the STAG computer have contributed significantly to the RAC research program."[376] The U.S. Army Chemical Corps Operations Research Group also used the STAG IBM 7090 on a non-reimbursable basis.[377]

STAG used both hand-played and computerized wargames, the latter being preferred because of the tremendous advantages of computers in reducing time and expense. STAG's first major wargaming success was the Field Army Ballistic Missile Defense System (FABMDS) wargame model approved for development by the Army vice chief of staff on 26 August 1960.[378] Because no contracting funds were immediately available, Col. DeQuoy decided to begin development of the model in-house.[379] The model, which was designed to support the evaluation of contractor proposals by the Army Rocket and Guided Missile Agency at Redstone Arsenal in Alabama, was essentially an IBM 7090 mathematics simulation of FABMDS in operation against an enemy ballistic missile attack in the post-1965 period, and it involved more than twenty-four parameters and thus more than fourteen thousand combinations involving those variables alone.[380] In April 1961, a $15,750 contract was awarded to the Service Bureau Corporation for necessary programming, and the project subsequently went forward.[381]

In March 1961, the DCSOPS authorized STAG to assist the Eighth United States Army (EUSA) in Korea with its wargaming efforts. STAG subsequently examined certain conclusions drawn from EUSA wargames by the Synthetic Tactics system in Korea and prepared a model that enabled future EUSA wargames to be played on a computer.[382] Out of STAG's work with EUSA came a land warfare model, later extended to support any size force, that could be used to analyze and evaluate EUSA's operational and contingency plans.[383]

CENTAUR was the computerized land warfare model designed by STAG as a tool for the operational testing of worldwide Army campaign and contingency plans.[384] Described as a "two-sided, free play, closed man-computer simulation," CENTAUR was developed in two phases.[385] In Phase I, the STAG Land Warfare Division prepared a division-level game to test division operations orders against specific objectives established by the division staff whose plan was being tested. In Phase II, data from the division-level game were used to expand CENTAUR to a field army–level and then to a theater army–level game (LEGION) to test Army plans against criteria established by the Army Staff. Work on CENTAUR began on 11 September 1961 with projected completion of the division-level game in December 1963, and of the theater-level game in December 1965.[386]

Development of CENTAUR required significant resources, including an interdisciplinary team of assigned officers, enlisted personnel, professional civilians, and administrative civilians, and contract analysts from Booz-Allen Applied Research and contract programmers from Computer Concepts, Inc.[387] The IBM 7090 was used to develop and run CENTAUR, and a linked IBM 1401 was used as an input/output device.[388] Programming for CENTAUR was an extension of FORTRAN known as CENTAUR Operating System, developed by Computer Concepts.[389] CENTAUR was designed to be able to change the game parameters at any time as better information became available.

CENTAUR was played in four separate rooms: Red War Room, Blue War Room, Control Room, and Computer Room, and communication among players and umpires was by message, telephone, or personal contact. The operations plan to be test was provided to the Blue Team by the Control Group. CENTAUR was a major advance over more-primitive wargames as a means of performing "timely studies of practical usefulness to the modern military planner."[390]

One unique feature of STAG model design was that each model was accompanied by the complete and detailed explanation of the logic and thinking that went into it, the various courses of action and why each one was selected, and why some elements were included and others were not.[391] This was done in the hope that it would save the Army thousands of dollars and thousands of man-hours for restudying existing undocumented models or the development of new ones.[392] Overall, STAG had significant success in the military wargaming field and soon became an indispensable and permanent part of the Army OR program.[393]

Recruitment and Training of Army OR Personnel

The expansion of ORO (and its successor, RAC) and the establishment of many new Army OR organizations in the 1950s and early 1960s created substantial challenges for Army OR program managers. Among the most pressing and persistent problems were the recruitment and training of adequate numbers of qualified operations research analysts. By the early 1960s, the military services required approximately thirty to fifty new operations research analysts each year to sustain the growth of military OR programs.[394] Most candidates were drawn from the national pool of men and women trained in mathematics and the physical sciences, and operations research programs had to compete with industry and other government programs for the limited number of candidates available. Throughout the 1940s and 1950s, the Army and the other services faced a severe shortage of suitable engineering and scientific personnel, partly because American universities produced too few such people and partly because of the competition from industry and the difficulties of hiring and retaining scientific talent under the existing civil service rules.[395] Indeed, the demand for scientific talent by the government became so great in the 1950s that many observers voiced concern about the constraint on national economic growth and scientific work in industry caused by the drain of scientists to government positions.[396]

Two factors served to alleviate the difficulties of finding sufficient numbers of qualified OR analysts trained in mathematics and the physical sciences during the 1950s: (1) the extension of OR to the study of political, economic, and social issues and the consequent increase in the proportion of analysts drawn from the social sciences and humanities, and (2) a substantial increase in academic training programs in operations research.

In the two decades after Pearl Harbor, the scope of OR studies expanded tremendously and the traditional focus of operations research—the evaluation of weapons and equipment, field organization of military forces, and tactics—widened to include the study of human behavior; higher-level strategy and policy; and political, economic, and social issues. Accordingly, the demand for analysts trained in the social sciences and humanities increased proportionately.[397] The trend toward hiring personnel from disciplines other than mathematics and the physical sciences was led by ORO, and. by 1953, more than 40 percent of the ORO staff was drawn from the behavioral and social sciences.[398] Between 1948 and 1962, the percentage of natural scientists (biologists, for example) hired by ORO/RAC remained fairly small and constant and the number of engineers and physical scientists (physicists, for example) declined, but the number of social scientists, mathematicians, statisticians, and computer specialists increased substantially.[399] Between 1953 and 1963, the ratio of engineers, physical scientists, and natural scientists to behavioral scientists employed by ORO/RAC changed from 4:3 to 2:5.[400] By 1963, the distribution of social scientists employed

by Army operations research organizations was striking: RAC employed 90 percent of the economists, HumRRO employed 80 percent of the psychologists, and SORO employed 67 percent of the political scientists.[401] In general, the two groups learned to cooperate and to complement one another, but there continued to be a degree of tension between the "hard scientists" and the "soft scientists."[402] The constantly increasing number of computer specialists employed by Army OR organizations formed yet a third group.

Although the demand for new OR analysts increased steadily throughout the 1950s and early 1960s, the difficulty of recruiting qualified individuals was also eased somewhat by substantial improvement in the United States in the means and methods of training operations research analysts.[403] Training for Army OR analysts took three general forms: formal academic courses in universities; on-the-job training; and seminars, conferences, and short-term training sessions conducted by various organizations for both analysts and users of operations research.[404]

Formal academic training programs in operations research in the universities expanded significantly in the 1950s. Formal education in operations research began in 1951, and the first doctoral degrees in OR were awarded by MIT and JHU in 1955.[405] In 1954, only four universities (MIT, Johns Hopkins, Case Institute of Technology, and the Moore School of Electrical Engineering of the University of Pennsylvania) offered degree programs in OR, but, by 1959, nineteen universities offered doctoral programs in the field.[406]

Once an OR analyst was employed by one or another of the Army OR groups, his or her training continued in a variety of forms, including on-the-job training, mentoring, and attendance at seminars, conferences, and training sessions sponsored by universities, industry, or the military OR organizations themselves.[407] On-the-job training—the classic means of transmitting the theory, methods, and procedures of military OR—also increased in sophistication over two decades. By the early 1960s, the concept of assigning personnel from the supported organization to train and work as analysts with the supporting OR group had become commonplace and produced promising results.[408]

The principal Army OR organizations, such as ORO, conducted a wide range of in-house training, including courses in basic mathematics, statistics, and computer science, courses in operations research theory and methods, and orientation courses for new personnel and for clients. There were also seminars at which the results of OR studies were presented.[409] Considerable attention was given to "training" the "users" of operations research to recognize its benefits, limitations, and general methods.

The increasing number of operations conferences, symposia, and seminars sponsored by universities, industry, and the military OR groups provided additional opportunities for OR training, and the activities and publications of the Operations Research Society of America and the Military Operations Research Society did much to promote the sense of community and the exchange of information among operations research practitioners in the military, and to provide a forum for the "popularization" of OR in the general community.[410]

Despite the substantial growth and improvement of OR training programs, problems remained. In 1963, it still took twelve to thirty-six months to produce an effective, contributing OR analyst.[411] And, although the training of civilian OR analysts had expanded dramatically between 1941 and 1963, by the early 1960s few military officers had been trained and qualified as OR analysts. Moreover, despite the urgent need for OR training, the Army seemed to offer fewer opportunities than the other services and not all of the opportunities available to Army OR analysts were being used.[412] There also remained an unmet need for a central collection of information on military OR methods—a central library, abstracting service, and publication—that would have facilitated OR training and practice.[413]

The Demise of ORO, 1961

The relationship of the Army, The Johns Hopkins University, and ORO from 1948 to 1961 was not without disagreement and controversy. Continued distrust of operations analysts by Army personnel, questions about the timeliness and focus of ORO studies, the ever-expanding scope of ORO interests, and, above all, Ellis Johnson's irascible personality caused tensions that led in August 1961 to the cancellation of the Army's contract with JHU and the replacement of ORO with a new, independent research organization, the Research Analysis Corporation.

Despite the success of OR in many areas during the 1950s, there remained a number of Army officers who were unwilling to accept the "meddling" of operations analysts, just as later there would be those who rejected organizational effectiveness or performance-based training. For the most part, their visceral dislike of OR was based on nothing more than the belief that civilians should not be involved in "Army business." Others failed to see how Army interests were served by an organization such as ORO that operated with a good deal of independence and objectivity rather than being a good Army "team player."[414]

The issue of the timeliness and focus of ORO studies that arose during the early 1950s remained a nagging problem into the early 1960s. The efforts of Johnson and his management team at ORO had largely solved the timeliness problem by 1960, although some Army leaders continued to have unrealistic expectations about the time in which their demands could be met. The question of the focus of ORO

studies was a bigger problem. The office's work program had gradually shifted during the 1950s from a focus on weapons analysis and the evaluation of Army organization and tactics toward questions of higher-level strategy and national policy.[415] Army leaders, of course, were preoccupied with finding solutions to the pressing practical problems of mounting an effective military response to an aggressive Soviet Union, and they were less concerned about more-nebulous issues. Moreover, many ORO studies had begun to touch on matters of policy, and the Army was determined to deal with policy matters in its own way.[416]

Johnson believed that the future for OR in support of the military was limited and he wished to keep ORO in the front rank of OR studies.[417] Moreover, based on his experience with the mining campaign against Japan in World War II and more than a decade of dealing with the horrible possibilities of nuclear warfare, Johnson had come to believe that there was more to be gained by directing ORO efforts toward understanding the root causes of conflict and the development of national policies for avoiding war or ending it quickly.[418] Accordingly, he wanted to continue the trend toward involvement of ORO in the study of such topics as nation building, social policy, and the solution of a variety of problems somewhat remote from the immediate, practical interests of his Army paymasters. The three areas seen by Johnson as ripe for the future application of OR were regional and world development, medicine, and charity.[419] To keep ORO on the cutting edge of operations research, Johnson suggested in several letters to the president of JHU, Dr. Milton S. Eisenhower, that ORO ought to expand its application of OR to "the development of large areas, and more specifically, to underdeveloped areas," particularly Africa.[420]

By the early 1960s, the Army had options other than ORO for meeting its most pressing needs for operations research support. Other contractors had entered the field, many originally as subcontractors for ORO. HumRRO, SORO, and the Combat Operations Research Group (CORG) (run by Technical Operations, Inc., at HQ CONARC) were in full operation, and the Army's in-house OR organizations, STAG and the technical services OR groups, were available. In fact, by FY 1962, at least eleven Army agencies were sponsoring OR studies and at least twenty in-house OR groups were attached to various Army commands and agencies.[421] Such an array of alternatives made it possible to "gamble" with the cancellation and transfer of the ORO contract.

Many observers agreed that Johnson's personality was a major factor in Army leaders' dissatisfaction. Johnson had a well-defined concept of where he wanted to take ORO, and he promoted his vision vigorously and with perhaps less tact than might have been prudent. He did not suffer fools gladly and could be very direct in his criticism of those who did not share his vision. As a consequence, he was frequently at odds with his Army Staff overseer, the chief of research and development, regarding the direction of ORO research and the use of its resources. Particular points of disagreement were the degree to which ORO would be free to select and conduct research projects of its own choosing and the secrecy requirements imposed by the Army.[422] Although he frequently disagreed with Army leaders on the direction ORO should take and on other matters, Johnson was respected; on 16 January 1958, he was awarded the Army Distinguished Civilian Service Medal.[423]

Johnson's relationship with the leaders of JHU was always correct, but his demands could be exasperating, and he was apparently deeply unhappy about the reluctance of university officials to support wholeheartedly his proposals for an operations research center at JHU and the extension of the ORO research into nation building and other sensitive social policy issues.[424] For their part, university leaders were beginning to question the wisdom of close contractual relationships with the federal government and the military in particular.[425] There was growing concern throughout the American academic community about the loss of independence and academic freedom associated with large-scale government–university contracting.[426] Many academics rued their growing dependence on government funding, particularly in the sciences and fields dealing with social policy. There was also a growing opposition on campus to the U.S. government's efforts in the fields of psychological warfare and counterinsurgency—opposition that would erupt in the 1960s in active protest against the war in Southeast Asia.

The specific reason for the cancellation of the Army-JHU contract for ORO remains unclear, but it certainly hinged on the fact that the Army leaders concerned had lost confidence in Johnson as the director of ORO. The relationship between Johnson and Army leaders worsened in 1960, and the matter finally came to a head in the summer of 1961 when the Army made the replacement of Johnson a condition for renewing the contract with JHU. University president Dr. Eisenhower was sympathetic to the Army point of view, but faced with an Army ultimatum, he stood his ground and refused to be bullied into dismissing Johnson.[427] After trying unsuccessfully to convince Johnson to step down voluntarily and after consulting senior members of the ORO staff, Eisenhower concluded that the only solution agreeable to both parties would be for the Army not to renew the ORO contract.[428] Bowing to the inevitable, Johnson resigned in July 1961. Dr. Lynn Rumbaugh became acting director and negotiated the work program for the coming year.[429]

Long before the actual cancellation of the Army's contract with JHU, the Army took steps to ensure that the work of ORO would continue. A survey of the Army's long-range requirements for scientific support conducted by the Army Research Office in 1960 resulted in a recommendation that a nonprofit organization take over the contract with The Johns Hopkins University for ORO.[430] The assistant secretary of the Army (research and development), Finn J. Larsen, proposed that a corporation be set up to assume the ORO mission, and Army leaders agreed that a new corporation was "the best way of preserving the needed combination of competence, objectivity, independence from proprietary biases, flexibility, and responsiveness."[431] As a result, the Research Analysis Corporation was incorporated in Washington, D.C., on 6 June 1961, and the Army asked John T. Connor, the president of Merck & Company, to assemble a board of trustees for the new corporation.[432] The next day, Dr. Hector R. Skifter, president of Airborne Instruments Laboratories, was named the first chairman of the board. Other board members included Connor, John F. Floberg (general counsel, Firestone Tire and Rubber Company), J. H. Pickering (Wilmer, Cutler, and Pickering), Dr. Hendrik W. Bode (vice president, Bell Telephone Laboratories), Gen. James McCormack, Jr. (vice president, MIT), and General of the Army Omar N. Bradley (chairman of the board, Bulova Watch Company).[433] In July, Frank A. Parker, Jr., who had served as a naval officer in World War II and was a former assistant director of defense research and engineering, was elected president of RAC.[434]

The Army contract with JHU for ORO expired at 2400 hours, 31 August 1961. RAC began operations on 1 September 1961, following the signing of a contract by Assistant Secretary of the Army Finn J. Larsen; the Army chief of research and development, Maj. Gen. William J. Ely; and RAC president, Frank Parker, Jr.[435] RAC took over ORO's physical assets and contractual obligations, most of the ORO staff of more than 300 technical and 135 administrative personnel, and ORO's working relationships with other agencies.[436] RAC made few early changes in the ORO organization, and the ORO work program continued virtually unchanged.[437] By the end of 1961, the takeover was complete.

The official Department of Defense explanation for the change from ORO to RAC was that the "Army's growing requirements for scientific support in the short range and long range planning fields indicated the need for an independent nonprofit organization offering flexibility and expansion capability."[438] Although the Army-JHU-ORO relationship ended in acrimony, no one denied that during its thirteen-year life, ORO, which had published 648 studies containing thousands of recommendations, most of which had been adopted by the Army, had compiled a substantial record of achievement and had great influence on many aspects of Army weaponry, organization, tactics, and strategy.[439]

Conclusion

The shift of the Army's principal operations research contract from the university-sponsored Operations Research Office to the independent Research Analysis Corporation marked the end of an era in at least two respects. The Army would no longer rely only on one OR organization to meet its needs, and university-sponsored OR organizations would no longer be the preferred form.

In 1950, ORO was the Army's only full-scale OR organization. By the early 1960s, in response to the demands of the Cold War, the Army OR program had expanded to include a substantial number of OR groups spread throughout the Army. In fact, in May 1963, there were six principal Army OR organizations: the Research Analysis Corporation, the Human Resources Research Office, the Special Operations Research Office, the Strategy and Tactics Analysis Group, the Combat Operations Research Group (operated by Technical Operations, Inc.), and the Combat Developments Command operations research element (operated by Stanford Research Institute). Together, the six organizations employed more than four hundred analysts and technical aides and were responsible for the bulk of the Army's OR activities.[440] In addition, other OR groups were active in the various technical services, and eleven Army agencies supported some twenty in-house OR groups in nine commands—groups that ranged in size from two to forty professional analysts and employed approximately two hundred civilian and military personnel.[441]

From World War II to the early 1960s, the U.S. armed forces and the American academic community had a close working relationship. But the growing opposition on campus to government-sponsored research, which would erupt in the disorder and active protest against such relationships in the mid-1960s, led the armed forces to transfer the bulk of their research contracting to private, independent organizations, both nonprofit "think tanks" and for-profit corporations.[442] The RAND Corporation had long dominated the Air Force OR program. In September 1961, the Army replaced the ORO sponsored by The Johns Hopkins University with the new RAC, and in July 1962, the Navy combined its several OR elements under the Center for Naval Analyses administered by the Franklin Institute.[443]

Not only did the number of OR organizations serving the Army increase and the nature of their sponsorship begin to change between 1950 and 1962; significant progress was also made in developing more effective OR techniques and methods and expanding OR into new fields.[444] Indeed, OR as a discipline itself evolved at high speed, and the effects of that rapid evolution were seen in several important areas.

First, as the Army chief of research and development, Lt. Gen. Dwight E. Beach, told a gathering of Army OR personnel in March 1963, OR in the Army had expanded "from narrow specific projects of a hardware nature to broad theoretical problems involving complete segments of military operations."[445] Whereas World War II operations analysts generally worked on very well-defined and immediate problems, analysts in the 1950s and early 1960s found it "necessary to address aggregated rather than individual effects and to establish a broader concept of objectives."[446] Under Johnson's direction ORO had demonstrated the applicability of OR techniques to the analysis of the political, economic, and social issues pertinent to military strategy and national policy. Moreover, there was an increasing need for synthesis, particularly because OR analysts were becoming ever more specialized in the focus of their inquiries.[447]

Second, the nature of the problems that OR analysts were called on to address also changed substantially in the postwar period. During World War II the focus had been on optimizing the performance of existing systems, but by 1950 the focus had shifted to guiding the development of future systems.[448] By the mid-1950s, Army analysts had successfully applied OR techniques to a large variety of problems, including

> 1. determination of the operational requirements for, and the military characteristics of, new weapons and equipment; 2. cost and effectiveness studies which involve the determination of the relative costs in men, money, and materials to achieve desired results with competitive weapons systems and aim to ensure that research and development effort is placed on the most promising weapons, instead of being dissipated across the board; 3. weapons and equipment tests; 4. the tactical employment of new weapons systems; 5. economic and logistic studies which involve determination of the impact of weapons production on national resources, the costs at various production rates, and related logistics problems.[449]

Third, the lack of active combat operations following the end of the Korean War in 1953, and the growing costs of field exercises, forced OR analysts to rely increasingly on data derived from computer simulations and wargames.[450] Consequently, computer simulations and wargames became major methods in the combat development process and prompted the creation of such organizations as STAG.

Finally, there was a shift from approaching problems on a disciplinary basis to a focus on "the problems of policy, choice, and decision."[451] OR studies of such matters were best carried out by interdisciplinary teams, and OR analysts were obliged to employ a "rational, quantitative approach," which joined "the contributions of many disciplines in a cooperative effort."[452]

By 1962, the Army's operations research program had passed through the throes of adolescence and had reached a vigorous young adulthood. OR was generally accepted as a useful tool for the military decision maker and had proven itself in a wide variety of areas requiring analysis. The Army's OR capability had expanded in terms of both the number of active OR groups and the number of analysts employed. The Army was increasingly eager to incorporate the recommendations of OR analysts into the continuing process of development of weapons, equipment, organization, tactics, and strategy. On the whole, operations research in the Army was poised to make a mature contribution.

CHAPTER THREE NOTES

[1]Larry R. Tinberg, "Operations Research and the US Army," student essay, U.S. Army War College, Carlisle Barracks, Penn., 1983, p. 3; William F. Whitmore, "Military Operations Research—A Personal Retrospect," *Operations Research* 9, 2 (1961): 259.

[2]Donald W. Meals, "Trends in Military Operations Research," *Operations Research* 9, 2 (1961): 252.

[3]U.S. DOD, *Annual Report of the Secretary of Defense, July 1, 1958, to June 30, 1959*, in U.S. DOD, *Annual Report of the Secretary of Defense and the Annual Reports of the Secretary of the Army, Secretary of the Navy, Secretary of the Air Force, July 1, 1958, to June 30, 1959* (Washington: USGPO, 1960), p. 27.

[4]Edward M. Parker and David B. Parker, "Trial by Combat: Operations Research for the Army," *Combat Forces Journal* 1, 10 (51): 17; Seymour I. Gilman, "Operations Research in the Army," *Military Review* 26, 4 (1956): 56. DOD spending on OR was a part of the greatly increased spending on R&D during the period. In 1950, DOD spent about $1.1 billion on R&D; by 1963 that figure had grown to some $12.4 billion (see U.S. Congress, Office of Technology Assessment, *A History of the Department of Defense Federally Funded Research and Development Centers*, Background Paper OTA-BP-ISS-157 [Washington: USGPO, 1995], p. 20 [hereafter cited as OTA History]).

[5]Ellis A. Johnson, "The Long-Range Future of Operational Research," *Operations Research* 8 (Jan–Feb 60): 15; Ellis A. Johnson, "A Survey of Operations Research in the U.S.A.," *Operations Research* 5, 2 (Jun 54): 43.

[6]Johnson, "Survey of OR," p. 43. In 1954, the government was spending annually approximately $20,000 per OR analyst, including salary, travel, technical and administrative support, and overhead (see Gilman, "OR in the Army," p. 56).

[7]William T. Bradley, "Operations Research in the Armed Services," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1957, p. 6; Johnson, "Long-Range Future," p. 15; Johnson, "Survey of OR," p. 43.

[8]ORO, *Semiannual Report 1950*, vol. III, no. 2 (Fort McNair, Washington, 31 Dec 50), p. 5.

[9]Thornton L. Page, George S. Pettee, and William A. Wallace (assisted by Capt James Martin, USNR, and Alice L. Johnson), "Ellis A. Johnson, 1906–1973," *Operations Research* 22, 6 (1974): 1150.

[10]Ibid.; Herbert Yahraes, "The Mysterious Mission of ORO," *Saturday Evening Post*, 23 Feb 52.

[11]Eugene P. Visco, "The Operations Research Office" (PB–20–96–3), *Army History* 38 (Summer 1996): 27; ORO, *Semiannual Rpt 1950*, vol. III, no. 2, p. 5; Yahraes, "Mysterious Mission," p. 3.

[12]ORO, *Semiannual Rpt 1950*, vol. III, no. 2, p. 5.

[13]Visco, "ORO," p. 27.

[14]William L. Whitson, "The Growth of the Operations Research Office in the U.S. Army," *ORSA Journal* 8, 6 (1960): 812. ORO personnel in the Far East Command were given simulated ranks and served in uniforms with special badges.

[15]OTA History, p. 21. ORO analyst Sam W. Marshall (not to be confused with S. L. A. Marshall) and his pilot, Maj. Edward G. Kelly, were shot down 25 miles inside the North Korean lines but were rescued (see Yahraes, "Mysterious Mission," p. 10).

[16]Ltr, Lowell J. Reed (president, JHU) to Ellis A. Johnson (director, ORO), Baltimore, 11 May 55,JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR/ORO, Jan–Dec 55.

[17]Selwyn D. Smith, Jr., "An Evaluation of Army Operations Research," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1957, p. 20.

[18]Whitson, "Growth of ORO," p. 812; Yahraes, "Mysterious Mission," pp. 9–10; Florence N. Trefethen, "The History of Operations Research," JHU-ORO Informal Seminar in Operations Research, 1952–53, Baltimore, 1953, p. 17.

[19]ORO, *Semiannual Rpt 1950*, vol. III, no. 2, pp. 6–7; Parker and Parker, "Trial by Combat," p. 16.

[20]ORO, *Semiannual Rpt 1950*, vol. III, no. 2, p. 5.

[21]Trefethen, "History of OR," in Joseph F. McCloskey and Florence N. Trefethen, eds., *Operations Research for Management* (Baltimore: Johns Hopkins University Press, 1954), p. 27. The B–29 was fully equipped with up-to-date navigation and radar equipment, which made it well suited for night operations. Pertinent ORO studies included *Preliminary Evaluation of Close Air Support Operations in Korea* (ORO–R–3–FEC, Aug 51), *A Study of the Effectiveness of Air Support Operations in Korea* (ORO–T–13–FEC, Nov 51), and *Effectiveness of Radar-Controlled Night Bombing* (ORO–T–33–FEC, Nov 52). Close air support was also studied by DOD WSEG. In early September 1950, then Brig. Gen. James M. Gavin led a WSEG team, including the distinguished scientists Charles Lauritsen, William B. Shockley, and Edward Bowles, to Korea to study close air support (see James M. Gavin, *War and Peace in the Space Age* [New York: Harper & Brothers, 1958], pp. 129–30).

[22]Lorna Jaffe, *Quantitative Analysis and Army Decision Making* (Alexandria, Va.: U.S. Army Materiel Development and Readiness Command Historical Office, Dec 84), p. 10. The pertinent ORO study was *Tactical Employment of Atomic Weapons* (ORO–R–2–FEC, Jul 51).

[23]Yahraes, "Mysterious Mission," pp. 10–11. The pertinent ORO study was *The Employment of Armor in Korea* (ORO–R–1–FEC, 2 vols., Jul–Aug 51).

[24]Trefethen, "History of OR," p. 18.

[25]Paul Linebarger, *Possible Operations Research in FEC Psychological Warfare*, ORO–T–2–FEC, Tokyo JHU ORO, 16 Sep 50, p. 3.

[26]Trefethen, *History of OR," p. 18.* Among the many pertinent ORO studies were *"An Evaluation of PSYWAR Influence on North Korean Troops* (ORO–T–12–FEC, 1951), *An Evaluation of PSYWAR Influence on Chinese Communist Troops* (ORO–T–16–FEC, 1951), *Eighth Army Psychological Warfare in the Korean War* (ORO–T–17–FEC, 1951), and *Psychological Warfare and Other Factors Affecting the Surrender of North Korean and Chinese Forces* (ORO–T–40–FEC, 1953).

[27]Jaffe, *Quantitative Analysis*, pp. 9–10. For example, one result of the ORO's efforts was that psychological operations came to be regarded in FEC as a weapon rather than as an intelligence application, and the responsibility for psyops was transferred from FEC G-2 (Intelligence) to G-3 (Operations). See Trefethen, "History of OR," p. 18.

[28]OTA History, p. 21. The several studies produced by Marshall included *Notes on Infantry Tactics in Korea* (ORO–T–7–EUSAK, 1951).

[29]Jaffe, *Quantitative Analysis*, p. 9.

[30]Ibid., p. 10.

[31]U.S. Department of the Army, *Army Regulations No. 15–480: BOARDS, COMMISSIONS, AND COMMITTEES—Operations Research Office* (Washington: HQ, DA, 4 Apr 51), para. 2. *AR 15–480* was reissued several times during the period; the last version was issued on 11 April 1961.

[32]ORO, *ORO Today: Why the Operations Research Office Has Been Reorganized and What It Is Doing* (Chevy Chase, Md.: ORO, 1955), p. 15. The details of the reorganization were laid out in an internal staff memo, *Reorganization of ORO, 1954* (ORO–S–422; 1954).

[33]Ibid., pp. 15–16.

[34]ORO, *ORO Today*, p. 13.

[35]Ibid.

[36]ORO, *ORO Today*, pp. 14–15.

[37]The Technical Council was composed of all the ORO officers down through the division chiefs and other senior staff members designated by the director. The council monitored research quality and advised the director on problems of ORO policy affecting the research program.

[38]ORO, *ORO Today*, p. 15. For a time, Ellis Johnson experimented with the use of analysts as personnel managers, but he soon shifted to professional personnel managers (personal communication, Eugene P. Visco to the author, Nov 03).

[39]The initial mission, organization, and functions of the Tactics Division are outlined in ORO, *ORO Today*, p. 8.

[40]Philip H. Lowry, Tactics Division, in ORO, *A Discussion of the ORO Work Program*, ORO–SP–71, Chevy Chase, Md., ORO, 1958, p. 19.

[41]The initial mission, organization, and functions of the Strategic Division are outlined in ORO, *ORO Today*, p. 10.

[42]The initial mission, organization, and functions of the Logistics Division are outlined in ORO, *ORO Today*, p. 9.

[43]Responsibility for civil affairs and military government was transferred to the Strategic Division by 1958.

[44]The initial mission, organization, and functions of the Intelligence Division are outlined in ORO, *ORO Today*, p. 11.

[45]The initial mission, organization, and functions of the Home Defense Division are outlined in ORO, *ORO Today*, p. 11.

[46]James H. Henry, "Air Defense Division," in ORO "Discussion of ORO Work Program," 1958, pp. 51–54.

[47]The initial mission, organization, and functions of the Field Division are outlined in ORO, *ORO Today*, p. 13.

[48]ORO, *ORO Today*, pp. 28–29.

[49]Ibid., p. 28. There was apparently also an OR section at Headquarters, United States European Command, in Stuttgart, Germany, that was not an adjunct of ORO (see Page and others, "Ellis A. Johnson," p. 1151).

[50]On Hugh Cole and his team at the ORO-USAREUR, see the oral history interview with Cole by Dr. Wilbur Payne, 8 Mar 89, conducted as part of the Office of the Deputy Under Secretary of the Army for Operations Research Oral History Project. Cole himself was the author of the volume on the Lorraine campaign in the official Army history of World War II.

[51]Emmette Y. Burton, Jr., "The Role of Operations Research in the Army," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1955, pp. 10–11.

[52]ORO, *ORO Today*, p. 29. The subsequent transformation of the ORO field office at Fort Monroe into the Combat Operations Research Group (CORG) is discussed in detail in Chapter 4 of this volume.

[53]Ltr, Ellis A. Johnson (director, ORO) to ACS, G-3, Operations, U.S. Army, Washington 13 Feb 52, sub: Relation of ORO with the University, p. 1, JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR/ORO, Jan 51–Jun 52.

[54]Memo, Baltimore, 26 Jun 51, sub: Plan for the Establishment of ORO as a Separate Division of JHU as of 1 Jul 51, JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR/ORO, Jan 51–Jun 52. The memo also addressed fiscal and personnel issues as well as the responsibilities of the ORO director.

[55]Whitson, "Growth of ORO," p. 811, Figure 2.

[56]Ltr, Johnson to ACS, 13 Feb 52, p. 2.

[57]Whitson, "Growth of ORO," p. 811.

[58]Joseph DiMarzo (secretary, JHU Advisory Board for ORO), Min of the First ORO-JHU Advisory Board Meeting, Chevy Chase, Md., 12 Jun 52, p. 2, JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR/ORO, Jan 51–Jun 52.

[59]Responsibility for ORO oversight was assigned by paragraph 3 of the successive editions of *AR 15–480*.

[60]See paragraph 4 of the successive editions of *AR 15–480*.

[61]The organization and functions of the PAGs were prescribed in paragraph 6 of the successive editions of *AR 15–480*. PAG missions, relationships, functions, and procedures were set forth in greater detail in Ltr, Col Herbert W. Mansfield (chief Operations and Personnel Research Div, OCRD) to "See Distribution," Washington, 18 Nov 55, sub: Amplification of Functions, Department of the Army PAGs for the ORO, College Park, Md., U.S. NARA II, RG 456 (formerly RG 337), Entry 1033, Box 116 of 154, Folder 334 ORO. Normally, PAGs were established to work with each ORO group (for example, the Infantry Group in the Tactics Division).

[62]Whitson, "Growth of ORO," p. 812.

[63]Ibid., pp. 811–12; Ellis A. Johnson, "Introduction," in ORO, "Discussion of ORO Work Program," pp. 10, 13, Figure 12.

[64]As early as 1953, the advertisements for ORO employment in *The Journal of the Operations Research Society of America* listed anthropology, biology, economics, experimental psychology, geography, history, international relations, medicine, political science, social psychology, and sociology as "fields or disciplines, among others, actively represented on [ORO's] professional staff" (personal communication, Eugene P. Visco to the author, Nov 2003).

[65]U.S. Army Ordnance Corps, Office of Ordnance Research, *Proceedings of the First Ordnance Conference on Operations Research*. Office of Ordnance Research Rpt No. 55–1 (Durham, N.C.: Office of Ordnance Research, Ordnance Corps, Jan 55), p. 86.

[66]Parker and Parker, "Trial by Combat," p. 16.

[67]ORO, *Revised Summary of ORO Projects, Special Studies, and Field Operations to May 31, 1952, Volume I* (Chevy Chase, Md.: ORO, 28 Jul 52), p. iii.

[68]Lynn H. Rumbaugh, "A Look at US Army Operations Research—Past and Present," Combat Systems Technical Paper RAC–TP–102 (McLean, Va.: Research Analysis Corporation, Apr 64), p. 8, Table 1, n. b.

[69]Seymour I. Gilman, "The Role of Operations Research in the Army," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1954, p. 41, Annex 1.

[70]Rumbaugh, "Look at US Army OR," p. 8, Table 1. At the same time, the total number of professional OR analysts employed by the five principal Army OR establishments (RAC, HumRRO, SORO, CORG, and the OR office at CDEC) was 411. Of 272 analysts who joined ORO between 1956 and 1961, thirty—more than 10 percent—were women (see Visco, "The ORO," p. 29).

[71]Hugh M. Cole, "Selection and Training of Operational Research Scientists," in Max Davies and Michel Verhulst, eds., *Operational Research in Practice: Report of a NATO Conference* (New York: Pergamon Press for Advisory Group of Aeronautical Research and Development, NATO, 1958), p. 175. The average age of ORO analysts in 1956 was 35, versus 40 for the first analysts hired by ORO in 1948 (see Cole, "Selection and Training," p. 174).

[72]Page and others, "Ellis A. Johnson," p. 1151.

[73]In 1955, the permanent ORO staff included one retired Army general, three retired Army colonels, a retired Air Force general, and a retired Navy admiral. Several high-ranking retired military personnel, including General Thomas Handy, were employed as consultants (see Burton, "Role of OR," p. 10).

[74]Burton, "Role of OR, p. 10.

[75]Whitson, "Growth of ORO," p. 812; Burton, "Role of OR," p. 10.

[76]Visco, "The ORO," p. 29.

[77]Page and others, "Ellis A. Johnson," pp. 1152–153.

[78]Cole, "Selection and Training," pp. 176–77.

[79]Smith, "Evaluation of Army OR," p. 16; Cole, "Selection and Training," p. 172.

[80]Cole, "Selection and Training," p. 176.

[81]ORO, *Fields of Knowledge and Operations Research*, ORO–SP–124, Bethesda, Md.: JHU ORO, Jan 60. The papers on the contributions of various disciplines to OR were originally presented in the November 1958–May 1959 Theoretical Panel Season at ORO.

[82]Macon Fry, "Criteria for Selecting Operations Research Personnel," in ORO, "Fields of Knowledge," p. 5.

[83]William L. Whitson, *The History of Operations Research (I)*, Seminar Paper 2, 15 Oct 52, JHU-ORO Informal Seminar in Operations Research, 1952–53, Baltimore, p. 7 (hereafter cited as Whitson, Seminar Paper 2).

[84]Cole, "Selection and Training," pp. 173–74. For some reason, according to Cole, sociologists did not make very good OR analysts.

[85]Johnson, "Long-Range Future," pp. 10–11.

[86]Cole, "Selection and Training," pp. 172–73.

[87]Many of the most famous ORO personalities are discussed by Eugene Visco in "The ORO," pp. 28–30.

[88]"Made Associate Director of Operations Research," *New York Times*, 25 Apr 51.

[89]ORO, *ORO Biographies*, vol. II (Chevy Chase, Md.: ORO, various dates, 1957–63).

[90]ORO, *ORO Biographies*, vol. I.

[91]Visco, "The ORO," pp. 29–30.

[92]ORO, *ORO Biographies*, vol. I.

[93]Ibid., vols. I, II; Visco, "The ORO," p. 29.

[94]Ltr, Thornton L. Page to Bill Pitts, Houston, Texas, after 30 May 87, reproduced on the Computer UFO Network at http://www.cufon.org. The committee was headed by Howard P. Robertson, a mathematical physicist who had served in the AAF operations analysis program in WWII, and included, among others, Luis Alvarez who subsequently won a Nobel Prize in physics. Thornton Leigh Page was born in 1913 and was educated at Yale University (B.S., 1934) and Oxford University (Ph.D. in astrophysics, 1938). Following WWII service as both a civilian and a lieutenant commander, USNR, in the Navy OR program, he was a professor of astrophysics at the University of Chicago (1946–50). Following his service with ORO (1951–58), he taught astronomy at Wesleyan University (1958–68) and was associated with the NASA Manned Spacecraft Center

in Houston, Texas; the Naval Research Laboratory; the University of Houston and Wesleyan University; and several commercial aircraft firms. A friend of the well-known astronomer Carl Sagan, Page became the resident expert on UFOs at NASA after he moved to the Johnson Space Flight Center in Houston in 1968. He died in 1996.

[95]Margaret Emerson, ORO technical librarian, remembered Kissinger as "sort of a Harvard graduate student in tennis shoes." See the oral history interview of Margaret Emerson by Eugene P. Visco, 7 Nov 99, conducted as part of the Deputy Under Secretary of the Army for Operations Research Oral History Project.

[96]Yahraes, "Mysterious Mission," p. 5. Visco ("The ORO," pp. 27–28) gave a very detailed account of the Chevy Chase and Bethesda facilities, an account that I have followed closely here.

[97]The "science" in question was domestic science. One room in the Science Building was elegantly equipped with a large crystal chandelier, hung to about 7 feet from the floor. The room had been used to teach young ladies how to set a formal dining table (personal communication of Eugene P. Visco with the author, Sep 03).

[98]A summary of the early negotiations between the Army and the university can be found in "Report on Proposed Building for ORO," (Chevy Chase, Md. [*?*], before 30 Jun 57), which contains copies of correspondence on the matter among ORO, the Army chief of research and development, and JHU (in JHU Archives, Records of the Office of the President, Series I, Box 34, Folder 47.2 ICR/ORO, Jan–Dec 57).

[99]Personal communication of Eugene P. Visco with the author, 25 Jul 03. Visco was an ORO employee at the time.

[100]Personal communication of Eugene P. Visco with the author, 11 Sep 03.

[101]Ordnance Corps, *Proceedings*, p. 86.

[102]U.S. Army RDB Project Card (RCS CSPRD–1), OR, Project No. 0–97–01–002, dated 31 Dec 55 (copy in Smith, "Evaluation of Army OR, Annex 7, pp. 60–63).

[103]Lester D. Flory, *Analysis of the ORO Research Program with Respect to Timeliness*, ORO–TP–16, Bethesda, Md., ORO, Nov 60, p. 11, Table 2.

[104]Whitson, "Growth of ORO," p. 809. The $11 million did not include direct costs and contracting costs for OR establishments in the technical services.

[105]Ibid., p. 812.

[106]Charles A. H. Thomson, *The Research Analysis Corporation: A History of a Federal Contract Research Center* (McLean, Va.: Research Analysis Corporation, Jun 75), p. 14.

[107]The evolution of the ORO research program in the early 1950s is covered in some detail in Flory, "Analysis of the ORO Research Program," pp. 20–23. Unless otherwise noted, the following account is drawn from Flory's study.

[108]Project MAID dealing with the military aid program was completed before the "balanced program" went into effect. The balanced program is usually said to have had only fifteen projects. That number does not account for the two later additions.

[109]Flory, "Analysis of the ORO Research Program," p. 21. Projects ANALAA, ARMOR, TREMABASE, GUNFIRE, ALCLAD, POWOW, and DONKEY were already under way as of 31 December 1950.

[110]Page and others, "Ellis A. Johnson," p. 1152.

[111]A detailed description of the work projects pursued by each of the five ORO divisions and BRAND can be found in ORO, *ORO Today*, pp. 18–29.

[112]Flory, "Analysis of the ORO Research Program," p. 23. The 17 standing projects were rescinded, and the FY55 program included 154 study projects, of which 40 were never initiated, were suspended, or showed no progress.

[113]Ibid., p. 21.

[114]Rumbaugh, "Look at US Army OR," p. 7.

[115]The new annual ORO work program usually went into effect on 1 November of each year.

[116]Visco, "The ORO," p. 32.

[117]Smith, "Evaluation of Army Operations Research," p. 13a. Ellis Johnson was convinced that approximately 10–15 percent of the total effort of major OR establishments should be devoted to "long-range investment in basic operational research" (see Johnson, "Long-Range Future," p. 22), and one of his major achievements as director of ORO was the creation of the OPSEARCH Group in the Strategic Division to conduct such basic research in OR methods and techniques.

[118]Whitson, "Growth of ORO," p. 820; Johnson, "Introduction," p. 11. The "search" was for the "best" direction to pursue to find the solution to a given problem. Put another way, "search" studies were about defining the problem.

[119]Whitson, "Growth of ORO," p. 820.

[120]In 1958, the ORO director estimated that about 80 percent of ORO recommendations were eventually adopted by the Army (see Johnson, "Introduction," p. 5).

[121]U.S. Department of the Army, *Semiannual Report of the Secretary of the Army for the Period January 1 to June 30, 1952* (hereafter cited as *Semiannual Rpt of the Sec Army*), in U.S. DOD, Office of Public Affairs, *Semiannual Report of the Secretary of Defense and the Semiannual Reports of the Secretary of the Army, Secretary of the Navy, Secretary of the Air Force, January 1 to June 30, 1952* (Washington: USGPO, 52), p. 86.

[122]Ellis A. Johnson and others, *Defense of the US Against Attack by Aircraft and Missiles*, ORO–R–17, Bethesda, Md., ORO, Aug 57.

[123]See Alfred Wohlstetter, *An Appraisal of ORO's Defense Study, R-17* (Santa Monica, Calif.: RAND Corporation, Feb 58), and George S. Pettee, *Comments upon an Appraisal of ORO's Defense Study, ORO–R–17* (Bethesda, Md.: ORO, May 58).

[124]Page and others, "Ellis A. Johnson," p. 1152; Johnson, "Introduction," p. 6.

[125]See, among others, Howard Brackney, Jerome B. Green, Lynn H. Rumbaugh, and Solomon H. Turkel, *Tactical Employment of Atomic Weapons*, ORO–R–2–FEC, Fort McNair, Washington, ORO, Jul 51; and Lynn H. Rumbaugh, Jerome B. Green, Solomon H. Turkel, and Edward G. Kelley, *The Tactical Employment of Atomic Weapons in the Defense of Central Europe—Summary Report*, ORO–R–1–EUCOM, Chevy Chase, Md., ORO, Oct 54.

[126]See Vincent V. McRae and Philip H. Lowry, *Requirements for Army Air Defense Nuclear Weapons*, ORO–T–387, Bethesda, Md., ORO, Jun 60; Macon Fry and others, *Volume I: Nuclear Reactor Power Plants for Aircraft Control and Warning Stations in the Arctic*, ORO–R–15 (Chevy Chase, Md. ORO, Nov 54); and Kay Bartimo and others, *Volume II: Nuclear Power Plants for Military Use Overseas*, ORO–R–15 (Chevy Chase, Md.: ORO, Jul 56).

[127]Alfred H. Hausrath, "Utilization of Negro Manpower in the Army," *Journal of the Operations Research Society of America* 2, 1 (54): 18–19.

[128]Burton ("Role of OR," pp. 17–20) provided a good outline of the study and its results, which I have followed closely here. See also Page and others, "Ellis A. Johnson," p. 1152; Johnson, "Introduction," p. 6.

[129]Hausrath, "Utilization of Negro Manpower," pp. 17n, 20–23. The ORO team included Hausrath, S. G. Billingsley, Joseph F. McCloskey, L. Van Loan Naiswald, N. K. Nierman, and Florence N. Trefethen. Subcontractors included International Public Opinion Research, Inc.; the American Institute of Research; and the Bureau of Applied Social Science Research of Columbia University.

[130]Alfred H. Hausrath and others, *The Utilization of Negro Manpower in the Army*, ORO–R–11 (Chevy Chase, Md.: ORO, Apr 55).

Dr. Hausrath himself summarized the results of the study in "Utilization of Negro Manpower," pp. 17–34 (reprinted in Joseph F. McCloskey and Florence N. Trefethen, eds., *Operations Research for Management* [Baltimore: Johns Hopkins University Press, 1954], pp. 353–67).

[131]Hausrath, "Utilization of Negro Manpower," p. 29.

[132]Murray Dyer and Julius Segal, *The POWOW TMs: An Assessment of ORO Psywar Research*, ORO–SP–51, Chevy Chase, Md., ORO, 13 Jun 56, pp. 1, 4. Dyer and Segal discussed in detail the ORO publications on psychological warfare produced as part of Project POWOW.

[133]Smith, "Evaluation of Army OR," p. 17.

[134]The most prominent of the ORO studies on psychological warfare at the strategic level is Murray Dyer, *Political Communication as an Instrument of State, Volumes I and II*, ORO–R–18 (Bethesda, Md.: ORO, Jun 57).

[135]U.S. Department of the Army, *Semiannual Report of the Secretary of the Army, for the Period January 1 to June 30, 1951* (hereafter cited as *Semiannual Rpt of Sec Army*), in U.S. DOD, Office of Public Affairs, *Semiannual Report of the Secretary of Defense and the Semiannual Reports of the Secretary of the Army, Secretary of the Navy, Secretary of the Air Force, January 1 to June 30, 1951* (Washington: USGPO, 1951), p. 92.

[136]Johnson, "Introduction," p. 7.

[137]Page and others, "Ellis A. Johnson," p. 1152; Johnson, "Introduction," p. 7.

[138]The role played by ORO in the development of the M16 rifle is described in Edward C. Ezell, *The Great Rifle Controversy—Search for the Ultimate Infantry Weapon from World War II through Vietnam and Beyond* (Harrisburg, Penn.: Stackpole Books, 1984) and summarized on the M16 Series Rifle Webpage: http://mwilson.hypermart.net/views/guns/m16.html (© David L. Velleux, 1997). See also Visco, "The ORO," pp. 31–32.

[139]ORO research included extensive interviews with infantrymen in Korea during the Korean War.

[140]Visco, "The ORO," p. 31.

[141]See Howard McFann and others, *Trainfire I: A New Course in Basic Rifle Marksmanship*, GWU–HRRO–TR–22 (Washington: HumRRO-GWU, Oct 55). The pop-up targets, a key feature of the TRAINFIRE system, were nicknamed "Cocky Kens" after Dr. Kenneth Yudowitch, a member of the ORO team that did the initial analysis (see Visco, "The ORO," p. 32).

[142]Smith, "Evaluation of Army OR," p. 35.

[143]Gilman, "Role of OR in the Army," p. 26.

[144]Smith, "Evaluation of Army OR," p. 15.

[145]Whitson, "Growth of ORO," p. 816.

[146]Johnson, "Introduction," p. 7.

[147]Whitson, "Growth of ORO," p. 815. Reports rated "fair" were simply those that did not make a contribution.

[148]Ibid., p. 816, Figure 6.

[149]Ellis A. Johnson, *Publications and Briefings for the Army: A Policy Directive to Division Chiefs—Information to Research Staff* (Bethesda, Md.: ORO, 1959).

[150]Ibid., p. i.

[151]Ibid., pp. 6–7

[152]Ibid., p. 12.

[153]Ibid., p. 19.

[154]Ibid., p. 20.

[155]Ibid.

[156]Thomson, *Research Analysis Corporation*, p. 15.

[157]Ibid., p. 15.

[158]Ibid.

[159]Quoted in Flory, "Analysis of the ORO Research Program," p. 3.

[160]Ibid., p. 19.

[161]Ibid., pp. 9–15; Memo, Lester D. Flory (executive director, ORO) to Division Chiefs, Bethesda, Md., 8 Jul 1960, sub: Analysis of Research Program (reproduced in Flory, "Analysis of the ORO Research Program," p. 24, Appendix B).

[162]Flory, "Analysis of the ORO Research Program," p. 19.

[163]Ibid., pp. 3–4.

[164]Johnson, "Introduction," p. 90.

[165]Ltr, Ellis A. Johnson (director, ORO) to Brig Gen Andrew P. O'Meara (CRD), Bethesda, Md., 31 Aug 1955 (quoted in Flory, "Analysis of the ORO Research Program," p. 5).

[166]Ltr, Brig Gen Andrew P. O'Meara (CRD) to Ellis A. Johnson (director, ORO), Washington, 19 Sep 1955 (quoted in Flory, "Analysis of the ORO Research Program," p. 5).

[167]Burton, "Role of OR," p. 27.

[168]Ibid., p. 28.

[169]Gilman, "Role of OR in the Army," pp. 28–30.

[170]Burton, "Role of OR," p. 30. Burton noted that "the time from date of publication of a particular ORO study to the date of its evaluation by Department of the Army has been too long. The longest time noted in my examination was 1 1/2 years and the shortest was 5 months" (pp. 24–25).

[171]Bradley, "OR in the Armed Services," p. 47.

[172]Ibid., pp. 49–50.

[173]Thomson, *Research Analysis Corporation*, p. 12.

[174]Smith, "Evaluation of Army OR," p. 35.

[175]Ibid., p. 37.

[176]Some of the special services performed by ORO are listed in Flory, "Analysis of the ORO Research Program" p. 28, Appendix D.

[177]Page and others, "Ellis A. Johnson," p. 1153. The internal seminars were suspended during the summer months inasmuch as ORO generally ran on a university-like schedule and because the ORO facilities were not air conditioned.

[178]Visco, "The ORO," p. 30.

[179]Ibid.

[180]Emerson interview, 7 Nov 99.

[181]Ibid.

[182]Thomson, *Research Analysis Corporation*, p. 13.

[183]Page and others, "Ellis A. Johnson," p. 1151.

[184]The ORO liaison officer was a practicing analyst who participated actively in ongoing studies. Ellis Johnson's collaborators included H. Anthony (Tony) Sargeaunt and Owen Wansborough-Jones in Britain and Omand Solandt in Canada (see Page and others, "Ellis A. Johnson," p. 1151). For a brief but interesting summary of the relationship of British and American OR teams in Korea, see K. Pennycuick, "Army Operational Research in the Far East," *Operational Research* 5, 4 (1954): 120–29. The small (three-man) British ORS Korea, which was informally combined with the small Canadian OR team, was attached to the Operations Research Office at Headquarters, Far East Command, and worked mostly on problems of equipment and weapons systems.

[185]The Tripartite Conferences were later renamed the ABC Discussions on Army Operational Research.

[186]Comments of G. Neville Gadsby, Session III, "The Organization of an Operations Research Group for Military Service," in ARO (Durham), *Executive Summary—United States Army Operations Research Symposium Conducted by Army Research Office (Durham) at Duke University, 27, 28, 29 March 1962* (Research Triangle Park, N.C.: Research Triangle Institute for ARO [Durham], 1962), pp. 87–89. On the organization of military OR in the United Kingdom as of late 1957, see also G. Neville Gadsby, "Organization for Operational Research in the United Kingdom," in Davies and Verhulst, *Operational Research in Practice*, pp. 154–62; and Pennycuick, "Army OR," pp. 120–29.

[187]Comments of Henry H. Watson, Session III, "The Organization of an Operations Research Group for Military Service," in ARO (Durham), *Executive Summary*, pp. 78–81. See also R. H. Lowe, "Operational Research in the Canadian Department of National Defence," *Journal of the Operations Research Society of America* 8 (Nov-Dec 60): 847–56.

[188]Watson, "Organization of an ORG," p. 80.

[189]For example, France established an OR group in every major military staff (National Defense Staff, Armed Forces Staff, and the Army, Navy, and Air Force staffs) using scientists drafted for national service (see the comments of Commandant André J. H. Mensch, in ARO [Durham], *Executive Summary*, pp. 75–77). For a summary of the status of OR in various NATO countries as of late 1957, see "The Status of Operational Research in NATO Nations," in Davies and Verhulst, eds., *Operational Research in Practice*, pp. 20–22; Thornton Page, "Letters to the Editor—Military Operations Research in NATO," *Operations Research* 4, 4 (1956): 482–84; and H. A. Sargeaunt, "Future Fields for Operational Research in the NATO Countries," in Davies and Verhulst, eds., *Operational Research in Practice*, pp. 181–94.

[190]Bradley, "OR in the Armed Services," pp. 5–6.

[191]"The Meaning and Function of Operational Research," in Davies and Verhulst, eds., *Operational Research in Practice*, p. 1. In addition, NATO established an Advisory Panel on Operational Research that also sponsored conferences on OR topics.

[192]Ibid.

[193]Théodore von Kármán (chairman, NATO Advisory Group, Aeronautical Research and Development), "Introduction," in Davies and Verhulst, eds., *Operational Research in Practice*, p. ix; Page, "Letters to the Editor," p. 483.

[194]"Meaning and Function," p. 1.

[195]Gen. Lauris Norstad, "Foreword," in Davies and Verhulst. eds., *Operational Research in Practice*, p. vi.

[196]Page, "Letters to the Editor," p. 482.

[197]Ibid.

[198]Ibid.; "Status of Operational Research in NATO Nations," p. 22. The Turkish OR group was supported by professional OR analysts from the other NATO countries. For example, George Hoffman worked with the Turks under the AGARD exchange program, as did Edward Paxson from RAND. The Turks focused primarily on logistic support and air defense problems.

[199]Page, "Letters to the Editor," p. 482.

[200]Comments of Dr. Erik Klippenberg," in ARO (Durham), *Executive Summary*, pp. 71–74. The permanent members of the Norwegian OR group were civilians, but military officers formed approximately 15–20 percent of the scientific staff, being seconded to Norwegian Defence Research Establishment for the duration of a given project. See also the comments of Dr. F. Möller in "Status of Operational Research in NATO Nations," p. 22.

[201]ARO (Durham), *Executive Summary*, pp. 71–74.

[202]Ibid., pp. 73–74.

[203]Erik Peter Rau, "Combat Scientists: The Emergence of Operations Research in the United States in World War II" (PhD diss., University of Pennsylvania, 1999), p. 339.

[204]See Trefethen, "History of OR," pp. 30–33.

[205]Johnson, "Survey of OR," pp. 45–46.

[206]Ordnance Corps, *Proceedings*, p. 81.

[207]Trefethen, "History of OR," p. 33.

[208]Ibid., pp. 33–34.

[209]Ibid.

[210]Johnson, "Survey of OR," p. 47.

[211]Ibid.; ARO (Durham), *Executive Summary*, p. 9.

[212]The history of the Operational Research Club is summarized by Nigel Cummings in "How the World of OR Societies Began," *OR Newsletter* (Apr 1997). See the Operational Research Society Web site, http://www. orsoc.org.uk.

[213]Cummings, "How OR Societies Began"; Trefethen, "History of OR," p. 34.

[214]Cummings, "How OR Societies Began." In 1978, the *ORQ* was renamed the *Journal of the Operational Research Society*, a monthly publication.

[215]Ibid. Membership leveled out at around three thousand in fifty-three countries in the early 1970s and has remained roughly the same since then.

[216]Since 1984, the Society has been a co-sponsor with the U.K. Ministry of Defence of an annual International Symposium on Military Operational Research, established to replace the symposia once sponsored by the NATO Advisory Panel on Operational Research.

[217]Trefethen, "History of OR," p. 34. In April 1951, the NRC Committee on Operations Research published *Operations Research with Special Reference to Non-Military Applications*, which described OR, its problems, and its personnel requirements. The committee also collected the names of approximately seven hundred people interested in OR (see Thornton L. Page, "The Founding Meeting of the Society," *Journal of the Operations Research Society of America* 1, 1 [1952]: 18).

[218]The "founding fathers" of the Operations Research Society of America, all members of the Formation Committee, were Philip M. Morse (chairman), John B. Lathrop (secretary/treasurer), Arthur A. Brown, Bonnar Brown, William J. Horvath, Ellis A. Johnson, George E. Kimball, Horace C. Levinson, Charles M. Mottley, George E. Nicholson, Jr., Thornton L. Page, Robert F. Rinehart, Hugh M. Smallwood, Jacinto Steinhardt, Frederick F. Stephan, Alfred N. Watson, and Lloyd A. Young (see Philip M. Morse, "The Operations Research Society of America," *Journal of the Operations Research Society of America* 1, 1 [1952]: 1–2).

[219]Page, "Founding Meeting," p. 18. The society was subsequently incorporated in the District of Columbia (see Morse, "Operations Research Society," p. 1).

[220]Trefethen, "History of OR," p. 35. *JORSA* was later renamed *Operations Research* and is now under the editorship of Dr. Lawrence Wein of the Sloan School of Management at MIT. *Operations Research* celebrated its fiftieth anniversary in 2002 (see INFORMS news release, "Respected Journal Celebrates 50th Year—Golden Anniversary of Organized Operations Research in America" [Linthicum, Md., 22 Mar 02]),

[221]Visco, "The ORO," p. 28. The seventy-one members and their affiliation are listed in "Members Attending the Founding Meeting," *Journal of the Operations Research Society of America* 1, 1 (1952): 26–27.

[222]Page and others, "Ellis A. Johnson," p. 1153.

[223]Ibid. An ORO analyst, Richard Zimmerman, won the Lanchester Prize in 1956 for his important paper on Monte Carlo modeling of combat.

[224]"The First National Meeting of the Society," *Journal of the Operations Research Society of America* 1, 2 (1953): 75.

[225]Johnson, "Survey of OR," pp. 43–44.

[226]Ibid.

[227]INFORMS news release, 22 Mar 02.

[228]M. C. Yovits and M. N. Chase, "The Role of the Military Operations Research Symposia (MORS) in the Operations Research Community," paper presented at Twenty-fourth National Meeting of the Operations Research Society of America, 7–8 Nov 63, pp. 1–5.

[229]Ibid., p. 2.

[230]The evolution of the Military Operations Research Symposia and of the Military Operations Research Society is summarized in Military Operations Research Society, *Index—Proceedings of Military Operations Research Symposia, Eleventh Through Twentieth Inclusive* (Military

Operations Research Society, Oct 68), p. i. See also Yovits and Chase, "Role of Military OR Symposia," pp. 1–5.

[231]The topics addressed in the first fourteen Military Operations Research Symposia are listed in Yovits and Chase, "Role of Military OR Symposia," p. 4.

[232]The actual transfer of responsibility for the symposia to the Office of Naval Research took place in September 1962 (see Yovits and Chase, "Role of Military OR Symposia," p. 3). The Executive Committee consisted of twenty-five members representing all military OR groups, one fourth of whom were replaced each year (see Yovits and Chase, p. 5). There were two symposium chairmen up to September 1962, both of whom were at ONR Pasadena: Dr. Charles DePrima (1957–60) and Dr. James E. Garvey (May 1960–September 1962) (see Yovits and Chase, p. 3).

[233]Yovits and Chase, "Role of Military OR Symposia," p. 4.

[234]Thomson, *Research Analysis Corporation,* 14. For example, Project SITE investigated effective methods and organization for Army training and education programs; Project TEAM sought to determine the important factors in interpersonal relationships and organizational motivation; and Project POWOW studied psychological operations.

[235]U.S. Department of the Army, Office of the Under Secretary of the Army, *Annual Report of the Office of the Under Secretary of the Army for the Period of 1 July 1950 to 30 June 1951* (Washington: DA, Jun 1951), p. 10.

[236]Ibid.; Meredith P. Crawford, *A Perspective on the Development of HumRRO* (Alexandria, Va.: George Washington University HumRRO, Apr 1968), p. 3. Dr. Crawford was the first director of HumRRO and served in that position for many years. His paper is a comprehensive summary of the origin and operation of HumRRO through 1967, and, unless otherwise noted, is the source of details in this account. The other principal source for the following account is a presentation by Dr. Bruce A. Braun to the Sixteenth Meeting of the Committee on Human Resources of the DOD Research and Development Board, Washington, 1–2 Nov 51, pp. 20–37 of the meeting transcript (in NARA II, RG 330, Entry 342, Box 24; also available at http://www.gwu. edu/~nsarchiv/radiation/dir/mstreet/commeet/meet8/brief8/tab_f/br8f1h.txt) (hereafter cited as Braun Presentation).

[237]Braun Presentation, p. 19.

[238]Meredith Pullen Crawford was born at Sweet Briar, Virginia, in 1911, was an undergraduate at Vanderbilt University, and received his doctorate in psychology from Columbia University. During WWII, he served in the Army's aviation research laboratory. He was director of HumRRO from 1951 to 1976, and was very active in the American Psychological Association. He died in Washington, D.C., on 21 May 2002.

[239]Braun Presentation, p. 23.

[240]Crawford, *Perspective on HumRRO*, p. 4.

[241]*Annual Report, Under Secretary of Army, 1 Jul 50 to 30 Jun 51*, p. 11.

[242]Braun Presentation, pp. 22–23.

[243]Early HumRRO budget data are discussed in Braun Presentation, p. 25.

[244]Paul Dickson, *Think Tanks* (New York: Atheneum, 1971), p. 148.

[245]Braun Presentation, p. 26.

[246]Braun Presentation, p. 26; Crawford, *Perspective on HumRRO*, p. 10.

[247]The annual salary for a new Ph.D. in experimental psychology rose from $6,000 in FY 1952 to around $11,550 in FY 1967 (see Crawford, *Perspective on HumRRO*, pp. 9–11).

[248]Crawford, *Perspective on HumRRO*, p. 1.

[249]Ibid., p. 19.

[250]Ibid., pp. 13–14.

[251]From 1965, the group was known as the HumRRO Policy Council.

[252]Dickson, *Think Tanks*, pp. 148–49.

[253]See McFann and others, *Trainfire I*. As noted above, ORO also played a key role in the development of the TRAINFIRE concept.

[254]James E. Hewes, *From Root to McNamara: Army Organization and Administration, 1900–1963* (Washington: U.S. Army Center of Military History, 1975), p. 403. The Office of the Chief of Psychological Warfare was redesignated as the Office of the Chief of Special Warfare on 6 November 1956, and that office was abolished and its functions transferred to the Special Warfare Directorate of the Office of the Deputy Chief of Staff for Operations on 1 June 1958.

[255]The story of the development by the Army of a research capability in the special warfare area is summarized in a thirteen-page staff study enclosed with Memo, Col George S. Blanchard (director of Special Warfare) to Maj Gen James D. Alger (ADCSOPS, HQDA), Washington, 10 Mar 64, sub: Special Operations Research Office (SORO), U.S. Army CMH, HRC, 400.112 SORO General (hereafter cited as SORO Staff Study). See also American University, Special Operations Research Office, *Fact Sheet on Special Operations Research Office (SORO)* (Washington: SORO, American University, 1 Mar 62), CMH, HRC 400.112 SORO General (hereafter cited as SORO Fact Sheet).

[256]SORO Staff Study, p. 2.

[257]Ibid., p. 1.

[258]Ibid., pp. 8–11.

[259]Ibid., p. 11.

[260]Ibid., p. 12; SORO Fact Sheet, p. 2.

[261]SORO Fact Sheet, p. 2; SORO Staff Study, p. 12.

[262]SORO Fact Sheet, p. 1.

[263]SORO Staff Study, p. 1.

[264]SORO Fact Sheet, p. 3.

[265]SORO Staff Study, p. 11.

[266]SORO Fact Sheet, p. 2.

[267]SORO Staff Study, p. 4.

[268]SORO Fact Sheet, p. 2.

[269]Notes prepared by Stetson Conn (chief historian, CMH), 28 Mar 1964, sub: Some Observations and Conclusions Concerning the Suggested Assignment of SORO's Special Area Studies Division to the Office of the Chief of Military History, CMH, HRC 400.112 SORO General.

[270]SORO Fact Sheet, p. 2

[271]Rumbaugh, "Look at US Army OR," p. 13.

[272]Considerations of space and focus permit only a brief synopsis of the development of the computer here. An excellent summary of that development (which I have followed closely) is provided by J. C. Ranyard, "A History of OR and Computing," *Journal of the Operational Research Society* 39, 12 (1988): 1073–86.

[273]Ranyard, "History of OR and Computing," p. 1073.

[274]Ibid.

[275]Ibid., pp. 1073–74.

[276]Ibid., p. 1074.

[277]On the development of ENIAC, see Ranyard, "History of OR and Computing," pp. 1073–74, and Martin H. Weik, "The ENIAC Story," *Ordnance* (Jan–Feb 61), available at http://www.ftp.arl. mil/~mike/comphist/eniac-story.html). See also Kevin W. Richey, "The ENIAC," available at http://www.ei.cs.vt.edu/~history/ENIAC.Richey.html.

[278]Before the advent of the electronic computer, calculations were done by hand, mostly by university-trained women who were known as "computers."

[279]Weik, "ENIAC Story." The initial contract was for $61,700, but the total eventually reached just over $486,800.

[280]Ibid. As newer, more-powerful and more-rapid electronic computers became available, ENIAC's workload was shifted to them. ENIAC was finally shut down at 11:45 p.m., 2 October 1955. It is now preserved partly at the Smithsonian Institution and partly at the U.S. Military Academy Museum.

[281]Ibid.

[282]Ranyard, "History of OR and Computing," p. 1074; Richey, "ENIAC."

[283]Weik, "ENIAC Story."

[284]Ranyard, "History of OR and Computing," p. 1074.

[285]Ibid.

[286]For example, the Apple II computer cost 40 times less than the 1967 PEGAGUS computer at Leeds University (see Ranyard, "History of OR and Computing," pp. 1081–82).

[287]Ibid., pp. 1073–74.

[288]Ibid., p. 1076.

[289]Ibid.

[290]Again, considerations of space and focus preclude a detailed history of the development of wargaming here. That development is cogently summarized in John P. Young, "A Brief History of War Gaming" (CORG Staff Memo No. 41, Fort Monroe, Va.: CORG, HQ, CONARC, 18 Oct 55), and I have followed it closely. See also Peter P. Perla, *The Art of Wargaming* (Annapolis, Md.: Naval Institute Press, 1990); Robert D. Specht, "War Games," in Davies and Verhulst, eds., *Operational Research in Practice*, pp. 144–53; Howard C. Walters, Jr., "The History of War Games," Chemical Corps Officer Career Course Historical Study (Fort McClellan, Ala., U.S. Army Chemical Corps School, 3 Apr 61); and Scott J. St. Clair, "Barriers to Using Models and Simulations," available at http://www.msiac.dmso.mil/journal/ltc_44_1.html). For a discussion of the technical aspects of wargaming, see Dean S. Hartley III, "Battle Modeling," in Saul I. Gass and Carl M. Harris, eds., *Encyclopedia of Operations Research and Management Science*, 2d (Centennial) ed. (Dordrecht: Kluwer Academic Publishers, 2001), pp. 53–57. The terms "simulation," "model," and "wargame" are used interchangeably here, although only the "wargame" genuinely involves the existence of two or more opposing players.

[291]Perla, *Art of Wargaming*, p. 17.

[292]Young, "Brief History of War Gaming," pp. 1–4.

[293]Ibid., p. 3.

[294]Ibid., pp. 3–4.

[295]Ibid., pp. 4–5.

[296]Ibid., pp. 4–6.

[297]Ibid., p. 6.

[298]Ibid., pp. 6–7.

[299]Ibid., p. 6.

[300]Ibid., pp. 7–9.

[301]Ibid., pp. 12–13.

[302]Ibid., p. 13.

[303]Specht, "War Games," pp. 144–45.

[304]Ibid., p. 145.

[305]A few American wargames were produced in the early nineteenth century, including Robert Smirk's *Review of a Battalion of Infantry* (1811); those of Capt. Douglas Brewerton during the Civil War; *War Chess, or The Game of Battle*, published by C. R. Richardson and Company in 1866; and the Reverend Wilhelm's *Militaire*, published in 1876 (see Young, "Brief History of War Gaming," p. 9).

[306]Young, "Brief History of War Gaming," pp. 9–11. *The American Kriegsspiel, A Game for Practising the Army of War Upon a Topographical Map* was published in Boston by the W. B. Clarke Company in 1898.

[307]Ibid., p. 9; Specht, "War Games," pp. 147–48.

[308]Young, "Brief History of War Gaming," p. 10. Lt. Totten's game was designed in 1880 but was not published until 1895.

[309]Ibid.; St. Clair, "Barriers," p. 2.

[310]Young, "Brief History of War Gaming," p. 10.

[311]For a brief insight into the Army's use of wargaming in the 1940s and early 1950s, see the Cole interview, 8 Mar 89.

[312]Walters, "History of War Games," pp. 17–18. Earlier, in 1927, John von Neumann had developed the basic mathematics of gaming, and in 1944, von Neumann and Oskar Morganstern published a complete exposition of game theory in *Theory of Games and Economic Behavior*, the scientific underpinning for sophisticated "operational gaming" (see Young, "Brief History of War Gaming," p. 14).

[313]Walters, "History of War Games," pp. 17–18.

[314]Comments of Dr. Merrill M. Flood, "Introduction," Session VII, "Application of Simulation Techniques to Tactical and Logistical Problems, in ARO (Durham), *Proceedings of the United States Army Operations Research Symposium, 26, 27, 28 March 1963, Durham, North Carolina, Part I*, ORTAG–25 (Durham, N.C.: ARO [Durham], 30 Sep 63), p. 165.

[315]Donald W. Meals, "Trends in Military Operations Research," *Operations Research* 9, 2 (1961): 254–55; Young, "Brief History of War Gaming," p. 1.

[316]Page and others, "Ellis A. Johnson," p. 1152. As noted in Chapter 2 of this volume, the mine warfare group at NOL, which included Johnson, Lynn Rumbaugh, and Thornton Page (all of whom would later be associated with ORO), had used wargaming techniques just before the Pearl Harbor attack to study countermining techniques.

[317]Joseph O. Harrison, Jr., Robert G. Hendrickson, Arla E. Weinert, Paul Iribe, and W. Bruce Taylor, *The Capabilities of Computers and the Use of Computers Operated and Maintained by ORO*, ORO Staff Memo ORO–S–514, Chevy Chase, Md., ORO, 2 May 55, p. i.

[318]Ibid., p. ii; George Gray, "The UNIVAC 1102, 1103, and 1104," *Unisys History Newsletter* 6, 1 (2002).

[319]Gray, "UNIVAC."

[320]The UNIVAC 1103 was frequently down for mechanical reasons. Burnt-out vacuum tubes were a particular problem.

[321]Gray, "UNIVAC."

[322]Ibid.

[323]Nicholas M. Smith, "Strategic Division," in ORO "Discussion of ORO Work Program," p. 79.

[324]Ibid.

[325]Ibid., p. 80, Figure 77.

[326]Ibid., p. 79.

[327]Whitson, "Growth of ORO," p. 821.

[328]Ibid., p. 822. Eugene P. Visco recalled that, in the fall of 1956, the "final exam" for the analyst's computer course was to write a program to compute the arithmetic mean of a set of about ten two-digit numbers (personal communication with the author, Nov 03).

[329]Whitson, "Growth of ORO."

[330]Ibid., p. 810; ORO, *ORO Today*, p. 14.

[331]Ellis A. Johnson, "Conclusion and Summary," in ORO, "Discussion of ORO Work Program," p. 85.

[332]Johnson, "Introduction," p. 11.

[333]Smith, "Strategic Division," pp. 72–73; Johnson, "Conclusion and Summary," p. 85.

[334]ORO, *ORO Today*, p. 25.

[335]Smith, "Strategic Division," pp. 74, l76–77.

[336]Ibid., pp. 72–73.

[337]ORO, *ORO Today*, pp. 20–21.

[338]Lowry, "Tactics Division," pp. 25–26.

[339]Ibid., p. 26.

[340]The principal architect of Carmonette was Richard E. Zimmerman (see Richard E. Zimmerman, "A Monte Carlo Model for

Military Analysis," in Joseph E. McCloskey and John M. Coppinger, eds., *Operations Research for Management*, vol. II [Baltimore: Johns Hopkins University Press, 1956]).

[341]Seth Bonder, "Army Operations Research—Historical Perspectives and Lessons Learned," *Operations Research* 50, 1 (2002): 26.

[342]ORO, *ORO Today*, p. 27.

[343]William J. Merchant, "Intelligence Division," in ORO, "Discussion of ORO Work Program," p. 30.

[344]Ibid.

[345]Ibid., p. 32.

[346]ORO, *ORO Today*, p. 23.

[347]Hugh M. Cole, "Operations Division," in ORO, "Discussion of ORO Work Program," p. 43.

[348]ORO, *ORO Today*, p. 27.

[349]James H. Henry, "Air Defense Division," in ORO, "Discussion of ORO Work Program," pp. 52–53.

[350]U.S. Army STAG, *Organization and Functions Manual* (Bethesda, Md.: STAG, 1 Nov 62), p. 1-1 (hereafter cited as *STAG Manual*), in NARA II, RG 319, Entry 100, Box 1, Folder Organization and Functions Manual, 1962.

[351]Memo, Col Alfred W. DeQuoy (chief, STAG) to DCSOPS, HQDA, Bethesda, Md., 7 Jul 61, sub: Rpt of the Activities of the U.S. Army Strategy and Tactics Analysis Group (STAG), pp. 1–2, RG 319, Entry 100, Box 3, Folder 203–04 Quarterly Rpt, 2d Quarter, FY 62.

[352]U.S. Department of the Army, *Army Regulations No. 15–14: BOARDS, COMMISSIONS, AND COMMITTEES—United States Army Strategy and Tactics Analysis Group* (Washington: HQ, DA, 11 Sep 61), para. 2; *STAG Manual*, p. 2-1.

[353]*STAG Manual,* p. 2-1. The STAG Implementation Plan also provided for the award of contracts by STAG to civilian research organizations and other agencies to supplement its in-house capabilities or to obtain services not otherwise available within the Army establishment.

[354]U.S. Army STAG, Fact Sheet—U.S. Army Strategy and Tactics Analysis Group, Bethesda, Md., ca. 62, pp. 1–2, RG 319, Entry 100, Box 3, Folder 203–04 OPPR Program Rpt Files, 1962, Fact Sheets (hereafter cited as STAG Fact Sheet).

[355]*STAG Manual*, pp. 4-1–4-4.

[356]Ibid., pp. 4-5–4-7.

[357]*STAG Manual,* 4-8–4-10.

[358]Ibid., pp. 4-11–4-15.

[359]Ibid., pp. 4-16–4-18.

[360]Memo, Col Alfred W. DeQuoy (chief, STAG) to Lt Col Fisher, Mr. Onufrak, Dr. Ling, and Mr. Hurd, Bethesda, Md., 14 Sep 61, sub: Proposed Reorganization for FY 63–67, p. 2, RG 319, Entry 100, Box 1, Folder 201–22 DA Mobilization Program Planning Files, 1961.

[361]Ibid.

[362]Memo, DeQuoy to DCSOPS, 7 Jul 61, p. 1.

[363]Ibid., pp. 4–5.

[364]Ibid., pp. 2–3.

[365]*STAG Manual,* p. 1-1.

[366]Memo, DeQuoy to DCSOPS, 7 Jul 61, pp. 2–3, 7–8.

[367]Ibid., p. 3. The contract termination date was 30 May 1961, but it was later extended to 30 September 1961.

[368]Ibid., pp. 3–4. In April 1961, STAG had leased additional temporary space at 7805 Old Georgetown Rd. in Bethesda.

[369]Ibid., p. 11.

[370]Ibid.

[371]Ibid., pp. 9–10.

[372]Ibid., pp. 6–7.

[373]STAG Fact Sheet, p. 2.

[374]Memo, DeQuoy to DCSOPS, 7 Jul 61, pp. 10–11. See Ltr, Col Alfred W. DeQuoy (chief, STAG) to Ellis A. Johnson (director, ORO), Bethesda, Md., 9 Mar 61, sub: Sharing of STAG IBM 7090 Computer, RG 319, Entry 100, Box 4, Folder 302–04 Alot Files, 1961.

[375]Ltr, Ellis A. Johnson (director, ORO) to Col Alfred W. DeQuoy (chief, STAG), Bethesda, Md., 20 Mar 61, sub: Sharing of STAG IBM 7090 Computer, RG 319, Entry 100, Box 4, Folder 302–04 Alot Files, 1961. See also the series of letters between Lynn H. Rumbaugh (director, Combat Systems, RAC) and STAG regarding RAC's use of the STAG IBM 7090 computer on a shared-time basis, April–May 1962 (RG 319, Entry 100, Box 4, Folder 302–04 Alot Files, 1962).

[376]Ltr, Philip H. Lowry (acting director, Combat Systems, RAC) to Director of Strategic Plans and Policy, DCSOPS, HQDA, Bethesda, Md., 30 Jul 62, sub: Request Approval of Increased Use of STAG Facilities by RAC, RG 319, Entry 100, Box 4, Folder 302–04 Alot Files, 1962.

[377]Disposition Form, Brig Gen C. E. Hutchins Jr. (director of strategic plans and policy, DCSOPS, HQDA) to Chief, STAG, Washington, 21 Mar 62, sub: Use of STAG IBM 7090 Computer by U.S. Army Chemical Corps Operations Research Group, RG 319, Entry 100, Box 4, Folder 302–04 Alot Files, 1962.

[378]Memo, DeQuoy to DCSOPS, 7 Jul 61, p. 5; STAG Fact Sheet, pp. 2–3.

[379]Memo, DeQuoy to DCSOPS, 7 Jul 61, p. 5.

[380]Ibid., pp. 5–6; STAG Fact Sheet, p. 2.

[381]Ibid., p. 6.

[382]Ibid., pp. 8–9.

[383]STAG Fact Sheet, p. 2.

[384]On CENTAUR, see Ltr, Col Alfred W. DeQuoy (chief, STAG) to Director of Strategic Plans and Policy, DCSOPS, HQDA, Bethesda, Md., 1 Dec 62, sub: Fact Sheet—Land Combat War Gaming Model (CENTAUR), RG 319, Entry 100, Box 3, Folder 203–04 OPPR Program Rpt Files, 1962, Fact Sheets; Herbert Maisel, Charles Roberts, John Albertini, and Robert Mason, "The CENTAUR War Game," in Session VI-A (Clinic), ARO (Durham) *Proceedings*, pp. 107–28.

[385]Fact Sheet—Land Combat Wargaming Model (CENTAUR), p. 1; Maisel and others, "CENTAUR War Game," p. 109.

[386]Fact Sheet—Land Combat Wargaming Model (CENTAUR), p. 1.

[387]Ibid., p. 2; Maisel and others, "The CENTAUR Wargame," 117. The estimated cost in FY 1963 of contract analysts was 45 man-months at ca. $167,453 and of contract programmers 192 man-months at $578,860.

[388]Maisel and others, "The CENTAUR Wargame," 118. Switchable tape units were used to communicate between the two computers.

[389]Ibid., 120.

[390]Ibid., 108.

[391]Fact Sheet—Land Combat Wargaming Model (CENTAUR), 3.

[392]Ibid.

[393]In the early 1970s, STAG's theater-level analysis mission was expanded, and the organization was renamed the Concepts Analysis Agency (CAA). In 1998, CAA was renamed the Center for Army Analysis.

[394]Philip M. Morse, "Where Is the New Blood?" *Journal of the Operations Research Society of America* 3, 4 (1955): 387.

[395]See, for example, U.S. Department of the Army, *Semiannual Report of the Secretary of the Army, January 1 to June 30, 1956*, in U.S. DOD, *Semiannual Report of the Secretary of Defense and the Semiannual Reports of the Secretary of the Army, Secretary of the Navy, Secretary of the Air Force, January 1 to June 30, 1956* (Washington: USGPO, 1957), pp. 127–29.

[396]Jack Raymond, *Power at the Pentagon* (New York: Harper & Row, 1964), p. 151.

[397]Russell L. Ackoff, "The Development of Operations Research as a Science," *Operations Research* 4, 3 (1956): 266.

[398]Rumbaugh, "Look at US Army OR," p. 7.

[399]Ibid.

[400]Ibid.

[401]Ibid.

[402]Ackoff, "Development of Operations Research," p. 266.

[403]Joseph F. McCloskey, "Training for Operations Research," *Journal of the Operations Research Society of America* 2, 4 (1954): 391. In general, a good deal more attention was given to formal OR training in the United States than in Great Britain where OR had originated.

[404]Ibid., p. 386.

[405]ARO (Durham), *Executive Summary*, p. 9.

[406]McCloskey, "Training for OR," p. 388; ARO (Durham), *Executive Summary*, p. 9. In 1964, a senior OR practitioner, Lynn Rumbaugh, observed that, "to my knowledge the number of OR professors who are alumni of Army OR exceeds the number of persons with OR degrees working for the Army at present" ("Look at US Army OR, p. 7).

[407]McCloskey, "Training for OR," pp. 390–91.

[408]Ibid., p. 390.

[409]Ibid., p. 387.

[410]Ibid., pp. 387–88.

[411]Ibid., p. 386.

[412]"Highlights," in ARO (Durham), *Executive Summary*, p. 2.

[413]Ibid.

[414]Thomson, *Research Analysis Corporation*, pp. 15–16. See also Raymond, *Power at the Pentagon*, pp. 145–46.

[415]W. Scott Payne, "Political Science in Operations Research," in ORO, "Fields of Knowledge," p. 34.

[416]Thomson, *Research Analysis Corporation*, pp. 17–18.

[417]Johnson, "Long-Range Future," p. 16; Ltr, Ellis A. Johnson (director, ORO) to Dr Milton S. Eisenhower (president, JHU), Bethesda, Md., 1960, sub: Application of OR by ORO to Developing Nations, p. 1, JHU Archives, Records of the Office of the President, Series I, Box 34, Folder 47.2 ICR/ORO, Jan–Dec 60.

[418]Raymond, *Power at the Pentagon*, pp. 143–44.

[419]Johnson, "Long-Range Future," p. 17.

[420]See, *inter alia*, Ltr, Ellis A. Johnson (director, ORO) to Dr Milton S. Eisenhower (president, JHU), Bethesda, Md., 14 Apr 58, sub: ORO Performing Work for Other Than the Army, pp. 1–3, JHU Archives, Records of the Office of the President, Series I, Box 34, Folder 47.2 ICR/ORO, Jan–Dec 58]); Ltr, Johnson to Eisenhower, 1960, pp. 1–2.

[421]Jaffe, *Quantitative Analysis*, pp. 10–11.

[422]Dickson, *Think Tanks*, p. 150.

[423]Ltr, Wilber M. Brucker (secretary of the Army), to Dr Milton S. Eisenhower (president, JHU), Washington, 9 Jan 1958, sub: Presentation of Army Distinguished Civilian Service Medal to Ellis A. Johnson, JHU Archives, Records of the Office of the President, Series 1, Box 34, Folder 47.2 ICR/ORO, Jan–Dec 58.

[424]On the long history of Johnson's attempts to create an Institute for Operations Research at Johns Hopkins, see Memo, P. Stewart Macaulay (JHU), Baltimore, 22 Mar 51, sub: Memo of a Conversation with Dr. Ellis A. Johnson, ORO, on 21 Mar 51, pp. 1–3, JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR/ORO, Jan 51–Jun 52; Min of the First ORO-JHU Advisory Board Meeting, Chevy Chase, Md., 12 Jun 52, pp. 3–5; and Ltr, Ellis A. Johnson (director, ORO) to Lowell J. Reed (president, JHU), Chevy Chase, Md., 2 Dec 53, sub: Proposed Institute for Operations Research, pp. 1–4, JHU Archives, Records of the Office of the President, Series I, Box 33, Folder 47.2 ICR/ORO, Jul 52–Dec 53.

[425]Raymond, *Power at the Pentagon*, p. 143.

[426]Ibid., pp. 145–46.

[427]Thomson, *Research Analysis Corporation*, p. 18; Visco, "The ORO," p. 32.

[428]OTA History, p. 21. See also the Cole interview, 8 Mar 89.

[429]Thomson, *Research Analysis Corporation*, p. 19.

[430]U.S. Department of the Army, *Annual Report of the Secretary of the Army, FY 1961*, in U.S. DOD, *Annual Report of the Secretary of Defense and the Annual Reports of the Secretary of the Army, Secretary of the Navy, Secretary of the Air Force, for Fiscal Year 1961* (Washington: USGPO, 1962), p. 144.

[431]Ibid., pp. 18–19.

[432]*Annual Report of the Sec Army, FY 1961*, p. 144; Thomson, *Research Analysis Corporation*, p. 19.

[433]Thomson, *Research Analysis Corporation*, p. 19; "Navy Veteran Heads Army Research Office; General Bradley Serves on the Board," *Army-Navy-Air Force Journal* 99 (9 Sep 61): 26.

[434]Ibid.

[435]Research Analysis Corporation, "RAC Highlights, 1961–1971," *The RAConteur* 7, 11 (1971): 5.

[436]Thomson, *Research Analysis Corporation*, pp. 19, 22; "Navy Veteran Heads Army Research Office," p. 26.

[437]Thomson, *Research Analysis Corporation*, pp. 21–22.

[438]U.S. DOD, Office of Public Affairs, *News Release No. 893–61: Army Announces Contract Award to R.A.C.—Army Today Awarded $4.576 Million Contract for Operations Research to R.A.C., Bethesda, Maryland* (Washington: Office of Public Affairs, DOD, 1 Sep 61).

[439]Dickson, *Think Tanks*, p. 150; Visco, "The ORO," p. 32; Carl M. Harris and Andrew G. Loerch, "An Historical Perspective on U.S. Army Operations Research," *Military Operations Research* 4, 4 (1999): 5.

[440]OTA History, pp. 21–22.

[441]Ibid.

[442]Ibid., pp. 22, 28.

[443]Ibid., p. 23. Although the Center for Naval Analyses contract was later administered by the University of Rochester, on 4 August 1983, the Navy announced award of the Center for Naval Analyses management contract to the nonprofit Hudson Institute (see Keith R. Tidman, *The Operations Evaluation Group: A History of Naval Operations Analysis* [Annapolis, Md.: Naval Institute Press, 1984], p. xiii).

[444]Gilman, "Role of OR in the Army," p. 5; Trefethen, "History of OR," p. 35.

[445]ARO (Durham), *Proceedings*, p. 4.

[446]Tinberg, "OR and the US Army," p. 3, quoting *An Appreciation of Analysis for Military Decisions* (Santa Monica, Calif.: RAND Corporation, 1959), pp. viii–ix; Rumbaugh, "Look at US Army OR," p. 12.

[447]Meals, "Trends in Military OR," pp. 256–57.

[448]Ibid., pp. 253–54.

[449]Gilman, "OR in the Army," p. 60.

[450]Ibid., p. 253; Rumbaugh, "Look at US Army OR," p. 15.

[451]Hugh J. Miser, "Operations Research in Perspective," *Operations Research* 11, 5 (1963): 675.

[452]Ibid.; Robert J. Weeks, "The Army's Operations Research Training Program," student essay, U.S. Army War College, Carlisle Barracks, Penn., 1968, pp. 2–3.

W. Barton Leach, the "Father of Army Operations Research" (as Brig. Gen., USAF Reserve, 1950)

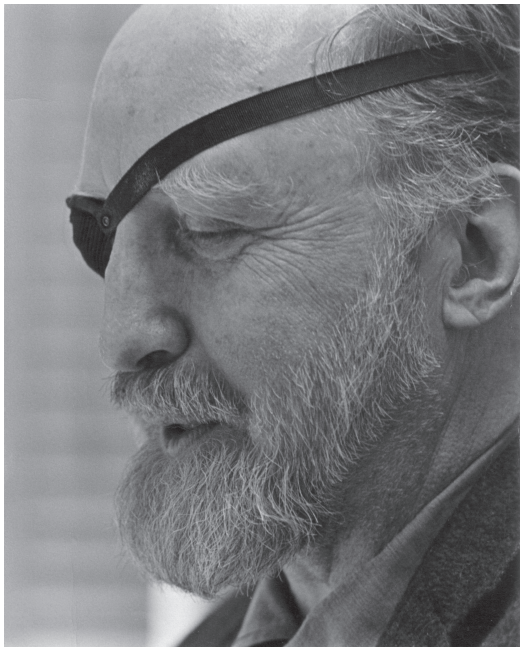
Vannevar Bush, the chairman of the Office of Scientific Research and Development, opposed expansion of the wartime Army operations research program.

National Defense Research Committee. Front Row (l. to r.): F. B. Jewett, President of the National Academy of Sciences; Rear Admiral J.A. Furer, USN, Coordinator of Research and Development, Department of the Navy; J.B. Conant, President of Harvard University; R.C. Tolman, Dean of the Graduate School, California Institute of Technology
Back Row (l. to r.): K.T. Compton, President of the Massachusetts Institute of Technology; Roger Adams, Head of the Chemistry Department, University of Illinois; C.P. Coe, United States Commissioner of Patents; Irvin Stewart, Executive Secretary, Office of Scientific Research and Development

The main building of the Operations Research Office complex at 7100 Connecticut Avenue, Bethesda, Maryland, in the mid-1950s

Brig. Gen. (USA Ret.) Lester D. Flory served as the Executive Director of the Operations Research Office, 1948–61.

Maj. Gen. John P. Daley greets Dr. Ellis A. Johnson, Verona, Italy, 1960. Daley was later promoted to Lt. Gen. and became the first commander of the U.S. Army Combat Developments Command. Johnson was Director of the Operations Research Office, 1948–61.



A distinguished astrophysicist and an expert on UFOs, Thornton L. Page was one of the better-known analysts and division chiefs in the Operations Research Office, 1951–58.

Analysts from the Combat Operations Research Group measure the distance a tank traveled after running over a simulated mine.

A war game in progress at the Combat Operations Research Group.

Col. Alfred W. DeQuoy, the first chief of the Strategy and Tactics Analysis Group (STAG), 1960

CHAPTER FOUR

Operations Research and Combat Developments, 1950–62

Following the Korean War, the managers and analysts of the Operations Research Office (ORO) and of its successor, the Research Analysis Corporation (RAC), expanded the application of operations research (OR) into new areas, such as human behavior, psychological operations, and political and economic analysis. They also refined methods, such as modeling, wargaming, and the use of computers. The extension of OR into new areas prompted the creation of a number of new Army organizations, such as the Human Resources Research Office (HumRRO), the Special Operations Research Office (SORO), and the Strategy and Tactics Group (STAG), which focused on the investigation of those new fields and the application of the new methods. However, the traditional core competency of OR—the analysis of weapons systems, organization, and doctrine—remained at the heart of OR in the Army throughout the 1950s and into the 1960s as the Army refocused its scientific research and development (R&D) efforts and evolved the new concept of "combat developments."

During the 1950s and early 1960s, as weapons became more sophisticated and more expensive and the pressures of the Cold War on the American economy demanded "more bang for the buck," OR became an increasingly important part of the new comprehensive combat developments process. While ORO, HumRRO, SORO, STAG, and other agencies provided important inputs, particularly at the higher end, OR work at the sharp end of combat developments was done in the OR groups created by the Army's technical services, Army Field Forces (later U.S. Continental Army Command), and the various test and evaluation agencies established during the 1950s and early 1960s.

By the 1950s, production capacity was no longer the most significant factor in military superiority; the ability to reduce lead time in developing and deploying new weapons, organization, and doctrine, and the ability to counter enemy R&D advances had become more important.[1] These were just the sort of problems with which OR could deal effectively. Consequently, the nascent OR groups in the Army's technical services grew into full-blown OR organizations and assumed an important role. At the same time, the new organizations created to manage the combat developments process made extensive use of simulations (wargaming) and other OR techniques to evaluate the effectiveness of the new weapons, organizations, and doctrines.

The Emergence of Combat Developments

Given the large stockpile of weapons and equipment left over from World War II and the new focus on nuclear weapons, Army R&D languished in the immediate post–World War II period. The onset of the Korean War, however, revived interest in developing new conventional weapons and equipment, and congressional appropriations for Army R&D projects increased substantially. Army leaders differed on how Army R&D should be managed. The Technical Services, supported by the Army Staff, favored the existing system in which the deputy chief of staff for logistics held primary responsibility for R&D, but most Army scientists and many senior officers directly involved in R&D wanted to make R&D a separate function, independent of the Army logistical system. The debate continued into the early years of the Kennedy Administration, but ultimately the scientists and senior R&D officers prevailed. The Army R&D program gained independent status, bringing significant changes to the Army OR program that was closely connected to the R&D effort.

Even as the controversy over the higher-level organization and management of the Army R&D program proceeded, the Army began to refocus on a new concept that integrated research and development into a larger process that tied the development of new weapons and equipment to the development of new organizational and tactical concepts. The shock of the Korean War and the pressing demands of

the Cold War competition with the Soviet Union forced the emergence of a comprehensive "combat developments" system to integrate the design of new weapons and equipment, organizations, and doctrine, and their increasingly complex testing under both simulated and actual field conditions. Organizations were created to perform the combat developments function, and OR played a prominent role in the new process, just as it had long played an important role in the narrower function of weapons design and evaluation.

The Need for an Integrated Combat Developments System

Until the 1950s, the efforts of the United States Army to integrate the development of new weapons and equipment, organizations, and doctrine were sporadic and largely ineffective.[2] The Army's system for doing so was fragmented, poorly coordinated, and focused primarily on adapting new technology to the design of new weapons that were often produced without a clear concept of how they would be used.[3] Whereas the design of new weapons and equipment generally kept pace with emerging technology, developing new organizations and doctrines to effectively use these weapons and equipment innovations was generally in the hands of agencies preoccupied with current operations. Thus, it lagged behind.[4] Moreover, no single office was responsible for the overall management of the Army's diverse weapons programs, organizational change, and doctrinal development.

The rapid technological changes initiated by World War II (atomic weapons, guided missiles, and space vehicles, to name only a few) as well as the threat to national survival posed by the Cold War with the Soviet Union and the concurrent dramatic reduction in reaction time posed by the Soviet nuclear threat, made clear the need for effective integration of the combat developments process.[5] Moreover, it was realized that "it would be 'penny wise and pound foolish' if the development of hardware were not preceded by an equally extensive development of the organizations and fighting techniques they implement."[6]

The focus of the new combat developments process was on the future, and its primary function was to adapt military operations to very rapid changes in technology and military requirements.[7] The Army's working definition of "combat developments" was set forth by Headquarters, Army Field Forces, in 1953 as

> the research, development, testing and early integration into units in the field of new doctrine, new organization and new materiel to obtain the greatest combat effectiveness, using the minimum of men, money and materials.[8]

The definition of "combat developments" adopted by the Office of the Chief of Army Field Forces (OCAFF) stressed the integration of developments in three distinct areas (weapons and equipment, organization, and tactical doctrine) and thus encompassed functions formerly performed by the OCAFF G-3 and the Research and Development Section.[9] In fact, combat developments included a wide variety of activities, including the development of concepts and doctrine, the design of force structure, the integration of materiel developments, the analysis of threats, acting as the proponent for command and control, and independent testing of proposed organizations and equipment.[10] Throughout, the focus was clearly on the development of effective concepts for the army of the future.[11]

By 1950, it was clear that the continued military superiority of the United States depended on the speed and soundness with which the Army reacted to adapt organization and doctrine to "ever more rapid changes in technological developments and military requirements."[12] It was soon recognized that OR would be at the center of the efforts to integrate new weapons, organization, and doctrine. As Edmund T. Pratt, Jr., then assistant secretary of the Army for financial management, told attendees at the Second Army Operations Research Symposium, in Durham, North Carolina, in March 1963:

> We will have to rely more heavily upon concurrent simulation, operations analysis, wargames, and theoretical studies in all phases to reduce lead time and produce the most effective force structure consistent with current missions and state of the art technology. To provide this increased capability, we must anticipate the need for qualified analysts who can apply modern methods and obtain timely and reliable solutions; this will require more emphasis on operations research training of Army personnel, military and civilian.[13]

Project VISTA

By 1950, many Army leaders and scientists recognized the need for an integrated process of developing weapons, organization, and doctrine. Among those calling for improvements in the Army's system for integrating new weapons, organization, and doctrine was Ellis Johnson, director of ORO, who noted that the Army could no longer wait until the outbreak of conflict before developing effective organization and doctrine for employing the available weapons.[14] Several agencies addressed the problem in the late 1940s and early 1950s, but their work was uncoordinated and had little effect.[15]

The emergence of an integrated combat developments program in the United States Army can be said to have begun only with the award in early 1951 of a contract sponsored by all three services to the California Institute of Technology to study the problem of land and tactical air warfare. The purpose of the study, called Project VISTA, was "to conduct a broad study of ground and air tactical warfare with particular attention to the defense of Western Europe in the immediate future" and to submit suggestions as to how the services could improve their weapons, techniques, and tac-

tics.[16] Project VISTA was chaired by Dr. Lee A. Dubridge, assisted by some of America's top scientists, including William A. Fowler, Robert T. Bacher, C. C. Furnas, Charles C. Lauritsen, Clark B. Millikan, J. Robert Oppenheimer, and Howard P. Robertson.[17]

The final report of Project VISTA was presented to Secretary of the Army Pace and the other service secretaries in February 1952. The Project VISTA report noted that America no longer enjoyed the long reaction time provided by her relative isolation between two great oceans and that the Army devoted too much time and effort to current operations and was thus unable to forecast the future and plan for it properly.[18] To provide for the necessary planning for the future, Project VISTA called for the creation of a "Combat Development Group," the purpose of which would be

> to forge and develop the new tactics, techniques, and tools of this new type of warfare . . . [and] to bring to an operational state the newest tactics, ideas, and inventions having application to the kind of warfare envisaged for Western Europe.[19]

The Project VISTA report also noted that to ensure its effectiveness the proposed Combat Development Group had to have

> a combat unit of sufficient size to include all elements of a working combat team . . . [and] a permanent staff that includes civilian scientists; it must have access to specialists in all relevant fields; and it must work in close coordination with Operations Research Office of the Army.[20]

The proposed Combat Development Group would thus constitute both a research team and a laboratory for developing and testing new weapons, organizations, and doctrines, and would be separate from the existing OCAFF schools and boards.[21] Although the chief of Army field forces, Gen. John R. Hodge, concurred with the general conclusions of the Project VISTA report, he opposed the creation of a separate combat developments command, noting that the proposed responsibilities of the Combat Development Group were already a part of the functions assigned to OCAFF, and that the desired integration of weapons, organization, and doctrine could be achieved more economically within the existing OCAFF system.[22]

Establishment of a Combat Developments Element in OCAFF

General Hodge's reservations regarding the establishment of an independent combat developments command were noted and the issue was discussed by OCAFF and the Headquarters, Department of the Army (DA) G-3, and in June 1952 the Army chief of staff, Gen. J. Lawton Collins, directed that a Combat Development Group be established as part of OCAFF.[23] The chief of Army field forces was assigned a dual responsibility for both

> evaluating the effect on our tactical doctrine of new scientific developments . . . [and] developing requirements for new weapons, where necessary, to meet the demands of new tactical concepts. This dual responsibility calls for the application of the methods of science [i.e., operations research, inter alia] to the overall problems of ground warfare.[24]

The final report of Project VISTA was approved by Secretary Pace in July 1952 and, that same month, OCAFF submitted a plan for taking over the functions listed by Project VISTA. The OCAFF plan was designed to take advantage of the existing OCAFF system of centers, schools, and boards as well as the long-standing relationship between OCAFF and the technical services.[25] Major features of the plan were the designation of the deputy chief of Army field forces as deputy for combat developments; the creation of a Combat Developments Division in G-3, OCAFF; and the establishment of combat developments departments in the various combat arms and other branch schools and in the United States Army Command and General Staff College (CGSC) at Fort Leavenworth, Kansas.

The Army combat developments system was officially inaugurated in September 1952, when the OCAFF plan was approved with certain modifications by Secretary Pace.[26] On 1 October 1952, the chief of Army field forces created the Office of the Deputy Chief of Staff for Combat Developments as well as the Combat Developments Department in CGSC and in each of the four combat arms service schools.[27] In December 1952, another new group—the Office of the Director of Special Weapons Development—was established at Fort Bliss, Texas, under Brig. Gen. William P. Ennis, Jr., to handle matters concerning atomic weapons. It was the first combat developments field agency of the Army to assist in developing and testing "the military application of atomic energy as it affects the doctrine, organization, equipment, and training of the Army in the field."[28]

The essential elements of the new combat developments system were in place by the end of 1952, and further improvements in coordination and clarification of roles and missions were made during 1953. In February 1953, OCAFF issued a *Combat Developments Planning Guide* to improve coordination and direction and to provide a set of objectives to measure progress.[29] The effectiveness of the new combat developments departments in the Army service schools was reviewed and it was found that the schools had become involved in routine operational matters and thus contributed little to the combat developments process.[30] In an attempt to solve the problem in May 1953, OCAFF directed each school to ensure that a number of personnel were isolated from current operations to focus more effectively on long-range developments.[31]

Problems similar to those found in the service schools also began to arise in the HQ OCAFF combat develop-

ments elements. The initial combat developments organization at HQ OCAFF consisted of small elements in each of the General Staff sections. The structure was inherently weak and lacked coordination and central direction, and the small combat developments elements soon became absorbed in day-to-day business rather than planning for the "Army of the Future."[32] Such field experimentation as was conducted was done in conjunction with traditional field exercises and maneuvers, an unsatisfactory method because such exercises and maneuvers emphasized training, and observation under controlled conditions was not possible.[33]

The principal fault was the placement of combat developments elements under the G-3 and the consequent diversion of their efforts to solve current problems.[34] After about a year of ineffectual operations, the combat developments elements in HQ OCAFF were reorganized in October 1953.[35] The Combat Developments Division of OCAFF G-3 was abolished and its personnel authorizations were absorbed by a separate Combat Development Group (later renamed the Combat Developments Section, then once again renamed the Combat Developments Division) under the deputy chief of Army field forces.[36] Two sections were established. The Combat Developments Special Section was small (only eight officers) and concerned itself with guided missiles, nuclear warfare, and chemical/biological warfare. As an exception to the forward-looking focus of combat developments, the Combat Developments Special Section also dealt with current problems of integrating missiles, nuclear warfare operations, and chemical/biological operations. The Combat Developments General Section had approximately fifteen officers, one of whom was stationed at Ann Arbor, Michigan, with Project MICHIGAN.[37] The section focused on long-range (at least ten years out) requirements for new weapons and equipment.

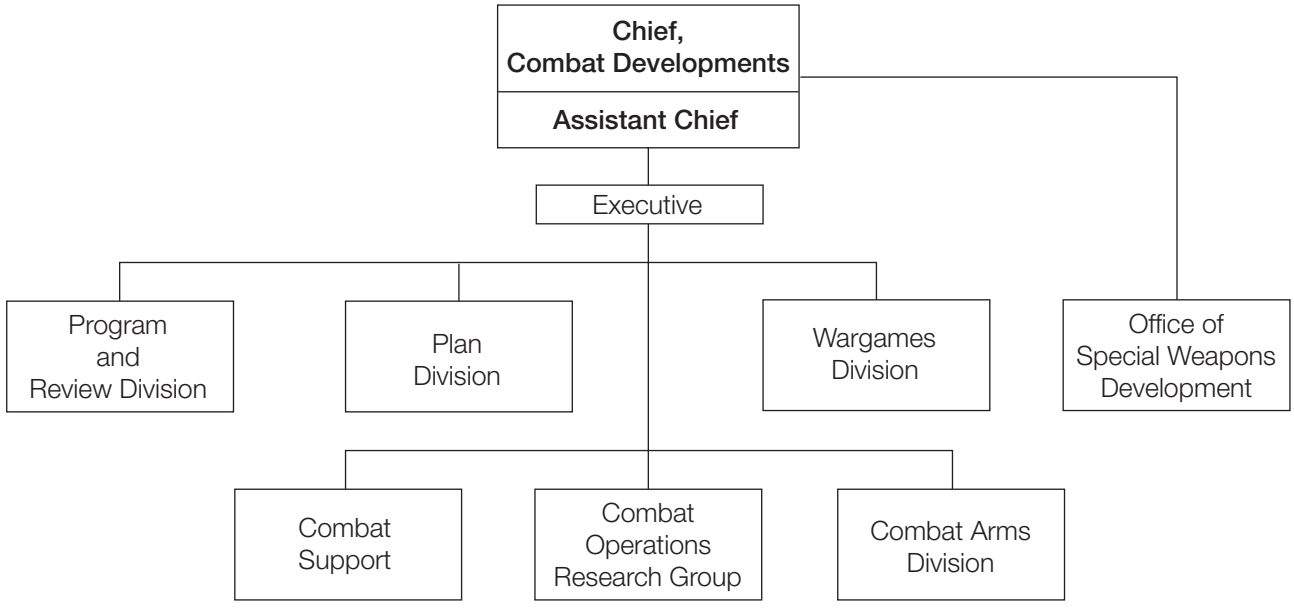
The Haworth Report

By 1954, the combat developments system was functioning, and there was liaison among OCAFF and the Army's principal overseas headquarters in Europe and the Far East.[38] However, several important deficiencies remained.[39] Because of the continuing emphasis on missiles and atomic weapons, the focus tended to be on the mid-range (five-year) period rather than the long-range future as originally envisioned. Also, the new system did not include active participation by the technical and administrative services (except for the Engineer Development Board of the Chief of Engineers), and there was little capacity for field experimentation other than that provided by field exercises and maneuvers that focused primarily on training. Moreover, the number of military personnel assigned to combat developments agencies was only about half of the number originally recommended by OCAFF, too few to carry out an effective combat developments program.

In early 1954, Secretary of the Army Robert T. Stevens established an ad hoc subcommittee of the Army Scientific Advisory Panel to study the Army's combat developments program.[40] The committee comprised leading scientists and businessmen and was headed by Dr. Leland J. Haworth, the director of Brookhaven National Laboratory.[41] The committee's report, known as the Haworth Report and submitted in October 1954, reaffirmed the findings of Project VISTA and made a number of recommendations for improvement of the Army's combat developments program—principally changes in Army organization and a strengthening of interservice and interagency relationships. The three principal conclusions of the Haworth Report were that "an intensive Combat Development program is essential to the establishment and maintenance of a combat-ready Army [and that] the focal points of this program should be a 'Combat Development Organization,' given broad responsibility for and wide freedom of action in the exploration and evaluation of new concepts in weapons, organization and tactics and their synthesis into an effective fighting system"; that the present effort was "vigorous and useful" but "inadequate in scope and in magnitude"; and that "an autonomous command at a special site possessing adequate staff, facilities, and troops for the execution of all aspects of Combat Development . . . should be considered as the ultimate goal."[42] In line with those three major conclusions, the Haworth Report contained nine specific recommendations:

1. That the Army's over-all Combat Development program be greatly expanded with drastically increased emphasis on field experimentation, including joint operations.
2. That the program be bold and imaginative and not limited in concept by existing weapons or by the organization, roles, and missions of the various military forces.
3. That the organization be placed in the Continental Army Command.
4. That the Chief be given broad responsibility and allowed wide freedom of action in the determination and execution of the over-all program, and that effective channels be established to ensure prompt and careful consideration of Combat Development findings and recommendations at appropriate levels.
5. That the organization include (a) a central group responsible for determining and coordinating the over-all program and for conducting broad theoretical and experimental studies, and (b) local groups, especially at the schools, which are subject to the authority of the Chief and which conduct appropriate specialized studies and tests and partake in more general programs.
6. That Combat Development staffs include personnel from the Technical Services assigned at the *working level* to assist in the experimental program, to ensure maximum cooperation between agencies, and ultimately to take familiarity with field problems back to the Technical Services.

FIGURE 4–1—COMBAT DEVELOPMENTS SECTION, HQ CONARC



Source: Jean E. Keith and Howard K. Butler, *United States Army Combat Developments Command: Origins and Formation* (Fort Belvoir, Va.: Office of the Historian, Deputy Chief of Staff for Management and Resources, U.S. Army Combat Developments Command, 1972), p. 27.

7. That the Combat Development organization be provided adequate resources—troops, equipment, and space—for conducting field experiments and tests.
8. That the Chief and his staff keep thoroughly familiar with related activities in all parts of military and civilian life, particularly with combat units of the Army, other military agencies and contractors involved in research and development, and the general progress of science and technology.
9. That specific budgetary provisions be made for Combat Development purposes and that they be protected from the perturbing effects of year-to-year fluctuations.[43]

HQ CONARC and Responsibility for Combat Developments

Implementing the recommendations of the Haworth Report and the concurrent June 1954 reorganization of the Army significantly improved the effectiveness of the Army's combat developments program. On 1 February 1955, the United States Continental Army Command (CONARC) replaced the Office of the Chief of Army Field Forces and assumed responsibility for training and combat developments throughout the Army.[44] In line with the recommendations of the Haworth Report, the Combat Developments Section of HQ CONARC was charged with broad responsibility for developing and testing of equipment, organization, and doctrine for units normally assigned to the field army and, with certain restrictions, for other Army units.[45] Organized as shown in Figure 4–1, the CONARC Combat Developments Section became "the focal point for study, evaluation and coordination of ideas from many sources."[46] Further positive steps were taken with the establishment of combat developments elements in each of the technical and administrative services and in some overseas commands, in accordance with a DA letter of 26 July 1955.[47]

The mission and responsibilities of the Combat Developments Section of HQ CONARC were set forth in detail in the 26 July 1955 HQ DA letter.[48] As laid out in the *HQ USCONARC Organization and Functions Manual,* the chief of the Combat Developments Section had general staff responsibility for

a. Development of operational, organizational, and materiel development objectives for the Army in the field.
b. Coordination of recommended materiel requirements and recommendation of their establishment to the Deputy Commanding General.
c. Conduct of selected combat development studies, field experiments, and tests, particularly those pointed toward the solution of problems generally in the periods 3 to 15 years hence.
d. Design and conduct (or participation in) selected field experiments and tactical troop tests and analysis of the results of such experiments and tests.
e. Advice and assistance to the field on the conduct of field experiments and tests.
f. Participation in maneuvers and exercises to acquire quantitative data needed for the solution of combat development problems.
g. Supervision of US Army Combat Development Experimentation Center.

h. Developing broad guidance and coordinating the efforts of USCONARC in determining the degree of automation which may be employed in the Army in the field.
i. Evaluating operational and organizational concepts by war gaming, map exercises, and associated analyses; devises techniques and procedures for war gaming to improve the validity and efficiency of war games.[49]

A parallel Material Developments Section at HQ CONARC set material development objectives and requirements for the field army and coordinated and supervised CONARC participation in materiel development (research, development, and testing) for the Army in the field.[50] The major functions of the commanding general, CONARC, in the material development area included recommending military requirements and military characteristics, providing user advice and guidance to the developing agency and the developer throughout development, conducting user tests, recommending type classification, and establishing the basis of issue.[51]

Combat Developments in the Army Schools

The combat developments system initiated in 1952 included combat developments elements at the Army War College, CGSC, and the various branch service schools. Operations research techniques were used by the military and civilian analysts in combat developments elements in each of the various Army schools.[52] Very-long-range concepts of weapons, organization, and doctrine were the province of the combat developments elements at the United States Army War College at Carlisle Barracks, Pennsylvania, and CGSC at Fort Leavenworth. The combat developments staffs at both Carlisle Barracks and Fort Leavenworth included OR analysts, and the long-range studies they produced incorporated the use of OR methods. Such studies set the scene for the development of more-discrete concepts by combat developments agencies associated with the various Army service schools operated by the combat arms and technical and administrative services.

At the Army War College, the responsibility for combat developments activity was assigned to one of the subordinate departments or divisions. By 1962, that responsibility was focused in the Doctrine and Studies Division, which was transferred to the new U.S. Army Combat Developments Command as a Class II activity, on 1 July 1962, and renamed the United States Army Institute for Advanced Studies (USAIAS) on 1 August 1962.[53] The stated goal of the institute was "to contribute to future Army effectiveness" by performing "research in the field of future Army operations by preparing and evaluating broad military studies affecting the national security."[54] The commandant of the Army War College was also the commanding general of USAIAS, the staff of which consisted of both military and civilian personnel. The civilian staff included OR analysts and administrative personnel, and the institute was supported by contractors (notably Operations Research, Inc.) and other civilian research organizations that provided personnel trained in the physical and social sciences, the humanities, and OR.[55]

CGSC at Fort Leavenworth had a long history of involvement in the development of Army organization and doctrine, dating back to the beginning of the twentieth century.[56] In November 1946, a Department of Analysis and Research was formed at CGSC to publish Army doctrinal manuals. The creation of the Army combat developments system in September 1952 increased the emphasis on combat developments at the college. In 1954, the commandant, Maj. Gen. Garrison H. Davison, set up an Executive for Research and Analysis to handle future doctrine based on a weapons system approach. New organizations at CGSC created to deal with combat developments included a Current Analysis Section, a Combat Developments Department, and an Advanced Operations Research Department. The Combat Developments Department worked out doctrine for a period five years into the future, and the Advanced Operations Research Department dealt with developments ten or more years into the future. Maj. Gen. Davison devoted considerable officer resources to the new combat developments mission, in part because he wanted the Army to have a capability independent of defense contractors and think tanks.[57] The CGSC Office of the Chief of Doctrine and the Department of Combat Developments were later inactivated, and the personnel were transferred, over the objections of HQ CONARC, to form the nucleus of the Combined Arms Group (CAG) and the Combined Arms Group Combined Arms Agency. Lt. Gen. Harold K. Johnson assumed command of CAG on 1 July 1962, and the CGSC staff and faculty continued to write doctrine and work closely with CAG.[58]

One of the recommendations of the Haworth Report was to improve the participation of the technical services in the overall combat developments system.[59] To provide HQ CONARC with better control and coordination of the combat developments activities of the technical services, on 26 July 1955 HQ DA directed the seven technical services and the three administrative services to create their own combat developments agencies to maintain contact with the combat developments elements in HQ CONARC, thereby forcing those branches to consolidate their previously scattered combat developments functions in one agency.[60] The resulting agencies were to analyze general combat developments and integrate them with the combat developments work in their own field and to "review contemplated operational, organizational, and equipment development projects, determine their relation to the general objectives and to existing projects, and insure that all pertinent projects were included in the

CONARC *Combat Developments Objectives Guide*."[61] They were also charged with ensuring that new technological developments in their field were promptly exploited and made known to other agencies and with overseeing the program of testing new equipment, organization, and doctrine as well as acting as the advisor to their respective DA staff and technical service chiefs on combat developments matters.[62]

The evolution of the combat developments system in the Transportation Corps (TC) was typical of that in the other technical services. Before August 1955, all combat developments functions and project reports were the responsibility of the various divisions of the Office of the Chief of Transportation, the Transportation Research and Development Command (later the Transportation Research and Engineering Command), the Transportation School, and other TC elements.[63] In August 1955, a Combat Developments Department was created in the Transportation School at Fort Eustis, Virginia, and all TC combat developments work was concentrated there. The department was authorized a strength of 11 officers, 4 enlisted men, and 9 civilians, and was organized in four branches. However, personnel shortages made it necessary to form committees to handle the workload.

On 15 October 1955, the Combat Developments Department was separated from the Transportation School and redesignated the Combat Developments Detachment under the staff supervision of the assistant chief of staff, G-3, Transportation Training Command. This reorganization further concentrated and strengthened the TC combat developments program and eliminated duplication of functions with the Transportation Board. The detachment was again reorganized on 27 July 1956 in accordance with a CONARC memorandum defining combat developments procedures.[64] The resulting detachment consisted of a commanding officer and five sections (Technical Advisory; Administrative; Review and Analysis; Project Study; and Planning, Program, and Liaison) to which an army aviation liaison officer was later added. On 1 October 1956, the TC Combat Developments Detachment was abolished and replaced by the Transportation Combat Development Group, a Class II activity under the chief of transportation located at Fort Eustis. On 3 January 1957, the functions, personnel, records, and equipment of the Transportation Board were transferred to the Transportation Combat Development Group, and necessary changes were made in the mission, organization, and operations of the Transportation Board.

Although there was a free exchange of ideas and information between all CONARC combat developments agencies, matters of policy, doctrine, and concepts requiring substantial actions or funds went through normal command channels. After 1 October 1956, all TC combat developments were under the direction and control of the deputy chief of transportation. The Transportation Combat Development Group established a liaison office at Headquarters, Combat Developments Experimentation Command, at Fort Ord, California, on 1 November 1956, to coordinate field experiments involving transportation doctrine, organization, and equipment. The Transportation Combat Development Group coordinated laterally with the combat developments agencies of the other technical services and combat arms, and vertically with HQ CONARC, DA, and the Department of Defense.

The Combat Operations Research Group

From the beginning, operations research was a central element of the combat developments process. Even before the formal assumption of the combat developments mission by OCAFF in October 1952, Gen. Mark W. Clark, the chief of Army field forces, had established a small group of officers who did operations analysis at the tactical level.[65] The July 1952 OCAFF plan for establishing a combat development group included provision for the employment under the existing civil service rules of civilian scientists and analysts to perform operations research.[66] An attempt was made to integrate OR analysts into all of the new combat developments elements in OCAFF, but the cumbersome civil service regulations hampered recruitment. To fill the gap, Ellis Johnson was asked to provide a group of analysts to work at Fort Monroe.[67] The OR field office at OCAFF was established in the late fall of 1952 with an initial complement of analysts on loan from ORO and it was placed under the operational direction of Maj. Gen. Robert M. Montague, the OCAFF chief of combat developments.[68] Dr. William L. Whitson, a veteran of the Navy's World War II OR program and a longtime senior ORO employee, was designated as director of the field office and Col. William L. Hardick (United States Military Academy, 1931) was assigned as deputy director.[69]

A special study group of military officers was assigned to work closely with ORO analysts.[70] Maj. Gen. Montague himself told students at the Army War College, in November 1954, that the creation of a combined military–civilian analyst group was intended to ensure that each element acted as a brake on the other to "make the military take the scientific viewpoint to a certain extent . . . [and keep] . . . the scientists from going off 'half cocked' so to speak, and coming up with an unworkable solution."[71]

As noted earlier, the new combat developments elements in OCAFF were diverted by current operations and had difficulty focusing on the future. This led to the eventual reorganization of the OCAFF combat developments elements. In August 1953, the OCAFF OR team was reorganized. The civilian analysts of the ORO field office were formally merged with a group of ten officers under the deputy chief of

Army field forces to form the Combat Operations Research Group (CORG).[72] Whitson continued as director of the new CORG, and Hardick remained as deputy director. In the fall of 1954, Dr. Whitson was replaced by Dr. Franklin C. Brooks, former chairman of the Armor Group at ORO.[73] Col. Hardick was replaced as deputy director in the spring of 1955 by Col. Lauren W. Merriam.[74] The CORG director reported to the deputy chief of Army field forces, and CORG soon became the focal point for application of OR in OCAFF.

Soon after CORG was established, CONARC replaced OCAFF as the agency responsible for Army training and combat developments. With the establishment of CONARC it was anticipated that responsibility for the direction and control of operations analysis activities within the continental United States and for all overseas theaters in peacetime would be assumed by HQ CONARC (that is, by CORG).[75] HQ CONARC was to provide operational analysis facilities for the combat theaters and field armies during actual hostilities. The existing missions of the CONARC development boards and the technical services were to be relatively unchanged, and the emphasis was placed on coordination rather than integration.

With the establishment of HQ CONARC, CORG became an integral part of the Combat Developments Division under the deputy commanding general/chief of combat developments. Initially, CORG was organized with an Administrative Section, a Wargaming Section, and a Field Experimentation Section.[76] By early 1956, it had been reorganized into an Administrative Section, an Art and Publications Section, a Tactical Analysis Department, and a Field Experimentation Department.[77] By 1 July 1956, CORG had been reorganized again, as shown in Figure 4–2.

The Analysis Teams comprised civilian analysts assembled on an ad hoc basis to meet the needs of specific projects, but the Research Teams were formed on a semipermanent basis.[78] The analysts assigned to the Research Teams were temporarily assigned to Analysis Teams as required for a specific project. The group also supplied a Wargames Analysis Team to assist other combat developments divisions of HQ CONARC in studies using wargames procedures.[79] A small number of CORG personnel were also used on an occasional and temporary basis at the various service schools and CONARC boards.[80]

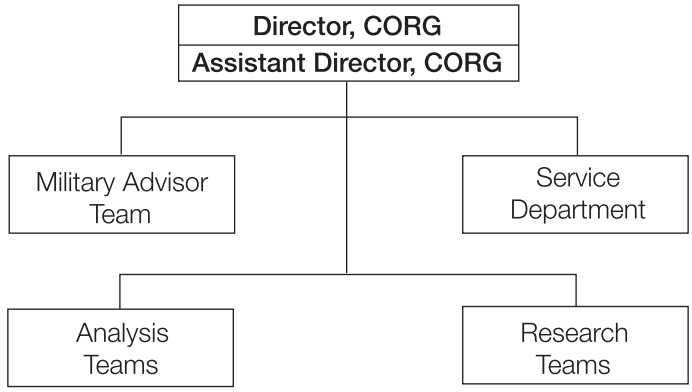
Military officers were assigned to the CORG Military Advisor Team by the deputy chief of staff for combat developments in a ratio of one officer to four CORG civilian analysts.[81] The functions of the Military Advisor Team included providing instruction for CORG scientists on military subjects; providing information on Army materiel, organization, and doctrine; providing judgment based on experience in military operations; assisting the scientists in contacting appropriate information sources; and participating in field activities with the scientists. The CORG Services Department provided administrative, graphics, publication, and reference services to support the CORG program.

In 1957, CORG was reorganized once again, as shown in Figure 4–3. By 1 May 1959, the Organization Group had been renamed the Support Branch, the Weapons and Materiel Group had been redesignated as the Weapons Branch, the Military Advisor Team, the Wargames Methods Group had been eliminated, and the Service Department had been renamed the Service Branch.[82] In late 1960, there was another reorganization of CORG into the Service Branch, the Operations Analysis Branch, and the Wargames Methods Branch.[83] In August 1962, shortly before it was transferred to the newly established Combat Developments Command, the CONARC Combat Developments Division was abolished and CORG was made subordinate to the deputy chief of staff for unit training and readiness.[84]

As of November 1954, approximately twelve ORO analysts and ten officers were working for Maj. Gen. Montague, the chief of the Combat Developments Division, OCAFF.[85] In response to the Haworth Report and the creation of HQ CONARC in 1955, the ORO personnel on temporary assignment to CORG were replaced with a more permanent staff of civilian analysts from Technical Operations, Inc., a firm from Arlington, Massachusetts.[86] Following a transitional period, Technical Operations, Inc., became the prime contractor for OR services for HQ CONARC in the fall of 1955.[87] It was anticipated that CORG's complement of civilian analysts would increase to approximately seventy in one or two years.[88] As of 1957, CORG's strength had grown to twenty-four civilian analysts, but the number of military personnel had dropped to four officers.[89] All of the military officers were later withdrawn, and as of 1 November 1960, CORG was staffed by twenty-three professional civilians and six administrative civilians.[90]

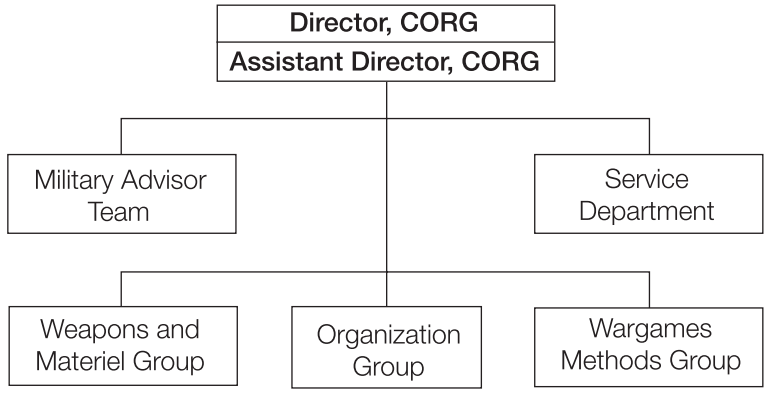
CORG's essential mission was to study changes needed in Army materiel, organization, and doctrine as a result of the introduction of atomic weapons.[91] Its principal functions were to apply scientific methods to solve short-term combat developments problems, conduct scientific research to produce new methods and facts for the solution of long-term combat developments problems, supply scientific assistance to other divisions of HQ CONARC, and maintain a collection of pertinent documents of interest to combat developers.[92] The CORG work program was built around two primary functions: (1) short-term technical analyses and scientific assistance to CONARC combat developments elements, and (2) longer-term research on fundamental combat developments problems.[93] The annual CORG work program was mutually agreed on by the CONARC deputy chief of staff for combat

FIGURE 4–2—ORGANIZATION OF CORG: JULY 1956



Source: U.S. Army Continental Army Command, CORG, *Combat Operations Research Group Work Program Summary* (Fort Monroe, Va.: HQ CONARC, 1956) (reproduced in Selwyn D. Smith Jr., "An Evaluation of Army Operations Research," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1957, Annex 4, p. 53; Headquarters, U.S. Continental Army Command, *Staff Directory* (Fort Monroe, Va., 1 Jul 56).

FIGURE 4–3—ORGANIZATION OF CORG: 1 MAY 1957



Source: Headquarters, U.S. Continental Army Command, *Staff Directory* (Fort Monroe, Va., 1 May 57).

developments and the CORG director with the effort divided about equally between the two primary functions.[94]

Short-term analysis projects were those of immediate importance to the combat developments program: they involved primarily the application of known facts and methods, had a high probability of a successful solution, and could be scheduled with some degree of accuracy.[95] Project PINPOINT was a typical short-term analysis project. Conducted at Camp Stewart, Georgia, PINPOINT studied the effects of ranges, angles of target, number of rounds fired, and type of weapons on antitank weapon position disclosure.[96] The longer-term research projects were studies of high importance in the long term, involved primarily the search for new facts and methods, had a relatively low probability of success, and could not be scheduled with accuracy.[97] In the main, CORG research projects focused on the tactical effectiveness of weapons and equipment systems, principles of effective combat organization, and the improvement of wargaming methods for evaluating new organizational and doctrinal concepts.[98] Among the key questions addressed by the group were the nature of warfare in the future; the effect of nuclear, chemical, and biological weapons; the optimal organization of ground forces; and how ground commanders should fight battles in the future.[99]

The results of CORG analyses and research projects were published in a variety of formats (such as staff memoranda, reports, memoranda, and staff papers) similar to those used by ORO.[100] Of particular note are CORG publications on wargames; data on weapons performance and effects gathered during field tests; field operations under nuclear warfare conditions; Army aviation; and a memorable series of studies by Virgil Ney in the 1960s on the evolution of various types of Army units, of the Army field manual, and of military unit control.

Generally, CORG focused its attention on two particular methods of developing and testing weapons, organization, and doctrine: wargaming and field experimentation. The group sought to apply scientific analysis and objective quantitative data to wargaming in place of professional opinion and subjective qualitative information.[101] One of the new wargaming techniques it developed was SYNTAC, or "synthetic tactics," a "dynamic, two-sided map maneuver with controlled intelligence flow."[102] Although the mission assigned to OCAFF by the Department of the Army seemed to dictate a focus on wargames at the corps and division levels, Maj. Gen. Montague and the CORG team decided to focus first on the battalion level as the foundation for later division- and corps-level gaming.[103] Initial emphasis was also placed on assembling the basic combat data needed for realistic gaming.

One of the principal functions of CORG was "to design tactical troop tests . . . with a view of obtaining maximum objectivity and scientific control, and to participate in and analyze the results of such tests."[104] Field experiments were designed by CORG joint military–civilian teams.[105] It soon became obvious to CORG and CONARC wargamers that the new games depended on assembling the basic combat data needed to evaluate any proposed new weapon, organization, or doctrine, much of which was outside the experience gained in World War II and Korea.[106]

Establishment of the United States Army Combat Developments Experimentation Command

The Army's combat developments system was focused on the future, and effectively planning for the future required adequate data on existing and proposed weapons systems, organization, and doctrine. The rapid pace of technological change meant that the data accumulated during World War II and Korea were often insufficient and outdated for looking into the future.[107] The one tool available that could assist in interpreting the existing data and helping make decisions was operations research.

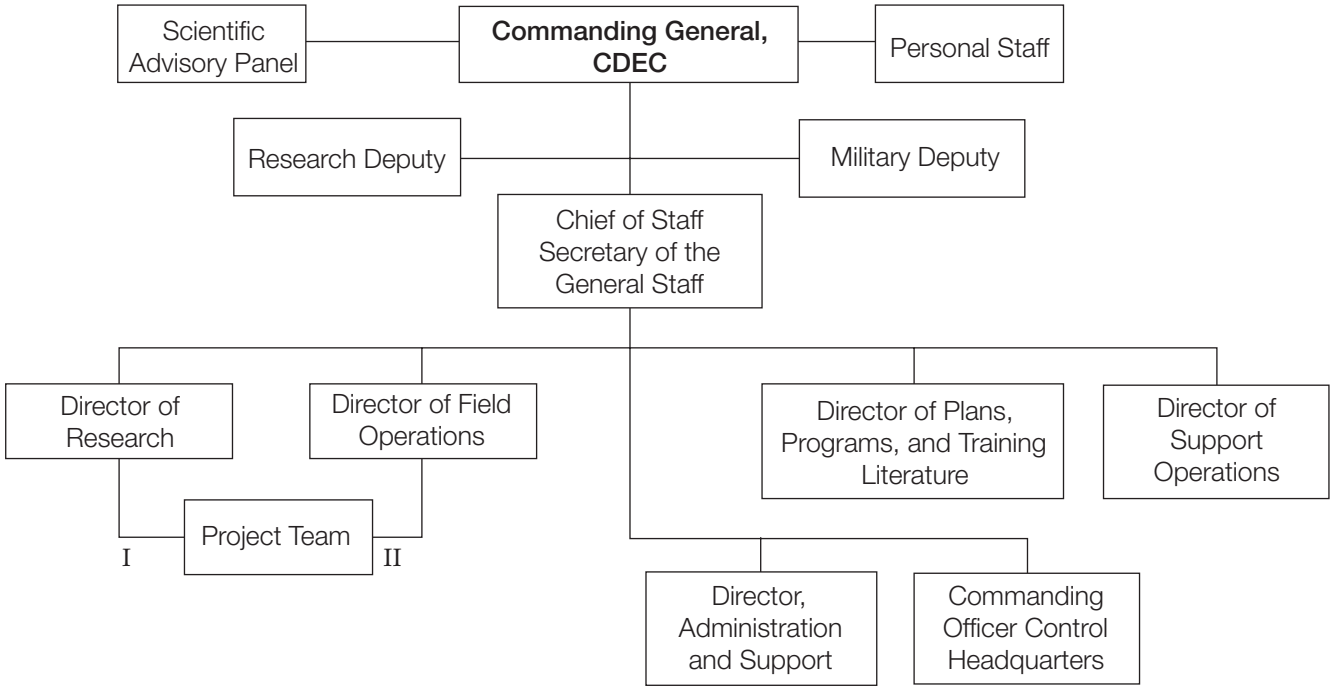
ORO had recognized the need for accurate, "modern" data. In March 1954, Ellis Johnson recommended an extensive program of field experimentation, and CONARC concurrently developed a field experiment called VULCO to supply future wargamers with vital information on the vulnerability of troops in nuclear warfare operations.[108] Attempts were also made to obtain needed data from maneuvers and field exercises, and CONARC combat developments elements produced "additional requirements for objective performance data and for the systematic observation of proposed concepts."[109] It was recognized that "the lack of combat experience in many new areas must be offset by providing intensive study, and realistic field experimentation, as an arena in which new theories, weapons, and equipment can receive the acid tests of practical field application."[110] Moreover, it was widely recognized that training maneuvers were an unsuitable vehicle for testing new developments because maneuvers were designed to train troops in *existing* weapons, organization, and doctrine, and combat developments experimentation was designed to change and improve all three.[111]

Despite the progress made by OCAFF/CONARC in integrating the Army's combat developments program, little attention was given to the key area of field testing. The Army worked closely with science and industry in the R&D field, but until 1954 little had been done toward field testing new developments in weapons, organization, and doctrine. The Project VISTA study (1952), the Haworth Report (1954), and a report by ORO (1958) all emphasized the need for a strong field experimentation element to evaluate Army innovations.[112] The Haworth Report in particular pointed out the inadequacy of a field testing system that would be tied to training exercises and maneuvers, and established three essential conditions for successful field experiments:

- Troops must be available for the sole purpose of experimentation.
- Weapons and equipment must be obtainable for experimental purposes regardless of how such weapons and equipments are normally procured, assigned, and employed.
- Sufficient funds must be provided and safeguarded against other demands to permit experimentation to proceed at a rate determined primarily by the capacity of the Combat Development personnel to work efficiently and effectively.[113]

The CONARC plan to implement the Haworth Report recommendations, submitted in February 1955, provided for troops from the continental United States and overseas commands to be made available for field tests, and the strong emphasis on field experimentation in the Haworth Report led ultimately to the creation of an establishment for such experimentation.[114] Following the recommendations of the Haworth Report, the chief of staff of the Army approved establishing an Army experimentation center on an interim basis during FY 1957–58, and, on 5 October 1956, the commanding general of CONARC, Gen. Willard G. Wyman, issued General Order No. 39, which established the Combat Developments Test and Experimentation Center (CDTEC),

FIGURE 4–4—UNITED STATES ARMY COMBAT DEVELOPMENTS EXPERIMENTATION CENTER: 1958



Source: U.S. Continental Army Command, *Report by USCONARC Ad Hoc Committee on Evaluation of the US Army Combat Development Experimentation Center* (Fort Monroe, Va.: Headquarters, CONARC, 4 Mar 58), Appendix II, p. 91. Cf. CONARC LOI (Fort Monroe, Va.: CDEC, 18 Oct 56), Appendix III, p. 95, Figure 12. Cf. CDEC, *Developing Tomorrow's Army Today* (Fort Monroe, Va.: CDEC, 1 Dec 58), p. 10, Figure 2.

effective 1 November 1956.[115] General Wyman followed up with a letter of instruction regarding the mission, functions, and support for the new organization.[116] The commanding general, Sixth U.S. Army, was assigned responsibility for the administrative and housekeeping support of CDTEC, which was activated at the Fort Ord–Camp Roberts–Hunter Liggett Military Reservation complex in California, and the 10th Infantry Regimental Combat Team, an element of the 5th Infantry Division, was designated as the troop test unit to support CDTEC.[117]

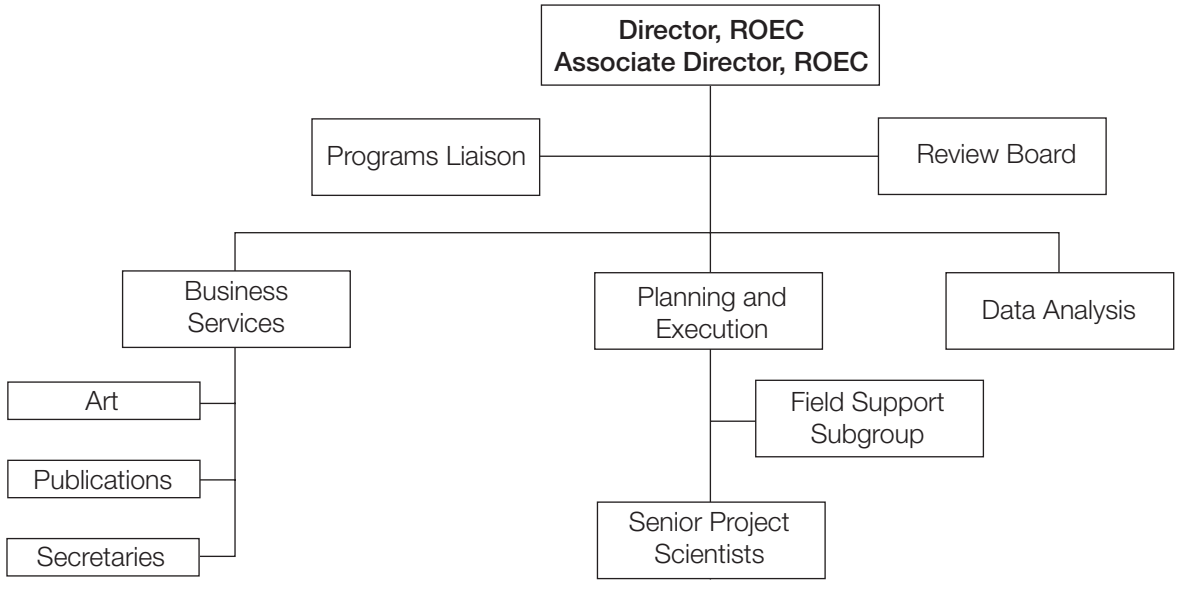
Prior to CDTEC's actual activation on 1 November 1956, the decision was made to change the designation of the new command to the United States Army Combat Developments Experimentation Center (CDEC) and direct references to "testing" were dropped from the official statement of mission and functions, although testing clearly remained a major function.[118] It was envisioned that CDEC would "provide the experimental facilities needed in the combat development system, a 'field laboratory,' combining a military experimental group, a scientific advisory group, and a body of troops with a trained experienced staff to conduct field experiments."[119] In general terms, the purpose of CDEC would be "to serve as a field laboratory for the evaluation, by objective experimentation, of those concepts of organization, operations, and logistics developed by the several agencies of the Combat Development System as may be directed by Headquarters, CONARC."[120] CDEC's official mission was "to assist the Commanding General, CONARC, in the discharge of his responsibilities for the development of, and experimentation with, concepts, organizations, doctrine, and procedures for the Army in the field."[121] To conduct its mission, CDEC was initially organized as shown in Figure 4–4.

The commanding general, CDEC, was specifically charged to

a. Prepare, conduct, and evaluate, with maximum objectivity and scientific control, experiments with concepts, organizations, doctrine, and procedures for future combat, as directed by the CG, CONARC. This function includes experiments for the integration of new materiel into organizations.
b. Report results of experiments and recommend, as appropriate, revision of the concept, organization, doctrine, or materiel under consideration.
c. Design and establish experimentation methods and procedures for the accomplishment of function *a* above.
d. Apply scientific analysis to solutions of combat development problems under consideration.[122]

CONARC General Order No. 39, on 5 October 1956, authorized a CDEC headquarters strength of 36 officers, 1 warrant officer, 20 enlisted personnel, and 16 DA civilians,

FIGURE 4–5—ORGANIZATION OF ROEC: 1958



Source: U.S. Continental Army Command, *Report by USCONARC Ad Hoc Committee on Evaluation of the US Army Combat Development Experimentation Center* (Fort Monroe, Va.: Headquarters, CONARC, 4 Mar 58), Appendix III, pp. 93–94, 97, 99, Figure 13 and Figure 14.

plus 20 scientists hired under a contract with Technical Operations, Inc., to staff the proposed CDEC Research Office.[123] CDEC was activated on 1 November 1956, with two officers and sixteen enlisted men present for duty. It soon grew.[124] By 18 January 1958, the assigned strength of CDEC had increased to 53 officers, 2 warrant officers, 41 enlisted personnel, 24 graded civilians, and 7 ungraded civilians.[125]

Operations research was at the heart of all CDEC operations. An integral part of the planned CDTEC organization was the Research Office of the Test and Experimentation Center (ROTEC), an agency staffed by contracted civilian scientists who would operate under the direction of the commanding general, CDTEC.[126] The 18 October 1956 CONARC Letter of Instruction (LOI) provided that

> in FY 57, ROTEC will be supported under the contract which provides for support of the Combat Operations Research Group (CORG) at Headquarters CONARC. Operations will be in accordance with provisions of that contract or any modification thereof. Negotiations for the establishment, modification, and renewal of any contract providing for ROTEC services will be conducted by this headquarters in coordination with CDTEC. The purpose of ROTEC is to assist the CG, CDTEC, in the establishment of scientific methodology and objective analysis of tests and experiments, and to conduct original research on problems related to the CDTEC mission and functions.[127]

ROTEC was initially established in Monterey, California, and was later redesignated the Research Office Experimentation Center (ROEC) and moved to Fort Ord.[128] Initially, the scientific personnel to staff ROEC were provided under the Technical Operations, Inc., contract with HQ CONARC.[129] However, the contract for supplying scientific services to CDEC was soon shifted to the Stanford Research Institute of Menlo Park, California, which maintained offices at Fort Ord near HQ CDEC.[130] The CDEC director of research, as the senior representative of the scientific contractor, managed the operations of ROEC and ensured that CDEC received "such scientific services as are necessary to accomplish through objectivity and scientific control, the mission assigned CDEC."[131] ROEC also served as a liaison with the other OR agencies throughout the Army, the other services, and the Department of Defense.[132]

The responsibilities of ROEC extended to designing experiments and experiment data evaluation plans, umpiring, establishing data recording procedures, collecting weapons effect data, analyzing experiment data, and preparing reports on experiments.[133] To carry out its assigned functions, ROEC was organized as shown in Figure 4–5.

The Programs Liaison office provided coordination between the programming elements of CDEC and ROEC during the early stages of projects.[134] For each project, a senior project scientist in the Planning and Execution Group worked with a senior project officer from CDEC to prepare detailed plans for the experiment. Selected members of ROEC constituted the Review Board that reviewed the proposed design of experiments submitted by the senior project scientist. The

Data Analysis Group supported the project scientists in preparing the experiment evaluation plan and assembling the weapons effects data tables needed by the umpires. For each ongoing project, a Field Support Subgroup checked the data, assembled it in a convenient form, and prepared simple summary statistics for the project scientist. The Business Services Group handled all administrative support for ROEC.

Employing civilian analysts was one means that CDEC used to "eliminate prejudice and opinion" and to meet the requirement to "quantify, objectively measure, and analyze the results of the battles [i.e., the experiments]."[135] In 1958, the strength of ROEC under the contract with the Stanford Research Institute was 20 civilian scientists, 6 technical assistants, and 11 administrative personnel.[136] Increases of ten additional scientists in FY 1958/59 and another ten scientists for FY 1960 and beyond were contemplated.[137] In addition to the civilian scientific personnel provided by the Stanford Research Institute, the commanding general, CDEC, also established a Scientific Advisory Committee of distinguished scientists and industrialists from the West Coast who met twice a year to examine the scientific objectivity and validity of CDEC operations and to advise the commanding general, CDEC, on needed corrections and improvements.[138]

CDEC was responsible for conducting field experiments on new materiel, organization, and doctrine developed by CORG and other elements of the CONARC combat developments system. For the most part the methods and procedures for such field experimentation had to be developed by CDEC "from scratch." The principal vehicle devised for carrying out CDEC's experimental work was the Experimental Project Team, comprising both military personnel and civilian scientists. The military personnel for the teams were drawn from the CDEC Directorate of Field Operations (later from the Directorate of Plans and Operations and the Directorate of Logistics Liaison), and the scientific personnel were furnished by the Research Office (Stanford Research Institute). Depending on the nature of the experiment, the team leader was either an officer or a scientist.

CDEC's initial experimentation program was based on the CONARC LOI of 18 October 1956, which called for completion of "an integrated combat group experiment by 1 July and experimentation on a continuing basis with platoon-size combat forces."[139] The results of the first experiment in the program—an examination of the firepower of the pentomic-type rifle company—were unsatisfactory because of faulty umpire techniques and procedures, and so the focus of the experiment was converted to "developing techniques and procedures that could be used for umpiring in all future CDEC experimentation."[140] In 1957, CDEC completed experiments on mortar gunnery, umpire techniques and procedures, 3.5-inch rocket launchers, howitzer gunnery, the tactical application of passive antipersonnel devices (the Claymore mine), PENTANA-type companies in mobile operations, and PENTANA-type combat surveillance units.[141]

Creation of the United States Army Combat Developments Command

The decade-long effort to organize and improve the Army combat developments systems culminated in 1962 with the establishment of the United States Army Combat Developments Command (CDC), a separate combat developments agency similar to the one originally envisioned in the February 1952 Project VISTA report.[142] The transfer of combat developments functions and personnel to CDC from HQ CONARC and CDC's absorption of CDEC marked the success of those who had long advocated a centralized Army combat developments system.

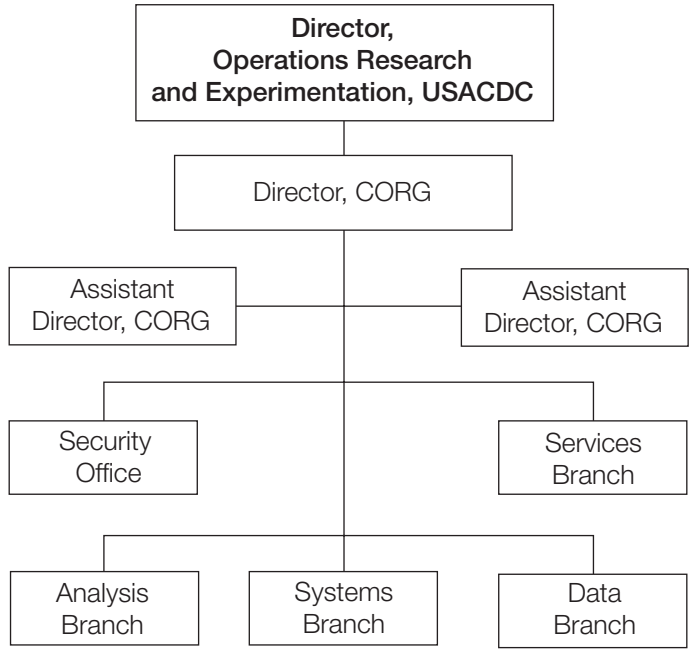
In 1961, the newly appointed secretary of defense, Robert S. McNamara, initiated a study of Department of Defense functions, organization, and procedures with a view to consolidating various functions and, among other changes, creating a functional structure for the Army's technical services.[143] The study, known as Project 80, was led by Deputy Comptroller of the Army Leonard W. Hoelscher, and its final report became known as the Hoelscher Report. One of the chief recommendations of the Hoelscher Report was that a new United States Army Combat Developments Command be created to integrate the combat developments activities of CONARC, the Army's technical and administrative services, and other Army agencies.[144] Accordingly, the United States Army Combat Developments Command was activated at Fort Belvoir, Virginia, on 20 June 1962 and became operational on 1 July 1962, under the command of Lt. Gen. John P. Daley. The principal mission assigned to the new command was

> to command all assigned field agencies; to formulate and document current doctrine for the Army; and, in anticipation of the nature of land warfare in the future, to determine the types of forces and materiel needed in the future, and how these forces and materiel should be employed.[145]

Speaking to the participants of the 1962 Army OR symposium, Lt. Gen. Daley indicated that there would be "many opportunities for operations research" in the new command.[146] He also referred to the usefulness of OR in evaluating new materiel, organization, and doctrine; noted the importance of selecting the right inputs for OR studies; and cautioned symposium participants to avoid overselling OR.[147]

As part of the consolidation of combat developments activities under the Combat Developments Command in late 1962, the Combat Operations Research Group at HQ CONARC was transferred to the control of CDC, and after

FIGURE 4–6—ORGANIZATION OF CORG: 1 JANUARY 1963



Source: Headquarters, U.S. Army Combat Developments Command, *Staff Directory* (Fort Belvoir, Va., 1 Jan 63).

reorganization it was made a part of the HQ CDC Operations Research and Experimentation Division, as shown in Figure 4–6.[148] On 1 July 1962, the Combat Developments Experimentation Command, including its Research Office Experimentation Command operated by Stanford Research Institute, also became part of the new Combat Developments Command.[149]

The changes in Army structure and methods ordered by Secretary of Defense McNamara and his associates radically transformed the Army R&D and combat developments systems. OR continued to be an integral and important part of the R&D and combat developments processes, however, and the new OR organizations created to support combat developments in the 1950s, such as CORG and ROEC, continued to prosper and provide critical insights for Army decision makers well beyond 1962.

Operations Research in the Technical Services, 1950–62

Despite the tremendous strides in the Army R&D and combat developments systems in the 1950s and early 1960s and the creation of a number of vigorous new OR organizations, such as CORG and ROEC, the operations research groups formed by the Army's technical services remained at the sharp end of the R&D and combat developments process. The technical services, notably the Ordnance Corps and Signal Corps, had employed OR methods as an integral part of their R&D programs during World War II, but (except for the Signal Corps in a brief period during the war) until the 1950s the technical services did not formally establish OR groups under that name. However, as early as 1950, the total funds and personnel dedicated to OR by the technical services exceeded those of ORO, and the increased emphasis on integrating the development of weapons, organization, and doctrine combined with the example of ORO prompted the establishment of formal OR groups in the technical services during the 1950s.[150]

All of the technical service OR groups were relatively limited in size and in the scope of their operations.[151] For the most part, they relied on civilian analysts hired under the civil service, but some of them, most notably the Signal Corps, made use of universities or nongovernmental private research firms to perform OR work under contract.[152] The technical services OR groups generally focused on the traditional weapons analysis types of problems, including "overall weapons and equipment system studies from an engineering viewpoint, determination of desirable characteristics for new weapons and equipment, and technical feasibility studies."[153] Although they appropriated the "operations research" title and generally made use of techniques common in OR work, the technical services programs were primarily engaged in "problem solving" and remained relatively unconcerned with

the more theoretical aspects of OR that organizations such as the RAND Corporation and ORO had taken up.

Ordnance Corps

The Ordnance Corps used OR techniques extensively for several years before forming a separate OR organization. The focal point of ordnance OR activities was in the Ballistic Research Laboratories (BRL) at Aberdeen Proving Ground, Maryland. BRL was established by the Ordnance Department in 1938 to perform engineering-type analyses of weapons and ammunition to provide a scientific basis for the design and development of ordnance materiel. During World War II and after, BRL used OR techniques to produce bombing pattern analyses; develop firing tables for different types of ammunition; and study the vulnerability of various targets, notably aircraft and tanks, to the effects of different types of ordnance.[154] The work performed at Aberdeen was used by the Army Staff, OCAFF, the various arsenals, the Weapons Systems Evaluation Group, the Atomic Energy Commission, and the other services to supplement their own research.[155] Even ORO made substantial use of the work done at Aberdeen.[156]

In January 1953, the Weapons Systems Laboratory (WSL), a part of BRL, established an OR group that operated under the general supervision of the assistant chief of ordnance who headed the Research and Development Division.[157] In 1954, the staff of WSL engaged in OR studies included two military and fourteen civilian professionals, the latter under civil service.[158] The annual budget for WSL OR activities was $435,000, and only approximately 15 percent of the laboratory's personnel and work effort was devoted to analytical OR studies; the remaining work was experimental.[159] WSL performed "overall weapons systems studies from an engineering and operations analysis viewpoint and conducted applied research on factors affecting system performance to establish desirable characteristics and proposed basic designs for new and improved weapons."[160] Mathematical models and OR techniques were applied, and high-speed digital computers and specially designed instruments were used "to predict the probability of success in the tactical employment of proposed or developmental weapons."[161] Among the specific tasks assigned to WSL were these:

(1) Conduct experiments, studies and analyses to determine the vulnerability of aircraft and missiles and the effectiveness of aircraft weapons in order to provide a basis for the comparative evaluation of the effectiveness of weapons under development, for the design of future weapons, and for reducing the susceptibility of our own aircraft and missiles to damage by ordnance items.
(2) Evaluate the effectiveness of antiaircraft weapon systems for defense of the continental U.S. and field armies, and compare competing AA [antiaircraft] weapon systems in realistic air defense problems on a cost-effectiveness basis.
(3) Conduct systems analysis studies on the effectiveness of atomic explosive weapons for use against ground or aerial targets.
(4) Determine the lethality or lethal areas of artillery shell, mortar shell and artillery type rockets in order to evaluate the effectiveness of these against personnel and materiel targets.
(5) Evaluate the overall battlefield effectiveness of tanks and make recommendations on how tank designs can best be improved.[162]

OR was also used at the various ordnance commands and arsenals, some of which (for example, Picatinny Arsenal in Dover, New Jersey; Frankford Arsenal in Philadelphia, Pennsylvania; and, after 1954, Redstone Arsenal in Alabama) established their own small OR groups.[163] In the early 1960s, the U.S. Army Weapons Command at Rock Island Arsenal in Illinois formed an OR group to perform both long-range and short-term studies. The Weapons Operations Research Division at HQ, Army Weapons Command, provided OR services to three subordinate installations and generated approximately 60 percent of its own studies.[164]

The Army Research Office

In June 1951, the Ordnance Corps established the United States Army Office of Ordnance Research (OOR) on the campus of Duke University in Durham, North Carolina, as its central office for monitoring basic research programs sponsored by the Ordnance Corps.[165] OOR administered scientific research conducted for the Ordnance Corps by universities, research institutes, and industrial laboratories and oversaw research conducted by Ordnance Corps personnel at arsenals and laboratories. At the time, about 70 percent of Ordnance research work was done in-house, but most basic research was parceled out to educational institutions and nonprofit research organizations.[166] In FY 1951, only $288,500 was devoted to ordnance basic research, but it was estimated that around $4.6 million annually would be required to support the basic research to be overseen by the new OOR.[167]

The original OOR program focused on basic research in five principal areas: exploratory, ballistics, materials and construction, combustion, and friction and wear.[168] To ensure that the research projects were properly designed and scientifically sound, in June 1951, the Ordnance Corps contracted with the National Research Council for the National Academy of Sciences to evaluate proposals for basic research submitted to it by OOR.[169] The first technical paper sponsored by OOR, prepared by Dr. Robert H. Cameron of Wayne State University in September 1951, dealt with a solution to a heat flow equation.[170] By the end of 1951, 88 projects had been initiated, and between 1953 and 1969 OOR steadily supported some four hundred active projects each year.[171]

Interest in OR was high at OOR, and the office included basic research in OR theories and methods among the fields for which it provided support. For example, OOR

funded a number of graduate assistantships at the Massachusetts Institute of Technology (MIT) for basic work in OR.[172] The office also sponsored the First Ordnance Conference on Operations Research, held at Frankford Arsenal on 14 May 1954.[173] The purpose of the conference was to "disseminate information on the methods and new developments in the field of operations research to a large number of government personnel in the hope that they might find these disciplines [that is, OR] applicable to many of their own problems."[174] Col. T. J. Kane, the commander of Frankford Arsenal, opened the meeting, and some 150 attendees listened to presentations by Dr. T. J. Killian, the chief scientist of OOR; Dr. Merrill M. Flood of Columbia University; Dr. Robert M. Thrall of the University of Michigan; Dr. Philip M. Morse of MIT; and Dr. George Shortley of ORO.

OOR proved to be a very successful agent for prioritizing, monitoring, and controlling the costs of scientific research, and by early 1958 the Army Scientific Advisory Panel was pressing the Army's chief of research and development, then Lt. Gen. James M. Gavin, to extend the concept to all Army-sponsored research.[175] As a result, on 24 March 1958, the Army's Research and Development Field Office at Fort Belvoir, Virginia, was redesignated as the U.S. Army Research Office (ARO) and moved to Arlington, Virginia.[176] Almost three years later, in January 1961, OOR was transferred from the direct control of the Office of the Chief of Ordnance to the Office of the Chief of Research and Development, was redesignated the U.S. Army Research Office (Durham), and was assigned responsibility for research in the physical sciences Army-wide, to include the technical services.[177] The Arlington office continued to have responsibility for the life sciences, psychology, social sciences, and earth sciences.[178]

The missions assigned to the newly created ARO included planning and directing the Army's various research programs to ensure that they met the Army's needs, making maximum use of the nation's scientific talent, providing a single point of contact with the scientific community, coordinating the R&D programs of the Army's technical services, and coordinating the Army's research programs with those of the other services and other government agencies.[179]

The Army Research Office (Durham) had an abiding interest in the use of OR, and, beginning in March 1962, ARO (Durham) sponsored a series of annual symposia on OR in the Army, the first of which was held on 27–29 March 1962, in Durham, North Carolina.[180] The commander of ARO (Durham) at that time was Col. George W. Taylor. Dean Marcus E. Hobbs of Duke University welcomed the two hundred civilian and military participants, who enjoyed a full program of professional papers and panel discussions on all aspects of OR.[181] The purposes of the symposia, as stated for the Second Army Operations Research Symposium in March 1963, were to

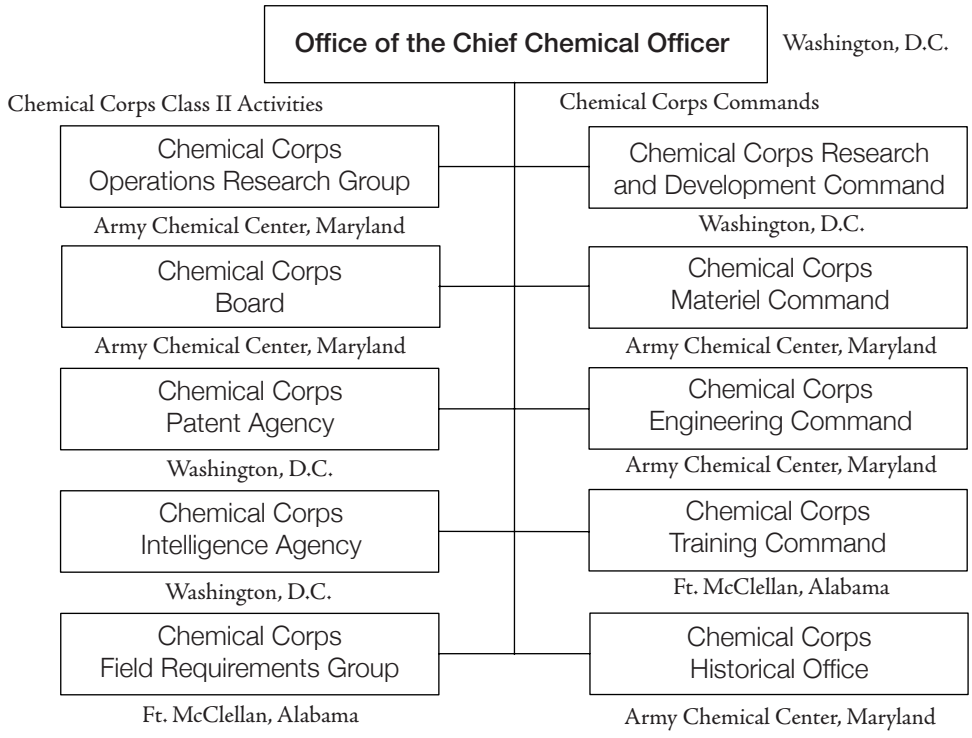
> 1.Emphasize the role of OR in improvement of military operations; 2. Acquaint key Army personnel with the Army's OR projects and in-house capabilities; 3. Provide a forum for presentation and discussion of Army problems amenable to solution through OR; 4. Inform Army operations analysts of new technological developments in OR; 5. Increase the applicability of results obtained in OR studies; 6. Afford Army operations analysts an opportunity to become acquainted with their colleagues and with nationally-known leaders in the field of OR.[182]

As a result of the first ARO-sponsored Army OR symposium, ARO took several actions to improve OR in the Army. An Operations Research Technical Assistance Group (ORTAG) was formed with representatives from all the Army Staff sections to examine technical aspects of OR. The group met for the first time in September 1962 and established a program of assistance visits to various Army commands that proved useful to the newly formed Army Material Command, the Combat Developments Command, and the Test and Evaluation Command, among others.[183] An Operations Research Steering Committee, headed by the director of Army research (that is, the chief of ARO), was also formed and met semiannually to oversee requirements and allocation of resources for OR and to advise the chief of R&D on the Army's overall OR program.[184] Meanwhile, the Research Planning Division of ARO managed the day-to-day oversight and coordination of Army OR programs.[185] A prototype was designed for a formal one-year course leading to a master's degree in OR for a limited number of officers and civilians, and provision was made for a number of orientation courses to make staff officers more familiar with the capabilities and limitations of operations research, but little progress was made toward the goal of creating a central repository of OR studies.[186]

ARO efforts to monitor and coordinate contracts for Army OR studies—including the working of the Operations Research Steering Committee and the project advisory groups established for each project or study contract—were governed by *Army Regulations No. 1–110*, which assigned responsibility for the bulk of the Army's contract OR program to the chief of research and development.[187] *AR 1–110* established overall policy guidance, procedures, responsibilities, and evaluation criteria concerning both management advisory services and OR studies or projects performed under contract (such as those prepared by ORO/RAC).[188] The objectives of the Army operations research program, as prescribed by *AR 1–110* were to

> a. Improve the overall effectiveness of the Army through analysis of various alternative solutions to major problems.
> b. Assist in determining the most efficient use of resources in operations.

FIGURE 4–7—ORGANIZATION OF THE CHEMICAL CORPS: JUNE 1956



Source: U.S. Army, Chemical Corps School, *Organization and Functions of the Chemical Corps* (Fort McClellan, Ala.: Chemical Corps School, 1956), p. 21, Figure 1; U.S. Army, Office of the Chief Chemical Officer, *Organization of the Army Chemical Corps, 15 June 1956* (Washington, D.C.: Office of the Chief Chemical Officer, Department of the Army, 1956), p. 21, Figure 1.

c. Promote, within the Chief of Research and Development's area of responsibility and authority, optimum awareness and prompt application of usable findings of projects or studies conducted by or for any element of the Department of the Army.[189]

It should be noted that, although the chief of R&D was charged with staff oversight of all Army contracts for OR services and studies as well as staff oversight of the OR programs of the technical services (therefore, control of most Army OR activities), he did not in fact exercise direct supervision of all such activities. The deputy chief of staff for logistics retained supervisory responsibility for the logistics OR program, including the logistical portion of the technical services programs; the chiefs of the technical services were responsible for supervising their service's OR programs; and the commanding general, CONARC, was responsible for overseeing CORG's study program and other OR activities in the CONARC combat developments system (such as ROEC).[190]

The Chemical Corps

Like the Ordnance Corps, the Chemical Corps made extensive use of OR-like methods for some time before forming a formal OR group. The Chemical Warfare Service was redesignated as the Chemical Corps on 2 August 1946, and the title of chief of the Chemical Corps was changed to chief chemical officer by the Army Reorganization Act of 1950.[191] In October 1951, the chief chemical officer established three Chemical Corps field commands: the Chemical Corps Materiel Command, the Chemical Corps Research and Engineering Command, and the Chemical Corps Training Command. The Chemical Corps was again reorganized in 1956, and the resulting organization was as shown in Figure 4–7.The Chemical Corps Operations Research Group (CCORG) was established at Edgewood Arsenal, a subpost of the Army Chemical Center (later the Chemical Warfare Center), Maryland, in May 1951 (before the four Chemical Corps commands) as a Class II activity under the direct supervision of the chief chemical officer. The distinguished chemist, Dr. W. Albert Noyes, Jr., then a member of the Chemical Corps Advisory Council, precipitated the creation of CCORG when he recommended to the chief chemical officer, Maj. Gen. Anthony C. McAuliffe (who had played a prominent role in the creation of ORO in 1948) that a group be assembled to study Chemical Corps problems.[192]

The formal mission of the group was "(1) To analyze and evaluate problems connected with CmlC [Chemical Corps] operations in areas as authorized and directed; (2) To provide the Chief Chemical Officer with scientific data, technical evaluations, and reports."[193] The Chemical Corps senior scientific adviser, also located at Army Chemical Center, Maryland, reviewed the studies referred to CCORG and the reports prepared by the group for the chief chemical officer.[194]

In 1954, CCORG had a strength of five military and eight civilian professionals under civil service, and an annual budget of $46,500, a little more than one one-hundredth of the ORO budget for that year.[195] Two years later, the group consisted of the director, Lt. Col. John A. Bacon, 6 officers, 3 enlisted men, and 8 civilians.[196] The three enlisted men assigned to CCORG were draftees with doctorates in chemistry and were part of the Army's Enlisted Scientific and Professional Personnel program.

The directors of CCORG, Lt. Col. Bacon and his successors (Lt. Col. A. Bowker and Lt. Col. Jack F. Lane) served mostly as administrators and facilitators, leaving the scientific direction of the group to the civilian scientific director.[197] The CCORG director also served as an ex-officio member of the executive council of the Chemical Board, which had its own operations research element, at least on paper.[198] The board—with a principal mission of proving long-range studies; field testing Chemical Corps organization, weapons, and doctrine; determining the proper application of chemical, biological, and radiological warfare systems in future military operations; and providing support and long-range guidance for the Chemical Corps Research and Development Program—was organized with an Executive Office, an Administrative Services Office, and four divisions: Advanced Studies, Special Projects, Field Service, and Operations Research.[199]

According to George Milly, who served as its scientific director, CCORG fashioned its own work program on its perception of the needs of the Chemical Corps and the Army.[200] The bulk of the work undertaken fell clearly into the weapons analysis and evaluation category, assessments of the properties and performance of various chemical agents with a view to developing some consistent pattern that could be used for planning purposes being the most common type of task. A good deal of effort was also directed at studies of the vulnerabilities of troops to various chemical agents. Restricted primarily to studies of chemical weapons, the work of CCORG did not extend to any appreciable degree to problems of Chemical Corps organization and doctrine. The methods used by CCORG included mathematical modeling but otherwise bore little resemblance to what is today defined as OR. At base, its work consisted of practical problem solving rather than the application of sophisticated theories.

George Milly recalled that the influence of CCORG gradually permeated throughout the Chemical Corps, but there was a certain degree of tension between the analysts at CCORG and the "sensitive scientists" in the various Chemical Corps laboratories who saw CCORG as always "second guessing" them. In fact, Milly also recalled that the CCORG analysts could not always rely on the data obtained from the labs and had to "proof" it themselves.

Although CCORG had little or no contact with the OR groups in the other technical services, it did work closely with ORO. In 1957, Milly and other members of CCORG prepared a comprehensive report on chemical weapons, known as "ORG 17," for Charlie Warner of ORO.[201] "ORG 17" was a major contribution and is still consulted today. CCORG also maintained some contact with the military OR groups in Britain, Canada, and Australia through participation in the annual tripartite/quadripartite OR conferences.

With the organizational changes in the Defense Department and the services instituted by Secretary of Defense Robert McNamara in the early 1960s, the Chemical Corps Operations Research Group was broken up. Some personnel were transferred to Rock Island Arsenal, and others were reassigned to the new Army Munitions Command. Milly, who by then was the director of CCORG, elected to leave government service rather than cope with the growing centralization of control over research and the drastic reorganizations then taking place.

The Signal Corps

The Signal Corps was the only Army technical service to establish a separate operations research organization before the 1950s, but the wartime Operational Research Branch in the Office of the Chief Signal Officer, led by Dr. William L. Everitt, was deactivated on 1 April 1946. The Signal Corps, however, continued to use integrated OR techniques in its R&D activities and in the field of communication traffic engineering.[202] The Signal Corps also maintained close contact with ORO, which conducted several studies of interest to the Signal Corps.

In May 1953, the chief signal officer signed a contract with a private electronics firm, Haller, Raymond and Brown, Inc., to establish a Signal Corps Evaluation and Analysis Group (SCEAG).[203] Monitored by the Plans and Operations Division in the Office of the Chief Signal Officer, the group had one military and sixteen civilian professionals at work in 1954, and the annual contract budget was $330,000.[204] A Signal Corps Resident Liaison and Operational Research Coordination Office was established at the Haller, Raymond and Brown offices in State College, Pennsylvania, to coordinate the OR program at the contractor's site with ongoing research at the Signal Corps laboratories and the various Army combat developments agencies.[205]

In January 1954, SCEAG submitted a study of the Signal Corps problem areas that might be addressed profitably using OR methods.[206] The SCEAG study led to the development of two OR proposals submitted to the Army Staff by the Signal Corps in 1954. SCEAG participated actively in the February 1954 tests conducted by the Combat Operations Research Group of the Office of the Chief of Army Field Forces at Fort Benning, Georgia, to study the infantry rifle company, and it assisted in field tests of new Signal Corps organizations and equipment at Fort Huachuca, Arizona, during the mid-1950s.[207]

The Signal Corps supported the development of the "pentomic Army," which demanded improved command, control, and communications (C^3) capabilities and long-range improvement in Army communications and electronics equipment and methods.[208] The chief signal officer, then Lt. Gen. James D. O'Connell, responded by taking a number of actions to ensure that the Signal Corps met the challenges in the last half of the 1950s. Among other measures, the Signal Corps revised and expanded its operations research and analysis efforts in an effort to find "new concepts, systems and techniques in all areas of Signal Corps interest."[209] The Signal Corps also expanded and accelerated its scientific R&D and combat developments programs and participated in Army field exercises and tests of new C^3 systems, organizations, and doctrine at strategic and tactical levels.

Throughout the 1950s, the Signal Corps maintained a close working relationship with ORO. ORO provided both studies pertaining to Signal Corps equipment, organization, and doctrine and ideas for the expansion and improvement of the Signal Corps' own OR efforts.[210] To facilitate the relationship, the Signal Corps maintained a full-time active-duty liaison officer at ORO, provided separate funds to ORO in FY 1956–FY 1958 to initiate and continue studies in communications and electronic warfare, and was represented on all of the ORO project advisory groups.[211]

The Army Medical Service

In the 1950s and early 1960s, the Army Medical Service (AMEDS) conducted an active R&D program and more than doubled its R&D expenditures between FY 1951 and FY 1960.[212] The AMEDS R&D program included not only basic medical research but also extensive use of contracted OR services to support the development and testing of new concepts of equipment, organization, and operational doctrine for field medical units. Beginning in FY 1960, AMEDS greatly expanded its combat developments program, and the AMEDS Combat Development Group, located at the Forest Glen Section of Walter Reed Army Medical Center in Silver Spring, Maryland, was assisted by Operations Research, Inc., to design new materiel and new organizational and operational concepts for the field medical service of the future.[213] Supported by the deputy chief of staff for logistics, HQ CONARC, and the newly established Combat Developments Command, the AMEDS Combat Development Group planned and conducted experiments at the CDEC field laboratory at Fort Ord to evaluate the new concepts.[214] The AMEDS Combat Development Group established close working relationships with other Army combat developments agencies and was assisted by the U.S. Army Medical Research and Development Command, which focused on medical research and the development of medical materiel and techniques.[215] The efforts of the AMEDS Combat Development Group accelerated in FY 1961, and a number of contracts were awarded to civilian OR agencies to provide "scientific and dispassionate evaluation of the various operational concepts which had been proposed."[216] During FY 1961, increased emphasis was placed on the use of OR studies to evaluate the capabilities of AMEDS to accomplish its mission. The initial study was an evaluation of field army medical support up to combat command level.[217] A model, suitable for computerization, was developed to indicate the effect of various factors, such as the combat situation, weather, terrain, unit staffing, and logistics, on the provision of medical support in the field.

The AMEDS Combat Development Group moved to Brooke Army Medical Center in Texas in July 1961, and the AMEDS combat developments program, including the use of OR, continued to expand.[218] AMEDS expenditures on R&D in FY 1962 increased to nearly $23.5 million, of which $14.7 million was for research contracts (including OR studies)—nearly double the amount in FY 1961.[219] The AMEDS R&D program included funding for a special "operations research project" that involved studies analyzing casualty distribution, location, design, construction, organization, patient care procedures, staffing criteria, and medical materiel for military hospitals.[220] The first two phases of these studies determined that simulation techniques were feasible, and, subsequently, computerized simulation models were designed, the necessary data were assembled, and preliminary studies involving a hypothetical battle situation were conducted.[221]

Operations Research in the Other Technical Services

By the mid-1950s, the other technical services, including the Quartermaster Corps and the Transportation Corps, as well as the Corps of Engineers and several of the combat arms, had also created OR groups or contracted with civilian research organizations for OR services.[222] Few details remain of the nature and scope of these programs and contracts, but they almost certainly involved the use of OR tech-

niques to evaluate new weapons systems, new organizations, and new operational doctrine.

Conclusion

The twelve years between 1950 and 1962 saw tremendous progress in the Army's ability to prepare for future war. The Army restructured its R&D establishment and created a number of effective new combat developments organizations responsible for the design of weapons, organization, and doctrine for modern warfare. Operations research was at the core of both the R&D and combat developments efforts, and a number of new Army OR groups were created to handle the ever-expanding workload. In general, the new OR organizations, such as the Combat Operations Research Group and the Research Office Experimentation Command, were highly successful and made significant contributions to the Army and the nation.

The use of operations research in the Army's technical services also expanded substantially between 1950 and 1962, but, despite its significant growth and increasing importance, OR in the technical services suffered from several defects. Whereas the agencies and procedures for coordinating and evaluating the work of new organizations, such as CORG and ROEC, were clearly prescribed, those for coordinating and evaluating operations research work in the technical services were not clearly spelled out in Army documents.[223] In his 1954 War College study, Col. Seymour I. Gilman noted that the growth of operations research in the technical services was "a healthy development which will supplement the work of ORO and broaden the base of qualified personnel in the Army," but "the integration of operational research agencies within the structure of the Chemical and Ordnance Corps is not conducive to the best results."[224] Gilman went on to recommend that "the Ordnance Corps and the Chemical Corps reexamine the status of operational research groups integrated into the Corps structure from the standpoint of providing improved results by independent status [that is, a shift from civil service to an ORO-like organization]" and that "those technical services without operational research groups study the feasibility of their early establishment."[225]

Although much remained to be done, particularly in the area of recruitment and training of OR personnel, by 1962 the Army had in place an operations research program capable of dealing effectively with the many and varied problems faced by Army leaders. RAC, HumRRO, SORO, and the newly formed STAG handled a wide variety of issues in higher-level policy, strategy, and operations. CORG and ROEC dealt with broad problems of R&D, combat developments, and field testing. And, at the sharp end of the R&D/combat developments system, the OR groups of the technical services addressed problems specific to their assigned functions. Although the system lacked central coordination and involved some duplication of effort, it performed well and more than proved its value as an essential aid to Army decision makers.

CHAPTER FOUR NOTES

[1]U.S. Congress, Office of Technology Assessment, *A History of the Department of Defense Federally Funded Research and Development Centers*, OTA-BP-ISS-157 (Washington: USGPO, 1995), p. 20 (hereafter cited as OTA History).

[2]John L. Romjue, *History of Field Experimentation Methodology in the United States Army, 1956–1970* (Fort Ord, Calif.: U.S. Army Combat Developments Command Experimentation Command, 1971), p. 3; Jean E. Keith and Howard K. Butler, *United States Army Combat Developments Command: Origins and Formation* (Fort Belvoir, Va.: Office of the Historian, Deputy Chief of Staff for Management and Resources, U.S. Army Combat Developments Command, 1972), p. 2 (hereafter cited as Keith and Butler, *CDC Origins and Formation*).

[3]Keith and Butler, *CDC Origins and Formation*, p. 3.

[4]Ibid.

[5]Marshall D. Moody, *The Transportation Corps Combat Development Program: Its Origin and Status*, in the series TC in the Current National Emergency: The Post-Korean Experience, Survey No. 11 (Washington: Office of the Chief of Transportation, DA, 1958), p. 1; Keith and Butler, *CDC Origins and Formation*, 3; Romjue, *Field Experimentation*, pp. 3–4.

[6]U.S. Continental Army Command, *Report by USCONARC Ad Hoc Committee on Evaluation of the US Army Combat Development Experimentation Center* (Fort Monroe, Va.: HQ, CONARC, 1958), p. 12 (hereafter cited as CONARC Ad Hoc Committee Rpt).

[7]Ibid., p. 17.

[8]Ibid., p. 215; Moody, *Transportation Corps*, pp. 2–3; James E. Hewes, *From Root to McNamara: Army Organization and Administration, 1900–1963* (Washington: U.S. Army Center of Military History, 1975), p. 259. Moody noted that this is the definition given in the *Final Report on Project VISTA* and in the *Report of the Ad Hoc Committee to Study the Army's Combat Development Program* (The Haworth Rpt) (Washington, 20 Oct 1954), p. 8. Curiously, despite the central importance to the U.S. armed services of "research and development" and "combat developments," neither term is defined in the official dictionary of U.S. military terms, Joint Chiefs of Staff, *Joint Publication 1–02: Department of Defense Dictionary of Military and Associated Terms* (Washington: Office of the Chairman, JCS, 23 May 1994).

[9]Hewes, *From Root to McNamara*, p. 259.

[10]U.S. Army TRADOC, Historical Office, *TRADOC On-Line*

History (Fort Monroe, Va.: Historical Office, HQ TRADOC), "Chapter 7: Combat Developments," available at http://tradoc.monroe.army.mil/historian.

[11]U.S. Army Combat Developments Experimentation Command, *Developing Tomorrow's Army Today* (Fort Ord, Calif.: U.S. Army CDEC, 1958), p. 5.

[12]Ibid., p. 8.

[13]Edmund T. Pratt, Jr., "Challenges in Army Operations Research," in U.S. ARO (Durham), *Proceedings of the United States Army Operations Research Symposium, 26, 27, 28 March 1963, Durham, North Carolina, Part I*, ORTAG–25 (Durham, N.C.: ARO [Durham], 30 Sep 63), p. 92.

[14]CONARC Ad Hoc Committee Rpt, p. 215.

[15]Moody, *Transportation Corps*, p. 3.

[16]James M. Gavin, *War and Peace in the Space Age* (New York: Harper & Brothers, 1958), p. 132; Moody, *Transportation Corps*, pp. 3–5; Keith and Butler, *CDC Origins and Formation*, p. 3.

[17]Gavin, *War and Peace*, p. 132. It should be noted that several of the participating scientists, notably Howard P. Robertson, had been involved in the wartime OR program.

[18]CONARC Ad Hoc Committee Rpt, p. 216.

[19]Keith and Butler, *CDC Origins and Formation*, p. 3.

[20]Ibid., p. 4.

[21]Ibid.; CDEC, *Developing Tomorrow's Army Today*, pp. 6–7.

[22]Keith and Butler, *CDC Origins and Formation*, p. 4.

[23]Ltr, Gen J. Lawton Collins (Army chief of staff) to Gen John R. Hodge (chief of Army field forces), Washington, 13 Jun 52, sub: Establishment of Combat Development Agency (cited in Keith and Butler, *CDC Origins and Formation*, pp. 4–5); CONARC Ad Hoc Committee Rpt, p. 216.

[24]Ltr, Collins to Hodge, 13 Jun 52 (quoted in Keith and Butler, *CDC Origins and Formation*, p. 5).

[25]Keith and Butler, *CDC Origins and Formation*, p. 5.

[26]Ibid. The principal changes were the use at HQ OCAFF of operations analysts drawn on a rotational basis from ORO rather than permanent civil service personnel (see the discussion of CORG below) and a 50 percent reduction in the personnel increase for the service schools recommended in the OCAFF plan.

[27]Keith and Butler, *CDC Origins and Formation*, p. 5; *TRADOC On-Line History*, Chapter 7.

[28]Hewes, *From Root to McNamara*, p. 259.

[29]Ltr, chief of Army field forces, Fort Monroe, Va., 21 Feb 53, sub: Combat Developments Planning Guide (cited in Keith and Butler, *CDC Origins and Formation*, p. 6). The *Combat Developments Planning Guide* later became the *Combat Developments Objectives Guide*. It listed broad problem areas and stated the objectives to be achieved.

[30]Keith and Butler, *CDC Origins and Formation*, p. 6.

[31]Ltr, chief of Army field forces, Fort Monroe, Va., 15 May 53, sub: Evaluation of Combat Developments Departments (cited in Keith and Butler, *CDC Origins and Formation*, p. 6).

[32]CONARC Ad Hoc Committee Rpt, p. 216.

[33]Romjue, *Field Experimentation*, p. 5; CDEC, *Developing Tomorrow's Army Today*, p. 7.

[34]Keith and Butler, *CDC Origins and Formation*, p. 6.

[35]CONARC Ad Hoc Committee Rpt, p. 216.

[36]Disposition Form, deputy chief (Combat Developments), OCAFF, to Chiefs of OCAFF Staff Sections, Fort Monroe, Va., 2 Oct 53, sub: Functions of Combat Developments Group, Office, Deputy Chief (cited in Keith and Butler, *CDC Origins and Formation*, p. 7, n. 13).

[37]Project MICHIGAN involved the study of ways to improve the Army's long-range combat surveillance capability (see Oliver R. Dinsmore, "Requirements for Operations Research Training of Army Officers," student research paper 66–4–129–U, U.S. Army War College, Carlisle Barracks, Penn., 1966, p. 24).

[38]Keith and Butler, *CDC Origins and Formation*, p. 8. In May 1954, HQDA authorized direct communication and staff visits between OCAFF and the overseas theaters in order to improve the correlation of combat developments in the continental United States with the actual problems of the theaters.

[39]Ibid., pp. 7–8.

[40]On the constitution, recommendations, and impact of the Haworth Committee, see Keith and Butler, *CDC Origins and Formation*, pp. 8–12; Romjue, *Field Experimentation*, pp. 5–7; and Moody, *Transportation Corps*, pp. 4–5.

[41]CONARC Ad Hoc Committee Rpt, p. 216.

[42]Keith and Butler, *CDC Origins and Formation*, p. 9.

[43]Incl (Haworth Rpt) to Ltr, Dr. Leland J. Haworth to Secretary of the Army Robert T. Stevens, Washington, 20 Oct 54, sub: Final Rpt of Ad Hoc Committee on Combat Development (cited in Keith and Butler, *CDC Origins and Formation*, pp. 10–11).

[44]Change No. 7 to HQ, DA, *Special Regulations No. 10–5–1: ORGANIZATION AND FUNCTIONS, DEPARTMENT OF THE ARMY (Washington, 11 Apr 50)*, Washington, 1 Feb 55 (reproduced in John C. Schermerhorn, "The Role of Operations Research in the Army," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1956, pp. 18–30).

[45]Moody, *Transportation Corps* , pp. 4–5.

[46]Ibid., p. 5.

[47]Ltr, HQ, DA [AGAM–P (M) 381 (19 Jul 1955) CS], Washington, 26 Jul 55, sub: Combat Developments Organization (reproduced in CONARC Ad Hoc Committee Rpt, pp. 219–21); Keith and Butler, *CDC Origins and Formation*, p. 11.

[48]CONARC Ad Hoc Committee Rpt, p. 9.

[49]CONARC Ad Hoc Committee Rpt, Appendix III, p. 39. Note that OR played a major role in most of the prescribed functions.

[50]CONARC Ad Hoc Committee Rpt, p. 8. The CONARC Materiel Development System is outlined in Appendix V, pp. 51–54 of the CONARC Ad Committee Report.

[51]Ibid., p. 11; CONARC Ad Hoc Committee Rpt, Appendix V, para. 2.a, p. 51.

[52]Joseph F. McCloskey, "Organization for Operations Research in the United States," in Max Davies and Michel Verhulst, eds., *Operational Research in Practice: Report of a NATO Conference* (New York: Pergamon Press for Advisory Group of Aeronautical Research and Development, NATO, 1958), p. 165.

[53]U.S. Army Combat Developments Command, Institute of Advanced Studies, Change 1 to *Organization and Functions Manual* (Carlisle Barracks, Penn.: IAS, U.S. Army Combat Developments Command, 12 Nov 68), p. 1. On 1 May 1963, the USAIAS was redesignated the U.S. Army Combat Developments Command Institute for Advanced Studies (USACDCIAS).

[54]Ibid.

[55]Ibid.; Dinsmore, *Requirements for OR Training*, p. 22.

[56]For the organization of combat developments at CGSC, see *TRADOC On-Line History*, Chapter 7.

[57]Ibid.

[58]Ibid.

[59]Keith and Butler, *CDC Origins and Formation*, p. 11.

[60]Ibid.; Hewes, *From Root to McNamara*, pp. 260–61; Moody, *Transportation Corps*, 5. Other DA Staff agencies, such as the Army Logistics Management Center, the Army Intelligence Center, the Army Security Agency Board, and the Finance Corps Field Service Board were brought into the combat developments system at the same time.

[61]Keith and Butler, *CDC Origins and Formation*, p. 11.

[62]Ibid., pp. 5–6.

[63]For a discussion of the Transportation Corps combat developments organization and program, see Moody, *Transportation Corps*, pp. 6–14. Unless otherwise noted, the following description is based on Moody's discussion.

[64]HQ, CONARC, *Memorandum No. 35*, Fort Monroe, Va., 19 Jul 56 (cited in Moody, *Transportation Corps*, p. 7).

[65]Ellis A. Johnson, "The Operations Research Office, US Army," in ORO, *The Second Tripartite Conference on Army Operations Research, 23–27 October 1950*, vol. II: Technical Proceedings (Washington: ORO, 1950), p. 167. Gen. Mark W. Clark was chief of Army field forces from 1 October 1949 to 5 May 1952 when he was replaced by Gen. John R. Hodge, who served until 30 June 1953. Subsequent chiefs of Army field forces and commanding generals of CONARC included Gen. John E. Dahlquist (24 August 1953–29 February 1956), Gen. Willard G. Wyman (1 March 1956–31 July 1958), Gen. Bruce C. Clarke (1 August 1958–30 September 1960), and Gen. Herbert B. Powell (1 October 1960–31 January 1963).

[66]Keith and Butler, *CDC Origins and Formation*, p. 5.

[67]*TRADOC On-Line History*, Chapter 7.

[68]Selwyn D. Smith, Jr., "An Evaluation of Army Operations Research," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1957, p. 9. Maj. Gen. Robert M. Montague (USMA 1919) had served in the 83d Infantry Division in Europe during WWII. He served as deputy chief of Army field forces and OCAFF chief of combat developments from 1952 to June 1955 when he was reassigned to command the U.S. I Corps in Korea.

[69]HQ, OCAFF, *Staff Directory* (Fort Monroe, Va., 1 Mar 54) (hereafter cited as HQ OCAFF *Staff Directory*).

[70]Hewes, *From Root to McNamara*, p. 260. As of 1 March 1954, the combined group numbered 12 military personnel, 12 professional civilians, and 6 administrative civilians (see HQ OCAFF *Staff Directory*, 1 Mar 54).

[71]Maj. Gen. Robert M. Montague, "Combat Developments and Operations Research," paper presented at the U.S. Army War College, Carlisle Barracks, Penn., 19 Nov 54, pp. 13–14.

[72]Keith and Butler, *CDC Origins and Formation*, p. 7.

[73]Franklin C. Brooks and Lauren W. Merriam. "CORG Plans Tomorrow's Army Today," *Army* 6, 7 (1956), p. 28. Dr. Brooks held a Ph.D. in physics from Yale University and had just spent eight months on loan to WSEG in Japan and Korea. In the spring of 1957, Dr. Donald W. Meals replaced Brooks as director. Meals held a Ph.D. in psychology from the University of Pennsylvania. He had served with ORO in Korea; was a U.S. representative to the 4th Tripartite Conference on Army Operations Research in 1953; and joined CORG in 1955, becoming assistant director the following year. Meals was replaced by Dr. Martin N. Chase in 1960.

[74]Col. Merriam (USMA 1933) had served in the European Theater of Operations during WWII and joined OCAFF in 1954 from Germany, where he had been the G-1 of V Corps. Col. Merriam was replaced in turn by Col. Herbert G. Sparrow (USMA 1933) in early 1956.

[75]Schermerhorn, Role of OR in the Army," p. 8.

[76]HQ, CONARC, *Staff Directory*, Fort Monroe, Va. (hereafter cited as HQ CONARC *Staff Directory*), 1 Jun 55.

[77]HQ CONARC *Staff Directory*, 1 Apr 56.

[78]U.S. Army Continental Army Command, Combat Operations Research Group, *Combat Operations Research Group Work Program Summary* (Fort Monroe, Va.: HQ CONARC, 1956) (reproduced in Smith, "Evaluation of Army OR," p. 52) (hereafter cited as *CORG Work Program Summary*).

[79]Ibid., p. 51.

[80]Emmette Y. Burton, Jr., "The Role of Operations Research in the Army," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1955, p. 10.

[81]*CORG Work Program Summary*, p. 52.

[82]HQ CONARC *Staff Directory*, 1 May 59.

[83]HQ CONARC, *Staff Directory*, 1 Nov 60.

[84]HQ CONARC, *Staff Directory*, 1 Aug 62.

[85]Burton, "Role of OR", 10.

[86]Keith and Butler, *CDC Origins and Formation*, p. 11; Romjue, *Field Experimentation*, p. 6.

[87]Smith, "Evaluation of Army OR," p. 9.

[88]Ibid.

[89]William T. Bradley, "Operations Research in the Armed Services," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1957, pp. 16–17.

[90]HQ CONARC *Staff Directory*, 1 Nov 60.

[91]Ibid., p. 15.

[92]Ibid., pp. 15–16; *CORG Work Program Summary*, p. 50; Office of the Chief of Army Field Forces, *Staff Memo No. 3*, Fort Monroe, Va., 2 Feb 54, sub: Combat Developments (reproduced in Keith and Butler, *CDC Origins and Formation*, p. 7); CONARC Ad Hoc Committee Rpt, p. 42.

[93]*CORG Work Program Summary*, p. 50.

[94]Ibid.

[95]Ibid., pp. 50–51.

[96]Brooks and Merriam, "CORG Plans," p. 30.

[97]*CORG Work Program Summary*, p. 51.

[98]Ibid.

[99]Brooks and Merriam, "CORG Plans," p. 28.

[100]All of the publications produced by CORG up to June 1970 are listed in Technical Operations, Inc., Combat Operations Research Group, *Final List of CORG Publications* (Fort Belvoir, Va.: Technical Operations, Inc., Combat Operations Research Group for Headquarters, U.S. Army Combat Developments Command, 1970).

[101]Brooks and Merriam, "CORG Plans," p. 30.

[102]Ibid., p. 29.

[103]Montague, "Combat Developments and OR," p. 14.

[104]OCAFF *Staff Memo No. 3* (reproduced in Keith and Butler, *CDC Origins and Formation*, p. 7).

[105]Brooks and Merriam, "CORG Plans," p. 30.

[106]Ibid.; CONARC Ad Hoc Committee Rpt, p. 9.

[107]U.S. Army Quartermaster Combat Developments Agency, *Operations Research Methods*, Special Project 62–41 (Fort Lee, Va.: U.S. Army Quartermaster Combat Developments Agency, May 1962), p. ii.

[108]CONARC Ad Hoc Committee Rpt, pp. 9–10.

[109]Ibid., p. 10.

[110]CDEC, *Developing Tomorrow's Army Today*, p. 6.

[111]CONARC Ad Hoc Committee Rpt, p. 13; Romjue, *Field Experimentation*, p. 7.

[112]Ibid., Annex B, p. 57.

[113]Keith and Butler, *CDC Origins and Formation*, pp. 11–12.

[114]Ibid., p. 12.

[115]CONARC Ad Hoc Committee Rpt, Appendix II, p. 91; CDEC, *Developing Tomorrow's Army Today*, p. 7.

[116]Ltr, HQ CONARC, to commanding generals, Sixth United States Army and Combat Developments Test and Experimentation Center, Fort Monroe, Va., 18 Oct 56, sub: Ltr of Instructions for the Combat Developments Test and Experimentation Center (reproduced in Smith, "Evaluation of Army OR," Annex 5, pp. 55–59) (hereafter cited as CONARC LOI, 18 Oct 56).

[117]Ibid., paras. 5–9.

[118]Subsequently, in 1959, CDEC was redesignated the U.S. Army Combat Developments Experimentation Command (see Larry R. Tinberg, "Operations Research and the US Army," student essay, U.S. Army War College, Carlisle Barracks, Penn., 1983, p. 8).

[119]CONARC Ad Hoc Committee Rpt, Appendix II, p. 91.

[120]CDEC, *Developing Tomorrow's Army Today*, p. 9.

[121]CONARC Ad Hoc Committee Rpt, Appendix II, p. 91. Cf. CONARC LOI, 18 Oct 56, para. 3.

[122]Ibid., Appendix II, pp. 91–92; CDEC, *Developing Tomorrow's Army Today*, p. 9

[123]Ibid., Appendix II, p. 91.

[124]Romjue, *Field Experimentation*, p. 8.

[125]CONARC Ad Hoc Committee Rpt, Appendix II, p. 92.

[126]CONARC LOI, 18 Oct 56, p. 10.

[127]Ibid.

[128]Hewes, *From Root to McNamara*, p. 261.

[129]Bradley, "OR in the Armed Services," p. 17.

[130]CDEC, *Developing Tomorrow's Army Today*, p. 11.

[131]Ibid.

[132]Bradley, "OR in the Armed Services," p. 17.

[133]CONARC Ad Hoc Committee Rpt, Appendix III, pp. 93–94, 97, Figure 13.

[134]The functions of the various ROEC elements are outlined in CONARC Ad Hoc Committee Report, Appendix III, p. 94.

[135]CDEC, *Developing Tomorrow's Army Today*, p. 13.

[136]CONARC Ad Hoc Committee Rpt, Appendix III, p. 93.

[137]Ibid., Annex C, p. 191, 193.

[138]Ibid., p. 12.

[139]CONARC Ad Hoc Committee Rpt, Annex B, p. 57.

[140]Ibid., Annex B, p. 58.

[141]Ibid., Appendix VI, p. 113.

[142]Keith and Butler, *CDC Origins and Functions*, pp. 9, 12. The 1954 Haworth Committee did not recommend the immediate creation of a new and separate Combat Development Command, but did note that such an action might be the ultimate goal.

[143]*TRADOC On-Line History*, Chapter 7.

[144]Ibid.

[145]Ltr, Lt Gen John P. Daley (Com Gen, CDC), *Briefing for the Army Policy Council, 20 March 1963* (incl to letter, Lt Gen John P. Daley, Fort Belvoir, Va., 25 Mar 63, sub: Status Rpt on US Army Combat Developments Command), pp. 1–2, U.S. Army Military History Institute, Carlisle Barracks, Penn.

[146]ARO (Durham), *Executive Summary—United States Army Operations Research Symposium Conducted by Army Research Office (Durham) at Duke University, 27, 28, 29 March 1962* (Research Triangle Park, N.C.: Research Triangle Institute for the Army Research Office [Durham], 1962), p. 4.

[147]Ibid.

[148]Lynn H. Rumbaugh, "A Look at US Army Operations Research—Past and Present," Combat Systems Technical Paper RAC–TP–102 (McLean, Va.: Research Analysis Corporation, Apr 1964), p. 6. CORG continued to support CDC from 1962 until its demise in 1970 (see Seth Bonder, "Army Operations Research—Historical Perspectives and Lessons Learned," *Operations Research* 50, 1 [02]: 25).

[149]Ltr, Daley, *Briefing,* 20 Mar 63, p. 3. CDEC underwent a major reorganization in December 1962.

[150]Johnson, "The ORO," p. 167; McCloskey, "Organization for OR," p. 166.

[151]Seymour I. Gilman, "The Role of Operations Research in the Army," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1954, p. 20.

[152]Burton, "Role of OR," p. 9; Gilman, "Role of OR in the Army," p. 20; Smith, "Evaluation of Army OR," p. 10.

[153]Gilman, "Role of OR in the Army," p. 20.

[154]Eugene P. Visco, "The Operations Research Office" (PB-20-96-3), *Army History* 38 (Summer 96): 25.

[155]U.S. Army Ordnance Corps, *Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland* (Aberdeen Proving Ground, Md.: Ordnance Corps, U.S. Army, 1955), pp. 18–19.

[156]Johnson, "The ORO," p. 167.

[157]Gilman, "Role of OR in the Army," p. 42, Annex 2; Smith, "Evaluation of Army OR," p. 10.

[158]Gilman, "Role of OR in the Army," p. 42, Annex 2.

[159]Ibid.

[160]Smith, "Evaluation of Army OR," p. 59, Annex 6.

[161]Ibid.

[162]Ibid.

[163]Gilman, "Role of OR in the Army," p. 42, Annex 2.

[164]Comments of Mr. Wells (chairman, Session VI–B), ARO (Durham), *Executive Summary*, p. 325.

[165]For a summary history of the Office of Ordnance Research and its successor, ARO, see "ARO History," at http://www.arl.army.mil/aro/history/history.htm. See also Raymond J. Snodgrass, *Survey of Ordnance Activities, September 1951–December 1952* (Washington: Historical Branch, Office of the Chief of Ordnance, DA, 1953), Fort McNair, Washington, U.S. Army Center of Military History, Office of the Chief of Military History, Historical Manuscript File 40–2.1 AA 1951–52.

[166]Snodgrass, *Survey of Ordnance Activities*, p. 53.

[167]Ibid., pp. 55–56.

[168]Ibid., p. 55.

[169]Ibid., pp. 54–55.

[170]"ARO History."

[171]Ibid.

[172]Philip M. Morse, "Where Is the New Blood?" *Journal of the Operations Research Society of America* 3, 4 (1955): 387.

[173]See U.S. Army Ordnance Corps, Office of Ordnance Research, *Proceedings of the First Ordnance Conference on Operations Research*, Office of Ordnance Research Rpt No. 55–1 (Durham, N.C.: Office of Ordnance Research, Ordnance Corps, Jan 55).

[174]Ibid., Foreword.

[175]Hewes, *From Root to McNamara*, p. 255.

[176]At the time ARO was established, the Army's newly assigned CRD, Lt. Gen. Arthur Trudeau, expressed interest in co-locating ARO with ORO, but he was apparently unable to guarantee the necessary funding (see Memo, P. Stewart Macaulay [provost, JHU] to Dr Milton S. Eisenhower [president, JHU], Baltimore, 15 Jan 59, JHU Archives, Records of the Office of the President, Series I, Box 34, Folder 47.2 ICR/ORO, Jan–Dec 1959).

[177]U.S. Department of the Army, *Annual Report of the Secretary of the Army for Fiscal Year 1961*, in U.S. DOD, *Annual Report of the Secretary of Defense and the Annual Reports of the Secretary of the Army, Secretary of the Navy, Secretary of the Air Force, for Fiscal Year 1961* (Washington: USGPO, 1962), p. 136.

[178]The Arlington office of ARO was disestablished in 1973, and the Durham office became *the* ARO. In 1974, as part of the STEADFAST reorganization, ARO was transferred to the Army Materiel Command as a separate reporting agency, and in April 1975, ARO moved from the Duke University campus to offices in the Research Triangle Park, North Carolina, and then to another location in the Research Triangle in November 1984. ARO, which continues to oversee the Army's scientific research programs, has been very successful, and twenty-seven Nobel Prize laureates have been among the scientists supported by ARO (see U.S. Army Research Laboratory Public Affairs Office, "ARO Celebrates 50th Anniversary," at http://www.aro.army.mil/news/50thanniv.htm).

[179]Hewes, *From Root to McNamara*, p. 255.

[180]See ARO (Durham), *Executive Summary*.

[181]Ibid., p. 1.

[182]ARO (Durham), *Proceedings*, p. iii.

[183]Remarks of Col. Charles B. Hazeltine, Jr. (asst director, ARO), Opening Session, ARO (Durham), *Proceedings*, pp. 5–6.

[184]ARO (Durham), *Executive Summary*, p. 8; Hazeltine, ARO (Durham), *Proceedings*, pp. 5–6.

[185]ARO (Durham), *Executive Summary*, p. 8.

[186]Hazeltine, ARO (Durham), *Proceedings*, pp. 5–6.

[187]U.S. Department of the Army, *Army Regulations No. 1–110: ADMINISTRATION—Contracting for Management Advisory Services and Operations Research Studies and Projects* (Washington: HQ, DA, 28 Jun 61). Changes and revisions to *AR 1–110* were issued from time to time.

[188]Ibid., para. 1. The policies and procedures prescribed in *AR 1–110*, particularly those related to the PAGs, owed a great deal to the policies and procedures worked out earlier for ORO and incorporated in *Army Special Regulations 705–5–5: RESEARCH AND DEVELOPMENT—Operations Research Office* and *AR 15–480: Boards, Commissions, and Committees—Operations Research Office*.

[189]*AR 1–110*, 28 Jun 61, para. 8.

[190]Ibid., para. 9.

[191]Unless otherwise noted, the following account of the organization and functions of the Chemical Corps is based on U.S. Army, Chemical Corps School, *Organization and Functions of the Chemical Corps*, Special Text 3–171 (Fort McPherson, Ga.: Chemical Corps School, Sep 56).

[192]Oral history interview of Dr. George H. Milly by Eugene P. Visco and Charles R. Shrader, 8 Aug 03. Dr. Milly served in the Test Division of the Army Chemical Center from 1947 to 1954, when he moved to CCORG. He subsequently became scientific director and then director of CCORG. Dr. William Albert Noyes, Jr. (1898–1980) was elected president of the American Chemical Society in 1947 and served as editor of the *Journal of the American Chemical Society* from 1950 to 1962. He was also the head of Division 8 of NDRC and was a consultant to CCORG, visiting Edgewood Arsenal on many occasions in the 1950s to review projects and provide advice. Maj. Gen. McAuliffe served as chief chemical officer from 1 October 1949 to 31 July 1951.

[193]*Organization and Functions of the Chemical Corps*, p. 42.

[194]Ibid., p. 29. According to George Milly (interview, 8 Aug 03), CCORG generated its own work program and its reports were not subject to review.

[195]Gilman, "Role of OR in the Army," p. 42, Annex 2. George Milly (interview, 8 Aug 03) recalled that when he joined CCORG in 1954, there were only four or five professional analysts, most of whom had been recruited by Dr. Noyes and most of whom returned to academia in 1954–56, making way for new personnel.

[196]U.S. Army Chemical Center and Chemical Corps Materiel Command, *Army Chemical Center and Chemical Corps Materiel Command* (Baton Rouge, La.: Army and Navy Publishing Company, 1956), CCORG group photo (no page number). The same volume also contains a photo of the group's building ("Post Scenes," no page number).

[197]Milly interview, 8 Aug 03.

[198]*Organization and Functions of the Chemical Corps*, p. 42. George Milly (interview, 8 Aug 03) stated that, to his knowledge, the Chemical Corps Board did not have an active OR element.

[199]*Organization and Functions of the Chemical Corps*, pp. 37–38.

[200]Milly interview, 8 Aug 03.

[201]Ibid.

[202]U.S. Army, Signal Corps, *Quadrennial Report of the Chief Signal Officer, U.S. Army, May 1951–April 1955* (Washington: Office of the Chief Signal Officer, DA, 15 Apr 55), p. 10.

[203]Ibid., p. 11. Gilman stated that SCEAG was established in July 1952 ("Role of OR in the Army," p. 42, Annex 2).

[204]Ibid.

[205]*Quadrennial Report of the Chief Signal Officer, May 1951–April 55*, p. 11. The liaison office at Haller, Raymond and Brown, Inc., was active from August 1953 to February 1955.

[206]Ibid.

[207]Ibid. SCEAG found that the key personnel of the test rifle company spent nearly 30 percent of their time on some sort of communication activity.

[208]U.S. Army, Signal Corps, *Quadrennial Report of the Chief Signal Officer, U.S. Army, May 1955–April 1959* (Washington: Office of the Chief Signal Officer, DA, 30 Apr 59), p. vi.

[209]Ibid.

[210]Ibid., p. 43.

[211]Ibid., pp. 43–44.

[212]U.S. Army, Office of the Surgeon General, *Annual Report of the Surgeon General, United States Army, Fiscal Year 1960* (Washington: Office of the Surgeon General, DA, 1960), p. 75, Table 12. Total AMEDS R&D budgets grew from $7 million in FY 1951 to $15.9 million in FY 1960. The in-service portion of that budget grew from $2.6 million to $7.1 million during the same period, and AMEDS contracting for R&D grew from $4.4 million to $8.8 million.

[213]Ibid., p. 73.

[214]Ibid.

[215]Ibid., p. 74. The U.S. Army Medical Research and Development Command was established in August 1958, as a Class II activity commanded by a brigadier general, with the mission of improving integration of Army medical research activities worldwide, management of AMEDS research funds, and logistic support of its component units.

[216]U.S. Army, Office of the Surgeon General, *Annual Report of the Surgeon General, United States Army, Fiscal Year 1961* (Washington: Office of the Surgeon General, DA, 1961), pp. 81–82.

[217]Ibid., p. 93.

[218]Ibid., p. 82; U.S. Army, Office of the Surgeon General, *Annual Report of the Surgeon General, United States Army, Fiscal Year 1962* (Washington: Office of the Surgeon General, DA, 1962), pp. 93–96.

[219]*Annual Report of the Surgeon General, 1962*, p. 93. The FY61 AMEDS R&D budget was approximately $15.5 million, of which $7.7 million was for research contracts. In FY 1962, the AMEDS expended approximately $14.7 million on 461 research contracts and 41 research grants.

[220]Ibid., p. 95.

[221]Ibid.

[222]See, *inter alia*, Gilman, "Role of OR in the Army," p. 42, Annex 2, and the annual reports of the quartermaster general, the chief of transportation, and the surgeon general for the fiscal years 1951–62.

[223]Burton, "Role of OR," p. 30.

[224]Gilman, "Role of OR in the Army," p. 35.

[225]Ibid., p. 36.

CHAPTER FIVE

The State of Army Operations Research, March 1963

On 26 March 1963, Army operations research (OR) program managers and analysts assembled in Durham, North Carolina, for the Second U.S. Army Operations Research Symposium sponsored by the Army Research Office (Durham).[1] A number of senior Army leaders (including Lt. Gen. Dwight E. Beach, the Army chief of research and development; Lt. Gen. John P. Daley, the commander of the newly formed U.S. Army Combat Developments Command; and Gen. Frank S. Besson, Jr., the commander of the newly formed U.S. Army Materiel Command) also attended and spoke at the symposium. Participants in the three-day conference listened to and discussed a wide variety of papers, both general and technical, on operations research. This assembly of Army OR specialists marked a milestone in the history of OR in the Army and served to sum up its tremendous progress over the previous two decades, the expanding scope of Army problems to which OR was being applied, the many new organizations dedicated to Army OR, the key issues remaining to be resolved, and the bright prospects for the future.

The list of organizations represented at the 1963 symposium confirmed the degree to which operations research had spread throughout the Army.[2] From the tentative efforts in the Signal Corps, Army Air Defense, and the Pacific theater in World War II, the number of Army OR groups and the number of analysts employed by the Army had expanded enormously. By March 1963, the bulk of the Army's OR work was being performed by contractor-operated organizations. There were also in-house programs that employed both military and civil service analysts as well as some minor activity at the Department of the Army staff level and at headquarters staff level in major Army commands.

In FY 1962, the "big five" Army contractor-operated OR organizations (the Research Analysis Corporation [RAC], the Human Resources Research Office [HumRRO], the Special Operations Research Office [SORO], the Combat Operations Research Group [CORG], and the Research Office Experimentation Center [ROEC]) alone employed more than four hundred technical personnel and accounted for the bulk of the Army OR effort.[3] There were also some twenty in-house OR groups, such as STAG and the Chemical Corps Operations Research Group, scattered among nine Army commands and agencies and employing two to forty professionals each for a total of some two hundred military and civilian personnel.[4] In addition, eleven Army agencies supplemented their in-house OR capability with the work of twenty different study contractors and fifty research studies of an OR nature.[5] Those contractors included universities and private research firms working on a broad range of topics from computer support to field medical systems to antimissile defense.

Although vigorous, the Army OR program was decentralized, with only the loosest central control at the level of the Army Research Office in the Office of the Chief of Research and Development. Consolidation of combat developments agencies under the U.S. Army Combat Developments Command and of R&D and logistics agencies, including the technical services, under the U.S. Army Materiel Command served to centralize OR work in those areas to a certain degree. There was some coordination of the various services' OR programs at the Department of Defense level, and some coordination and cooperation with the British, Canadians, Australians, and NATO allies. Connections were also maintained with university OR programs and with such OR professional organizations as the Operations Research Society of America and the Military Operations Research Society.

In FY 1949, the Army budget included only $1 million for operations research activities, but, by March 1963, the Army was spending more than $20 million per year on OR projects.[6] About half of the total annual Army OR budget went to contract research organizations such as RAC, Technical Operations, Inc. (CORG), the Stanford Research In-

stitute (ROEC), and the Planning Research Corporation; the remainder was about equally divided between in-house operations and university contracts, such as those for SORO and HumRRO.[7] In and of itself, the use of nongovernment contractors to provide essential OR services to the military aroused little controversy. The participants in the 1962 Army OR symposium had agreed that "both in-house and contract research offer advantages to the Army; neither appears to be sufficient by itself."[8]

Most participants at the 1963 symposium would also have agreed that the Army was receiving fair value for its money. By 1963, the OR groups in the United States armed services were producing approximately three thousand reports per year.[9] Increasingly, the characteristic OR product was a "general description of a broad problem such as ground warfare; the analysis of a broad concept or objective such as deterrence," and participants in the 1962 Army OR symposium had agreed that "broad conceptual problems may be the best targets for future Army operations research."[10] The topic areas addressed ran the gamut and included weapons evaluation studies, assessments of military organization and doctrine, strategic assessments, human behavioral studies, special operations and area studies, simulations and wargaming, cost analysis, and a host of other matters. By March 1963, one other primary application of OR was also beginning to gather momentum—that of OR to the higher-level management of the Army itself. The extension of OR into such "nontraditional" fields as human behavior analysis; the study of organizations; higher-level strategy; and political, economic, and social issues was principally an American development. Operations researchers in Great Britain and Canada continued to focus primarily on the types of problems that were characteristic of World War II operations research.[11]

Despite agreement on the overall progress of Army OR in the two decades since the beginning of World War II and the many contributions of OR studies to Army decision making during that time, the participants at the 1963 symposium disagreed on a number of issues and pointed out several areas in which problems in the Army OR program remained to be solved. The six major points of disagreement among the speakers at the 1963 symposium were short-range versus long-range research, the level at which OR teams should operate, the role of the "soft sciences" in OR, the degree to which OR teams should be free to select their own problems for study, the value of simulation; and the proper use of field test data.[12] In fact, the most salient disagreements and unsolved problems faced by Army OR organizations in March 1963 concerned the dangers of the increasing use of mathematical models and simulations and the need to focus on practical problems rather than on the theory of operations research.

As of 1963, approximately 25 percent of the three thousand reports produced annually by military OR groups in the United States either used simulation/wargaming as a basic tool or relied on the results of simulation/wargaming for their conclusions.[13] Although the increased use of high-speed digital computers as an aid to operations research was generally accepted, the use of mathematical models and simulations, including wargaming, raised some concerns. For one thing, the new mathematical and statistical techniques, the use of high-speed digital computers, and complex gaming made OR more effective, but also increased the need for extensive and sophisticated training.[14] Many OR practitioners expressed concern that the increased emphasis on simulation/wargaming caused operations researchers to loose sight of the importance of getting hard data on which to base the simulation/game decisions.[15] Others warned that the danger in the use of simulations as "large automatic systems for military control and decision . . . is that they get out of hand."[16]

From its rather primitive beginnings in World War II, operations research had progressed over two decades to include a substantial body of very sophisticated theory and methods based on advanced mathematics. By 1963, many OR analysts worked at the cutting edge of this new theory and methodology, and there was a tendency for OR to be defined by its complex mathematical theories and methodology. Even so, at its base OR remained "scientific problem solving" and the application of common-sense analysis (albeit using quantification when possible) to find workable solutions to practical problems in the development of weapons, organization, tactics, and strategy. The increasing sophistication of OR theory, particularly the development of sophisticated mathematical models and techniques, raised questions regarding the degree to which OR practitioners were losing sight of the practical problems needing to be solved and the interests and limitations of the "customers" whom Army OR organizations were pledged to serve. Some participants in the 1963 symposium warned that OR was a means for providing the military decision maker with reliable, practical solutions to real problems and that the analyst must focus accordingly on solving problems rather than developing new theories.[17]

Given the increasing definition of operations research by its theory and methodology, many leading operations researchers became concerned about the degree to which OR had become reliant on mathematical models and expressed the fear that OR might consequently "find itself excluded from deliberative and decision-making circles.[18] One founder of military OR in the United States, Philip M. Morse, observed that "operations research is an experimental science, concerned with the real world. It is not an exercise in pure logic. We must make our theories correspond to actual operations, and to do this we must compare predictions

with actual occurrences in a quantitative manner."[19] Reflecting on forty years of work in OR, another senior member of the American military OR community, Hugh J. Miser, noted some "unfortunate trends in OR," which included the attempt to set boundaries on OR and the rapid increase in the academic attention to models and theories, to the exclusion of the craft skills of professional practice that played an important role in the successes of OR in World War II.[20] Miser wrote that

> this expanding body of theory has tended to define the subject . . . academic programs devote almost all of their time to this burgeoning stream . . . many OR workers have begun to think of their subject as a scientific discipline defined by this flow of theory and models and their direct application. . . . Today's widespread conception of operations research as a discipline defined by its models—and its emphasis on getting clients to use models—places it atop the hill of rigor, but at a great sacrifice, both of relevance and breadth.[21]

The participants in the 1963 symposium were a diverse lot, and they differed on many issues, such as the use of mathematical models and simulations. Most of them agreed, however, that OR in the Army had come of age and that Army OR organizations were making substantial contributions to national defense. They also agreed that operations research had finally achieved general recognition as an important aid to the military decision maker, although it remained a complex and somewhat mysterious science to some military officers. Few of the symposium participants doubted that the future of operations research in the Army was bright or that Army OR organizations would continue to proliferate and prosper in the future.

CHAPTER FIVE NOTES

[1]See U.S. ARO (Durham), *Proceedings of the United States Army Operations Research Symposium, 26, 27, 28 March 1963, Durham, North Carolina, Part I*, ORTAG–25 (Durham, N.C.: U.S. ARO, 1963).

[2]Ibid., pp. 335–43. Among the attendees at the 1963 symposium were representatives of ARO; ARO (Durham); BRL, Aberdeen Proving Ground, Md.; CORG; HQ USACDC; Frankford Arsenal, Philadelphia, Penn.; HQ, USAMC; OCRD, HQ DA; HumRRO; Picatinny Arsenal, Dover, N.J.; RAC; ROEC; SORO; STAG; USAIAS, Carlisle Barracks, Penn.; U.S. Army CBR Combat Developments Agency, Fort McClellan, Ala.; U.S. Army CBR Operations Research Group, Edgewood Arsenal, Md.; U.S. Army Combined Arms Group, Fort Leavenworth, Kan.; U.S. Army Limited War Laboratory, Aberdeen Proving Ground, Md.; U.S. Army Personnel Research Office, Washington, D.C.; U.S. Army Weapons Command, Rock Island Arsenal, Ill.; and War Plans Division, ODCSLOG, HQ DA.

[3]Lynn H. Rumbaugh, "A Look at U.S. Army Operations Research—Past and Present," RAC–TP–102 (McLean, Va.: Research Analysis Corporation, 1964), p. 6; U.S. Congress, Office of Technology Assessment, *A History of the Department of Defense Federally Funded Research and Development Centers*, OTA–BP–ISS–157 (Washington: USGPO, 1995), p. 22.

[4]Rumbaugh, "Look at US Army OR," p. 6.

[5]Ibid.

[6]Edmund T. Pratt, Jr., "Challenges in Army Operations Research," in ARO (Durham), *Proceedings*, p. 91. In addition, there were other research projects involving the use of OR techniques but they were not identified as OR-related.

[7]Ibid.

[8]U.S. ARO (Durham), "Highlights," in *Executive Summary, United States Army Operations Research Symposium*, Duke University, 27–29 Mar 62 (Research Triangle Park, N.C.: Research Triangle Institute for the Army Research Office [Durham], 1962), p. 2.

[9]Comments of E. W. Paxson, RAND Corporation, in Session XI, 2d Army OR Symposium, ARO, *Proceedings*, pp. 321–22.

[10]Palmer Osborn, "Selecting Weapons Systems 1960—The Builder's-eye View," *Operations Research* 9 (Mar–Apr 1961): 265; U.S. ARO, "Highlights," ARO (Durham), *Executive Summary*, p. 2.

[11]Bruce L. R. Smith, *The RAND Corporation: Case Study of a Nonprofit Advisory Corporation* (Cambridge, Mass.: Harvard University Press, 1966), p. 13.

[12]Critique by Robert M. Thrall (professor of mathematics and operations analysis, University of Michigan) Session XI, ARO (Durham), *Proceedings*, pp. 318–19.

[13]Paxson's comments, Session XI, ARO (Durham), *Proceedings*, pp. 321–22.

[14]U.S. ARO, "Highlights," in ARO (Durham), *Executive Summary*, p. 2.

[15]Paxson's comments, ARO, *Proceedings*, pp. 321–22.

[16]Ibid.

[17]Thrall's critique, ARO, *Proceedings*, p. 317.

[18]Osborn, "Selecting Weapons Systems," p. 270.

[19]Philip M. Morse, "Where Is the New Blood?" *Journal of the Operations Research Society of America* 3, 4 (1955): 384–85.

[20]Hugh J. Miser, "President's Symposium: Science and Professionalism in Operations Research," *Operations Research* 35, 2 (1987): 315. Miser was president of the Operations Research Society of America from 1962 to 1963.

[21]Ibid., pp. 315–16. Among the corrective actions advocated by Miser for the operations research community were these: "1. to develop a clear conception of the domain dealt with by operations research; 2. to develop more coherent and realistic views of science and professional practice; 3. to increase the attention given to professional practice, particularly in educational programs; 4. to develop widely accepted standards of quality for operations research work; 5. based on a close scrutiny of the craft of professional practice, to develop and gain wide acceptance for a coherent view of what constitutes practice and how it is done well" (p. 318).

Epilogue

Despite the significant problems to be resolved, the participants in the 1963 Army Operations Research Symposium in Durham, North Carolina, were nearly unanimous in proclaiming the potential for operations research (OR) to meet the challenges of the future. As Dr. Paul M. Gross, president of the American Association for the Advancement of Science and the Pegram professor of chemistry at Duke University, had told the attendees during a dinner session at the first Army OR symposium in 1962, meeting the challenges of integrating the vast multidisciplinary projects of American science in the 1960s and beyond would require "operations analysis at its very highest level."[1]

The issues to be faced by Army OR program managers and analysts in the immediate future would indeed challenge them to contribute at the "very highest level." Those challenges were laid out clearly by the Hon. Edmund T. Pratt, Jr., assistant secretary of the Army for financial management, in a banquet address titled "Challenges in Army Operations Research" at the Second Army OR symposium on 26 March 1963:

> With regard to [the Army's mission of preparing to wage any type of war in the future], our major objective is to take maximum advantage of scientific and technological progress in the development of our weapons, transportation, and communication systems....We do not have sufficient time to conduct in sequence the formulation of new concepts; the research, development and production of new materiel; the organization and equipping of units; and the final field testing. Therefore, we will have to rely more heavily upon concurrent simulation, operations analysis, war games, and theoretical studies in all phases, to reduce lead time and produce the most effective force structure consistent with current missions and state of the art technology. To provide this increased capability, we must anticipate the need for qualified analysts who can apply modern methods and obtain timely and reliable solutions; this will require more emphasis on operations research training of Army personnel, military and civilian. . . . Operations research assignments will be very demanding. They will require imagination tempered with caution, and provide a real challenge to the operations researchers and to the military men working with him. But working side by side, and you must work as a pair all the way, I am sure that you can and will meet this challenge.[2]

Indeed, the Army OR program managers and analysts assembled to hear Dr. Pratt's address would soon recognize, if they had not done so earlier, that the future and its challenges were already upon them, precipitated in large part by the administration of President John F. Kennedy, which took office in January 1961. Secretary of Defense Robert S. McNamara and his "whiz kids" were already introducing radical changes in defense organization and procedures, and these changes would require flexibility and innovation on the part of Army OR practitioners in order to help Army leaders make key decisions on future weapons, organization, and doctrine as well as on the organization and management procedures of the Army itself. In August 1962, nine months before the second Army OR symposium convened, the Howze Board had submitted the final report of its comprehensive study of the role of air mobility in future warfare, the largest and most complex study of its kind up to that time and one that involved nearly all of the Army's contract and in-house OR groups and hundreds of civilian and military OR analysts. And even as Army OR personnel met in Durham, Army advisors and aviators were deeply involved in helping the Republic of Vietnam counter a growing Communist insurgency. The long Vietnam War would pose yet another opportunity for Army OR to demonstrate its value on the battlefield itself rather than in the laboratory and on the testing ground. The period of recovery and transformation that followed the war in Vietnam would test the mettle of Army operations researchers. With two decades of experience and success behind them, Army OR managers and analysts would prove equal to the challenge.

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[1]ARO (Durham), *Executive Summary—United States Army Operations Research Symposium Conducted by Army Research Office (Durham) at Duke University, 27, 28, 29 March 1962* (Research Triangle Park, N.C.: Research Triangle Institute for the Army Research Office [Durham], 1962), p. 5.

[2]Edmund T. Pratt, Jr., "Challenges in Army Operations Research," in ARO (Durham), *Proceedings of the United States Army Operations Research Symposium, 26, 27, 28 March 1963, Durham, North Carolina, Part I,* ORTAG–25 (Durham, N.C.: U.S. ARO [Durham], 30 Sep 63), p. 92.

APPENDIX A

Biographical Sketches

Two men dominated the development of operations research (OR) in the United States Army from 1942 to 1962. Between 1942 and 1945, Col. Walter Barton Leach, the chief of the Operational Analysis Division, Headquarters, United States Army Air Forces, tirelessly promoted the use of OR throughout the Army, recruited analysts and managers, established operations analysis sections in the various Army Air Forces commands at home and overseas, helped establish OR elements in the Army service forces and Army ground forces, and argued for the retention of an OR capability in the postwar Army and Air Force.

From the time of his appointment in August 1948 as director of the newly formed General Research Office (later the Operations Research Office [ORO]), administered by The Johns Hopkins University until the demise of the ORO in 1961, Dr. Ellis Adolph Johnson was the leading proponent of the use of OR as an aid to Army decision makers. Johnson established the ORO, recruited and trained its staff, and shaped its work program, constantly expanding the scope of projects undertaken by the ORO into areas of growing interest to the Army. He was largely responsible for the extension of OR into matters of national and military strategy and policy. He also actively supported the creation of other Army OR organizations, the growth of OR programs in academia, and the establishment of professional OR associations.

The character, actions, and accomplishments of both Col. Leach and Dr. Johnson are described in some detail in the text. What follows here are brief outlines of the basic biographical details of the lives and careers of both men.

Walter Barton Leach (1900–71)

Walter Barton Leach deserves more than any other person the title of "Father of U.S. Army Operations Research."[1] He was born in Boston on 6 January 1900, the son of Walter Barton and Grace Winifred (Wise) Leach. After serving in France as an infantry private in the United States Army (1918–20), he briefly attended the Université de Grenoble in the summer of 1920. Leach returned to the United States to attend Harvard University, where he earned a bachelor of arts degree cum laude in 1921. He went on to obtain a bachelor of laws degree cum laude from Harvard Law School in 1924, and then clerked for U.S. Supreme Court Justice Oliver Wendell Holmes (1924–25). Leach was admitted to the Massachusetts bar in 1925 and became a distinguished attorney with the Boston law firm Warner, Stackpole, and Bradlee (1925–30). In 1929, he became an instructor in law at Harvard Law School and subsequently rose to assistant professor of law (1930) and professor of law (1931–69) at the school. An expert on real property law, Leach was the author of several textbooks and journal articles on various aspects of the law.

In June 1942, Leach accepted a commission as a major in the Army of the United States. He was promoted to lieutenant colonel, Air Corps, in January 1943, and then to colonel, Air Corps, in August 1944. Leach was widely known and highly respected in the elite circles of the government and armed forces. Following submission of the extensive report he had prepared with Dr. Ward S. Davidson in August 1942, Maj. Leach was appointed chief of the Operations Analysis Division, Headquarters, United States Army Air Forces. He adopted the use of operations analysis in the U.S. armed forces as his personal crusade and became involved in every aspect of its development. His enthusiasm for OR was unbounded, and his influence extended to the Army service forces and Army ground forces as well as to the Navy. Although several military and civilian Army Air Forces leaders were extremely enthusiastic and influential in promoting OR, none surpassed Col. Leach in spreading the word and getting things done. Nearly every file box in the National Archives containing material on OR also contains some trace of his activity and influence. In 1945, he was awarded the Legion of Merit for his wartime service.

After World War II, Leach resumed his career as a Harvard Law professor, and eventually became the associate dean of Harvard Law School. He was Story professor of law at the school from 1960 to 1969. He was a visiting professor of law at Oxford University in 1952, and a professor in the Harvard Graduate School of Public Administration (1954–69). He was instrumental in founding the Defense Policy Seminar at the Harvard Center for International Affairs in 1954. Leach was also an advisor to John F. Kennedy during the 1960 presidential election campaign. A man of many interests, he was well known for being among those scholars who doubt the attribution of Shakespeare's works to "the Bard of Avon."

Leach continued to serve as an Air Force consultant from 1946 to 1966, and was presented with the Exceptional Civilian Service Award in 1949. He also continued his service in the U.S. Air Force Reserve, and was promoted to the rank of brigadier general in 1949. He was chosen by Secretary of the Air Force Stuart Symington to prepare the Air Force's defense of the B–36 bomber during the so-called revolt of the admirals in the 1950s.

Leach married Florence T. Malcolm on 14 June 1924. They had two children, Barbara and Richard Malcolm, and were divorced in 1941. His second marriage, to Jane McIlwraith on 10 March 1944, produced one son, David, and ended with her death in 1963. Leach was married a third time, to Blanche C. Bartlett, on 3 January 1964. He was a member of the American and Massachusetts Bar Associations, the Pi Eta Society, the Lincoln's Inn Society, and the Universalist Church. He also held membership in the Harvard Club and the Weston Golf Club (Boston, Massachusetts).

Walter Barton Leach died on 15 December 1971 in Waltham, Massachusetts, and is buried in Cambridge, Massachusetts.

Ellis Adolph Johnson (1906–73)

As director of The Johns Hopkins University Operations Research Office from 1948 to 1961, Ellis Adolph Johnson was the leading proponent of Army operations research during the post–World War II period.[2] He was born in Quincy, Massachusetts, on 2 September 1906, the son of Peter George and Elizabeth (Teklo) Johnson. He earned his bachelor of science degree in physics from the Massachusetts Institute of Technology (MIT) in 1928, and went on to earn the master of science degree in physics and the doctor of science degree in electrical engineering from the same institution in 1929 and 1934, respectively. He was a trainee at the Bell Telephone Laboratories and the New York Telephone Company (1926–29) before serving as research assistant and instructor in the Department of Electrical Engineering at MIT (1929–34). An expert on terrestrial magnetism, Johnson worked for the United States Coast and Geodetic Survey as an associate electrical engineer (1934–35) and as physicist and section chairman, geophysics of the crust, in the Department of Terrestrial Magnetism at the Carnegie Institution in Washington, D.C. (1935–0). Shortly before the United States entered World War II, Johnson became a consultant and then associate director of research for the Naval Ordnance Laboratory at the Washington Navy Yard, and he played a central role in early Navy OR work on mines and countermining techniques (1940–42). In 1942, he accepted a commission as commander, United States Naval Reserve, and went to the Pacific theater to serve on the staff of the commander in chief, Pacific. In that assignment, he developed and promoted the aerial mining campaign against Japan for the Navy and the Army Air Forces.

Demobilized in 1946, Johnson returned to his former position at the Carnegie Institution (1946–48) and served briefly (January–August 1948) as the technical director of the U.S. Air Force Office of Special Weapons before being selected to head the Army's new General Research Office in August 1948. As the first and only director of The Johns Hopkins University Operations Research Office, Johnson was active in promoting OR in the United States and abroad. He helped found the Operations Research Society of America and the International Federation of Operational Research Societies (1951–54), and promoted close contacts among the official military OR organizations in Australia, Canada, Great Britain, and the United States.

In 1961, Johnson left the ORO to become a professor and director of the Systems Research Center at the Case Institute of Technology in Cleveland, Ohio. He remained at Case until 1965, when he became coordinator of scientific affairs for the Department of Health, Education, and Welfare in Bethesda, Maryland (1965–67). He was later a consultant to the National Bureau of Standards in Gaithersburg, Maryland (1967–70).

For his long and distinguished service to the U.S. armed forces, both as a civilian and in uniform during World War II and after, Johnson was awarded the Distinguished Civilian Service Citation (Navy), the Legion of Merit (Navy and Air Force), Commendation Ribbon (Navy, two awards), Commendation (Air Force), and the Distinguished Civilian Service Medal (Army). He was also awarded the United Nations Korean Service Medal for establishing ORO operations in Korea in 1950. The Ellis A. Johnson Chair of Mine Warfare at the Naval Postgraduate School, Monterey, California, is named for him.

Ellis Johnson married Alice Gertrude Lagasse of Boston, Massachusetts, on 4 August 1934. They had two children, Betsy W. and Peter B. Johnson. He was a fellow of

the American Physics Society and a member of the National Research Council (member, Geophysics and Operations Research Committees), the Office of Naval Research Committee on Arctic Research, the American Geophysical Society, the Washington Philosophical Society, the American Optical Society, and the Cosmos Club (Washington, D.C.). He was also the author of more than 120 technical papers, principally in the fields of electronics, physics, geophysics, weapons development, and operations research.

Following a long and debilitating brain disease, Ellis Johnson died at the Veterans Administration Center in Martinsburg, West Virginia, on 16 December 1973.

APPENDIX A NOTES

[1]A brief official wartime (circa 11 July 1942) biography of Leach is housed in College Park, Maryland (NARA II, RG 218, Entry 343A, Box 57, Folder OA). Leach's personal papers (some 34 linear feet of them) are archived in the Harvard University Law School, Cambridge, Massachusetts. Additional details of his life are provided in *Who Was Who in America, Volume V: 1969–1973* (Chicago: Marquis Who's Who, 1973), p. 420.

[2]The principal sources for Johnson's biography include *Who Was Who in America, Volume VI: 1974–1976* (Chicago: Marquis Who's Who, 1976), p. 214; Thornton L. Page, George S. Pettee, and William A. Wallace (with Capt James Martin, USNR, and Alice L. Johnson),"Ellis A. Johnson, 1906–1973," *Operations Research* 22, 6 (1974), pp. 1141–155; ORO, *ORO Biographies*, vol. I (Chevy Chase, Md.: ORO, various dates, 1957–63).

APPENDIX B

Army Air Forces Operations Analysis Elements in World War II

Headquarters	*Station*	*Dates Active*	*Mission*	*Number of Personnel*[a]	*Chief of Section/Unit*	*Dates of Service as Chief*
Operations Analysis Division, HQ AAF	Washington, D.C.	Dec 42–Aug 45	Command	4	W. Barton Leach Roscoe C. Crawford (Acting)	Dec 42–Jul 45 Jul 45–Sep 45
Directorate of Air Defense, HQ AAF	Washington, D.C.	Mar 42–Sep 45	Air defense	8	Cyril M. Jansky, Jr.	Mar 42–Sep 45
I Bomber Command[b]	Long Island, N.Y.	Dec 41–Fall 43	Antisubmarine warfare	NA	Philip M. Morse[b]	Spring 42–Fall 43
Second Air Force	Colorado Springs, Colo.	Sep 43–Aug 45	Training	46	Deane W. Malott Joseph Kaplan Evan R. Collins	Sep 43–Dec 43 Dec 43–Jan 45 Jan 45–Aug 45
Third Air Force	Tampa, Fla.	Jul 44–Aug 45	Training	5	William M. Whyburn Will H. Connelly (Acting) Donald D. Durrell Will H. Connelly	Jul 44–Oct 44 Oct 44–Jan 45 Jan 45–Jun 45 Jun 45–Aug 45
Fourth Air Force	San Francisco,Calif.	Mar 44–Aug 45	Training	9	T. Stanley Warburton Anders J. Carlson	Mar 44–Jul 45 Jul 45–Aug 45
Continental Air Forces[c]	Washington, D.C.	May 45–Aug 45	Training	6	Lauriston S. Taylor	May 45–Aug 45
AAF Weather Wing	Ashville, N.C.	Jan 45–Aug 45	Weather	7	Joseph Kaplan	Jan 45–Aug 45
AAF School of Applied Tactics	Orlando, Fla.	Sep 42–Aug 45	Training	3	Robert L. Stearns David W. Raudenbush	Sep 43 Sep 43–May 45
Air Evaluation boards	Theater HQs	1944–1945	Evaluation	5	One operations analyst per board	NA
Strategic Bombing Survey	Europe, Pacific	1944–1945	Evaluation	1	Theodore Tannenwald, Jr.	Sep 44–Jan 45
AAF Training Aids Division	New York, N.Y.	Mar 44–Aug 45	Training	2	Arthur E. Pierce George P. Shettle	Mar 44–Apr 45 Jul 45–Sep 45
AAF Technical Training Command	Ft. Worth, Tex.	Jul 43–Sep 45	Training	1	Deane W. Malott	Jul 43–Sep 45
Eighth Air Force	England	Oct 42–Jun 45	Operational-bombardment	48	John M. Harlan Leslie H. Arps	Oct 42–Aug 44 Aug 44–Jun 45
VIII Fighter Command/VIII Air Support Command	England	Jun 43–Oct 44	Operational-fighter, training	7	Lauriston S. Taylor Ralph P. Johnson	Jun 43–Nov 43 Nov 43–Oct 44

Ninth Air Force	England, France, Belgium	Dec 43–May 45	Operational	21	Lauriston S. Taylor Carroll Zimmerman (IX Tactical Air Command)	Dec 43–May 45 Dec 43–May 45
Mediterranean. Allied Air Forces[d] (Twelfth Air Force)	Tunisia, Italy	Jul 43–May 45	Operational-bombardment	5	Irving H. Crowne	Jul 43–May 45
IX Bomber Command[e]	Benghazi, Cairo	May 43–Oct 43	Operational-bombardment	7	Samuel G. Frantz	May 43–Oct 43
Fifteenth Air Force	Tunisia, Italy	Nov 43–May 45	Operational-bombardment	7	Samuel G. Frantz George W. Housner	Nov 43–Jul 44 Jul 44–May 45
Eleventh Air Force	Aleutian Islands	May 43–Jul 45	Operational	9	Sidney K. Wolf Hamilton M. Jeffers Clyde H. Bond Ralph W. Anderson	May 43–Sep 43 Sep 43 Oct 43–Aug 44 Aug 44–Jul 45
Fourteenth Air Force	China	Jul 44–Aug 45	Operational	8	Seymour J. Janow (Acting) George W. Taylor Carl J. Rees	Jul 44–Oct 44 Oct 44–Jul 45 Jul 45–Aug 45
AAF, Pacific Ocean Area (Seventh Air Force)	Hawaii, Guam, Okinawa	Aug 44–Aug 45	Operational	10	Douglas Shearer Kenneth Lambert Norman M. Newmark	Aug 44–Dec 44 Dec 44–Jan 45 Jan 45–Aug 45
Fifth Air Force	Australia	Feb 44–Jul 44	Operational	9	Sidney K. Wolf	Feb 44–Jul 44
Thirteenth Air Force	Southwest Pacific Area, Philippines	Oct 43–Jul 44	Operational	12	Robert L. Stearns Livingston Hall	Oct 43–May 44 May 44–Jul 44
Far East Air Forces[f]	Australia, New Guinea, Philippines	Jul 44–Aug 45	Operational	20	Sidney K. Wolf	Jul 44–Aug 45
AAF, India-Burma Theater (Tenth Air Force)	India	Jan 44–Aug 45	Operational	13	Fowler Hamilton LeRoy A. Brothers David Mayer	Jan 44–May 44 May 44–Sep 44 Sep 44–Aug 45
Twentieth Air Force (USASTAF Rear)	Washington, D.C.	May 44–Aug 45	Operational-long-range bombardment	26	Robert L. Stearns Livingston Hall	May 44–Jun 45 Jul 45–Aug 45
XX Bomber Command (Eighth Air Force, Pacific)	Kansas, India, China, Okinawa	Dec 43–Aug 45	Operational-long-range bombardment	11	Hamilton M. Jeffers Dan B. Dyer	Dec 43–Mar 45 Mar 45–Aug 45
XXI Bomber Command	Colorado Springs, Colo.; Guam	Oct 44–Aug 45	Operational-long-range bombardment	27	Donald H. Loughridge LeRoy A. Brothers	Oct 44–Apr 45 Apr 45–Aug 45
301st Fighter Wing, Very-Long-Range	Ie Shima	Jul 45–Aug 45	Operational-very-long-range escort	4	Theodore Tannenwald, Jr.	Jul 45–Aug 45

[a]The number of personnel shown represents total analysts and supervisors; it does not include clerical and support personnel. Not all people served at the same time. [b]Operations analysis support provided by Navy ASWORG. [c]Assumed control of numbered Air Forces in the continental United States in March 1945. [d]Separated into the Operations Analysis Section (OAS) for the Twelfth and Fifteenth Air Forces in October 1944. [e]Transferred to the Fifteenth Air Force in November 1943. [f]Absorbed OAS Fifth and Thirteenth Air Forces in July 1944.
NA = not available.

Source: Based on LeRoy A. Brothers and others, *Operations Analysis in World War II: United States Army Air Forces* (Philadelphia: Stephenson-Brothers, 1949).

APPENDIX C

The Army Research and Development Program, 1924–62

From the time of its introduction into the United States Army during World War II, operations research (OR) was closely related to the process by which weapons and other equipment were designed, tested, and fielded. Early Army OR work focused on improving weapons design and performance, and although the use of operations research soon spread to questions of organization, doctrine, and higher-level policy, its application to concrete matters of weapons systems research and development (R&D) remained one of the primary uses of OR in the Army. Accordingly, until the early 1960s the Army OR organizations were managed as part of the overall Army R&D/combat developments system.[1]

Army Research and Development, 1924–45

Before World War I, the development of weapons and equipment for the Army was almost entirely in the hands of the supply services, each of which had its own system. The competition for resources in World War I made it obvious that some coordination was required at the level of the War Department General Staff, and the Army's first formal R&D program began with the publication on 15 December 1924, of *Army Regulations No. 850-25: MISCELLANEOUS—Development, Classification of, and Specifications for Types of Equipment*.[2] Under the provisions of *AR 850–25*, the War Department delegated responsibility for R&D to the technical services, but the regulation was revised in 1927 to charge the General Staff with preparing plans and policy for R&D and with determining all types of military equipment required. Per *AR 850–25*, the chiefs of the combat arms were responsible for initiating requests for the development of new weapons and equipment and for determining the desired military characteristics, whereas the chiefs of the supply services were responsible for actually designing and developing items within their sphere of interest.[3]

The 1924 regulations made testing and evaluation an integral part of the R&D process, but each arm and service operated its own test and evaluation system. The two basic types of tests were engineering tests conducted by the developing agency and service tests conducted by the using arm to determine the suitability of the item for field use. The user's final evaluation normally dictated the decision on standardization, a decision formally rendered by the secretary of war on the advice of the General Staff.[4] Staff supervision over the process was lodged in the Logistics Section of the War Department General Staff.

Additional revisions of *AR 850–25* were made in the 1930s, and the Army G-4 was singled out to supervise the Army-wide development program, but no General Staff section or branch was specifically charged with overseeing R&D until 31 October 1940, when an R&D section was organized in the Planning and Equipment Branch of G-4.[5] The R&D Section was renamed the Developments Section of the Requirements and Distribution Branch of G-4 in December 1940, and, several days after Pearl Harbor was attacked, the Developments Section was upgraded to a branch headed by Col. A . W. Waldron, with four officers and two civilians.[6] Under the Marshall Reorganization in March 1942, Headquarters, Army Service Forces, assumed overall responsibility for coordinating the Army's R&D efforts, and Headquarters, Army Ground Forces, inherited the functions of the chief of the arms, including determination of military needs and characteristics, the conduct of service tests, and final evaluation from the user viewpoint.

AR 850–25 was revised on 30 June 1943, but the new regulation was not substantially different from the earlier versions.[7] Meanwhile, the involvement of the Army in scientific matters had increased substantially, and the Army R&D program had grown more complex and operated with a faster pace. In September 1943, Dr. Vannevar Bush, the director of the Office of Scientific Research and Development (OSRD)

and chairman of the Joint New Weapons and Equipment Committee (JNWEC), and special consultant Harvey H. Bundy urged Secretary of War Henry L. Stimson to create a new staff division to help monitor scientific matters.[8] Their recommendation was based on three factors: the inability of Bush's JNWEC to meet Army needs fully; the selection by Army Chief of Staff Gen. George C. Marshall in the spring of 1943 of Col. William A. Borden, an experienced ordnance officer, to head efforts to expedite the development and deployment of weapons and techniques for jungle warfare; and Secretary Stimson's own interest in keeping the War Department abreast of the latest scientific developments and in acting forcefully to translate basic research into weapons for use against the enemy.[9]

On 13 October 1943, Secretary Stimson overruled the objections of Headquarters, Army Service Forces, and established the New Developments Division (NDD) in the War Department Special Staff.[10] Maj. Gen. Stephen G. Henry was named to head the new staff agency.[11] The functions assigned to NDD by Secretary Stimson included responsibility to keep Army civilian and military leaders and staff officers informed of new technological developments and "to initiate, coordinate, or direct research, development, standardization, and expeditious military application of new or improved weapons, devices, and techniques" and "to introduce and demonstrate to appropriate commanders or organizations new developments which have not received adequate consideration."[12]

A War Department circular issued on 15 August 1944 increased the scope of NDD to include "the introduction of new weapons to combat troops" as a major function, and the division subsequently played an important role in coordinating the introduction of new weapons and equipment in the field.[13] Working closely with OSRD's Office of Field Service, NDD consulted with the War Department and other agencies on the selection and overseas assignment of scientists and technicians inducted into the service. It arranged for trained teams to accompany new equipment to the theaters of operations, to demonstrate and exploit its full usefulness to the troops, and to observe its use in battle.[14] NDD also played a central role in the establishment and continued operations of the OR units formed in the headquarters of Gen. Douglas MacArthur's Southwest Pacific Area and Lt. Gen. Robert C. Richardson, Jr.'s Pacific Ocean Area.

Army Research and Development, 1945–50

The rapid growth of military technology triggered by World War II greatly increased the importance of scientific research and development, and the Army postwar R&D establishment expanded to deal with the new developments—such as guided missiles, electronics, and nuclear weapons—that were needed to meet America's new global commitments in the growing confrontation with the Soviet Union. One result was that research and development became big business in the United States during and after World War II. Between 1941 and 1950, the number of scientists and engineers engaged in research in the United States nearly doubled, rising from 87,000 to 151,000.[15] In FY 1949, the Army alone employed some 12,800 civilians and about 4,100 military personnel in R&D activities.[16] Slender budgets in the 1920s and 1930s had restricted the Army's R&D program, and from 1924 to 1940, the annual Army R&D budget never exceeded $3.5 million.[17] However, under wartime pressures Army R&D expenditures had risen quickly to $20.5 million in 1941, $89 million in 1942, $180 million in 1943, and they peaked at $164 million in 1944.[18] Despite many new requirements, postwar Army R&D budgets were significantly lower. In FY 1949, $115.5 million was appropriated for Army R&D, some 21 percent of the total Department of Defense (DOD) R&D budget of $550 million.[19]

Planning for the postwar Army R&D program began even before the end of the war. Just before V-E Day, on 1 May 1945, the Army deputy chief of staff, Lt. Gen. Thomas T. Handy, acting on the recommendation of NDD, published the first official Army policy on R&D, the essence of which was that only operational needs should supersede R&D in priority.[20] The policy prescribed closer liaison between developers and users, and the Operations Division of the General Staff was charged with formulating future requirements to guide the R&D process. All Army agencies were told to plan their R&D programs on a permanent postwar basis.

Responding to the request of the board of officers (the Patch-Simpson Board, headed by Lt. Gen. Alexander M. Patch) created by General Marshall on 30 August 1945 to examine the reorganization of the War Department, Maj. Gen. William A. Borden, director of NDD, sent forward his recommendations on 1 October 1945. The most important was a recommendation to create the position of assistant secretary of war for research and development.[21] Maj. Gen. Borden also recommended that a General Staff R&D division be created, the duties of which would include:

> supervision of post war graduate scientific and technical education; assignment and employment of scientists in the Army; War Department action on inventions; the dissemination of information on War Department research and development which is of value to other agencies of the government and to science and industry; the coordination and integration of communications and radar; and exploitation of psychological warfare.[22]

On 3 April 1946, the War Department created a War Department Research Council to assist in coordinating Army R&D policy.[23] The council consisted of the director of NDD as chairman; the assistant chief of staff for R&D,

Headquarters, Army Air Forces; the chief of the Development Section, Headquarters, Army Ground Forces; the director, R&D Division, Headquarters, Army Service Forces; and the chiefs of R&D for each of the technical services. The Research Council met for the first time on 17 April 1946 and discussed the R&D organization in the War Department reorganization proposed by the Patch-Simpson Board. At its next meeting, following the 11 June 1946 reorganization of the War Department, the council took up procedures for handling atomic energy projects, legislation to allow increased salaries for top scientists in the War Department, the R&D program and its budgetary implications, and the pending revision of *AR 850–25*.[24]

Meanwhile, the scope and objectives of the Army R&D program began to solidify. The objective of all Army R&D agencies was "to apply the results of scientific analysis and research to the development of the most advanced materiel, techniques, and countermeasures in the execution of the military policy of the United States," and the first priority was to ensure "that the materiel and techniques employed by our forces in combat are superior in every way to those of a possible enemy."[25] The basic principles governing the conduct of postwar Army R&D were defined as freedom of direction in basic research, the need for research in the Army programs, free exchange of information, maximum assistance from civilian science and industry, economy in the operation of military facilities, evaluation of foreign developments, and the need for long-range planning.[26]

The postwar Army R&D program received a substantial boost on 30 April 1946 when General of the Army Dwight D. Eisenhower, then the Army chief of staff, issued a memorandum that discussed the importance of scientific research to the Army and set forth Army R&D policy.[27] General Eisenhower's memorandum is particularly interesting in light of his later negative view of the so-called military-industrial complex. He wrote:

> The recent conflict has demonstrated more convincingly than ever before the strength of our nation can best derive from the integration of all of our national resources in time of war. . . . The future security of the nation demands that all those civilian resources which by conversion or redirection constitute our main support in time of emergency be associated closely with the activities of the Army in time of peace. . . . The armed forces could not have won the war alone. Scientists and business men contributed techniques and weapons which enabled us to outwit and overwhelm the enemy. Their understanding of the Army's needs made possible the highest degree of cooperation. This pattern of integration must be translated into a peacetime counter-part which will not merely familiarize the Army with the progress made in science and industry, but draw into our planning for national security all the civilian resources which can contribute to the defense of the country . . . the Army . . . has the duty to take the initiative in promoting closer relation between civilian and military interests. It must establish definite policies and administrative leadership which will make possible even greater contributions from science, technology, and management than during the last war.[28]

General Eisenhower then set forth five general policies "to ensure the full use of our national resources in case of emergency":

> 1. The Army must have civilian assistance in military planning as well as for the production of weapons. . . . The most effective procedure is the letting of contracts for aid in planning.
> 2. Scientists and industrialists must be given the greatest possible freedom to carry out their research.
> 3. The possibility of utilizing some of our industrial and technological resources as organic parts of our military structure in time of emergency should be carefully examined.
> 4. Within the Army we must separate responsibility for research and development from the functions of procurement, purchase, storage and distribution.
> 5. Officers of all arms and services must become fully aware of the advantages which the Army can derive from the close integration of civilian talent with military plans and developments . . . the Army's need for officers well trained in the natural and social sciences requires a thorough program of advanced study for selected military personnel. . . . A premium must be placed on professional attainments in the natural and social sciences as well as other branches of military science.[29]

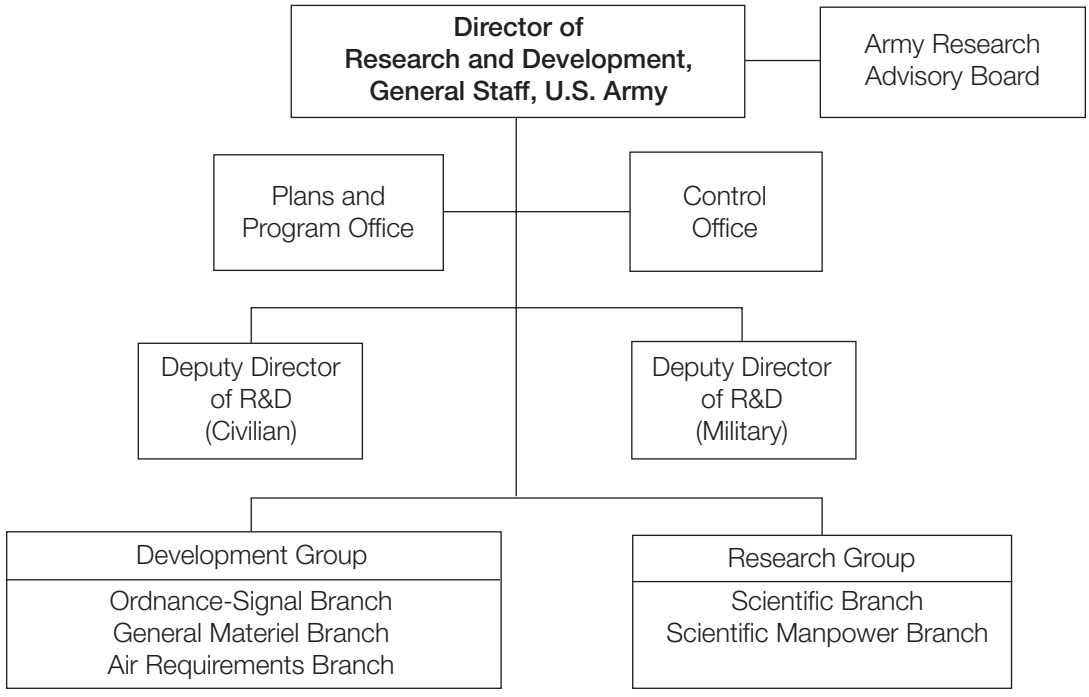
He then concluded by noting:

> In general, the more we can achieve the objectives indicated above with respect to the cultivation, support, and direct use of outside resources, the more energy will we have left to devote to strictly military problems for which there are no outside facilities or which for special security reasons can only be handled by the military.[30]

The day before issuing his statement on Army research and development, General Eisenhower took action to upgrade General Staff oversight of R&D by abolishing the New Developments Division and replacing it with a new General Staff R&D Division to be activated on 1 May 1946.[31] The director of the R&D Division was designated as the chief advisor to the secretary of war and the chief of staff on R&D matters and the application of national scientific research to the solution of military problems. Col. Gervais W. Trichel was named acting director of the new staff division, pending the assignment of Lt. Gen. Henry S. Aurand.[32] On 18 September 1946, Secretary of War Robert P. Patterson named the president of George Washington University, Dr. Cloyd H. Marvin, as deputy director of the R&D Division.[33]

The initial organization of the R&D Division was prescribed by *General Staff Circular 5–6*, dated 11 June 1946. The division was subsequently reorganized several times, with the third reorganization taking place on 9 April 1947. The organization of the R&D Division as of 23 October 1947 is shown in Figure C–1.

FIGURE C–1—R&D DIVISION, GENERAL STAFF, U.S. ARMY: 23 OCTOBER 1947



Source: Lowell R. Eklund, "Science and the Soldier: The Organization for Research and Development in the Army: Past, Present, and Future" (MS thesis, Syracuse University, 1947), Tab 24.

The creation of the R&D Division on a level with the other major War Department General Staff divisions was a significant step toward effective control of the Army R&D program. Writing to Dr. C. C. Lauritsen of the California Institute of Technology on 3 May 1946, the acting director of the R&D Division, Col. Trichel, noted that, "after fighting an uphill battle during most of the war, it now appears that research and development activities are going to be given the place in the War Department which they have always deserved."[34]

Despite increased emphasis on R&D in the Army and the recognition that an effective R&D program was essential to the nation's security, the Army R&D program in the immediate postwar years had many difficulties. There was a continuing problem in attracting and retaining top-notch scientific personnel; working conditions were not always first-rate; and funding tended to be uncertain.[35] In September 1947, Dr. Marvin prepared a study of the Army's R&D problems at the request of the new Secretary of the Army Kenneth C. Royall. In his study, Marvin recommended the reorganization of the R&D Division and its subordination to the Service, Supply, and Procurement Division of G-4; he set forth the arguments for an assistant secretary of the Army for R&D who would oversee scientific work in the Army, ensure effective coordination and mutual support between the Army and other government agencies, and see that proper weight was given to Army contacts with industry and science on matters of mutual interest.[36] He noted that

> research and development will strengthen its own position in the Army by encouraging the civilian economy to do as much as possible of this work for it, and by doing itself only what the civilian economy cannot or will not do.[37]

In November 1947, Marvin wrote to Secretary Royall proposing a number of ways in which the principles and recommendations contained in his 24 September report might be implemented.[38] Noting "the necessity of research as a vital part of the development of a modern army," he proposed a modernization of the Army's R&D program, including greater integration of R&D with strategic, operational, and logistical planning and the creation of an Army command in which the formulation of tactical doctrine would take place in conjunction with the determination of new requirements and testing of materiel.[39]

For the most part, Marvin's suggestions fell on sterile ground, but some of them were implemented piecemeal. The long-standing call for an assistant secretary of the Army charged with establishing policy and directing and supervising R&D activities was answered in March 1948. Three months earlier, as part of the December 1947 reorganization of the Army, the R&D Division was eliminated as a separate

entity and its functions were reassigned to an R&D group in the Service, Supply, and Procurement Division (later the Logistics Division).[40] The chief of the R&D group was designated as the deputy director for R&D and was vested with responsibility for staff supervision of R&D projects from their inception to their completion or adoption as standard Army materiel. Through the director of Logistics, he also advised the assistant secretary of the Army, the chief of staff, other General Staff divisions, and other DOD agencies on R&D matters.[41] He also acted for the director of logistics in directing and controlling the R&D work and budgetary activities of the technical services.

In part, the downgrading of the R&D Division was prompted by the loss to the newly created Air Force of responsibility for Army Air Forces R&D, which amounted to approximately two-thirds of the total Army R&D effort in dollar terms.[42] This downgrading of status came at a time when other government agencies were giving their R&D activities greater prominence and freedom. It would take the pressures of another war to revive the forward progress of R&D in the Army.

Army Research and Development, 1950–62

Army R&D received only desultory attention in the immediate post–World War II years. An enormous stock of weapons and equipment, much of it unused, was left over from the war, and at the same time the advent of nuclear weapons seemed to make all possible conventional weapons obsolete. However, the Korean War demonstrated that there was still a continuing need for conventional weapons and tactics as well as the new tactical nuclear weapons and doctrines. On 6 June 1950, less than three weeks before the outbreak of the Korean War, Secretary of the Army Frank Pace, Jr., told the graduating cadets at the United States Military Academy that

> We and our allies can never hope to compete with our potential enemies in numbers and masses of ground troops and weapons of a conventional type. It is therefore obvious that we in the Army must depend to a great extent upon intensive research and development directed at equipping our ground forces and the ground forces of our allies with such advanced and superior weapons that they can overcome the overwhelming numerical advantage of our potential enemies . . . the Army must continuously plan for the future.[43]

The renewed interest in Army R&D signaled by Secretary Pace's address and accelerated by the war in Korea was manifested in two ways. First, there was a substantial increase in the annual appropriations by Congress for Army R&D projects, including the construction of new research facilities. Second, there was an internal battle within the Army over how R&D should be managed. The Army Staff, reflecting the desires of the technical services, generally favored the status quo and the retention of R&D under the Deputy Chief of Staff for Logistics. On the other hand, the Army's civilian scientists and the senior officers mostly closely associated with the R&D process favored making R&D an independent function outside the Army's logistical system. The struggle continued from the Korean War into the early years of the Kennedy administration, and the scientists and senior R&D officers generally prevailed. A number of organizational changes provided increased independence and more-effective high-level Army staff supervision of the Army R&D program, and several new offices were created to handle growing Army R&D activities. Both the increase in funding for Army R&D and the changes in Army R&D management had a substantial effect on Army operations research programs, most of which were tied closely to R&D efforts and were supervised by senior Army R&D managers.

Army R&D Funding, 1950–62

Secretary of Defense Louis Johnson wrote to the chairman of the House Committee on Armed Services on 28 July 1950 to inform him that the aggregate amount appropriated for the U.S. armed services for FY 1946 through FY 1950 totaled some $90 billion, of which research and development on new weapons accounted for approximately 5 percent, or an average of slightly more than $500 million per year.[44] The Korean War prompted a substantial increase in DOD R&D expenditures. In FY 1950, DOD obligated some $520 million for military R&D, and the total obligation in FY 1951 was $1.1 billion.[45] DOD obligation authority for R&D continued to increase in subsequent years as did the total costs for Research and Development/Test and Evaluation (RDTE) of new weapons, costs that were considerably higher than the obligation figure for military R&D alone. For example, the total DOD RDTE costs for FY 1957 were estimated at $5.3 billion, and constituted 14.5 percent of all the funds made available to the Department of Defense for military functions.[46] About 50 percent of the FY57 DOD RDTE appropriation was allocated to industrial contractors, 10 percent to universities and other nonprofit institutions, and 40 percent to government laboratories that employed some 60,000 civilians and 50,000 military personnel.[47] By FY 1962, DOD RDTE programs accounted for approximately $7 billion, or nearly 15 percent of the total defense budget.[48]

Army RDTE appropriations, obligations, and expenditures increased proportionately during the period 1950–62, following a major jump during the Korean War. The Army's pre–Korean War FY51 R&D budget was $131 million.[49] However, the Army received two supplemental FY51 appropriations, bringing the total to $300 million, and another $61,120,225 was appropriated for new construction at Army R&D facilities.[50] The increased funding for Army

R&D resulted in a significant increase in the rate at which new weapons and equipment were introduced. During FY 1951, 321 new items of equipment resulting from the post–World War II R&D program were put into production, and an additional 300 items were expected to go into production in FY 1952 when the Army share of the DOD RDTE budget was $377.5 million).[51] By the beginning of the 1960s, Army budgets for RDTE had grown much larger. Direct obligations totaled $1.072 billion in FY 1960, $1.163 billion in FY 1961, and a planned $1.252 billion in FY 1962.[52]

The Reorganization of Army R&D

Although there was general agreement on the need for an effective Army R&D system—and although the substantial increases in funding for Army R&D during and after the Korean War provoked little controversy in Congress, the Executive Branch, or the Army—the question of how Army R&D should be organized and managed proved to be a troublesome matter. Throughout the 1950s and into the 1960s, there was intense debate within the Army leadership regarding the most effective and efficient way of managing the Army's rapidly growing RDTE activities.[53] Most of the Army Staff, backed by the still powerful chiefs of the technical services, viewed R&D as a subordinate function of the logistics system and sought to preserve the status quo.[54] The traditional view was opposed with increasing success by the ever-growing number of civilian scientists working for the Army aided by a small number of influential general officers assigned to important R&D positions who wished to remove R&D from the control of agencies concerned primarily with procurement and supply.[55] At times, the struggle was intense and threatened to slow the forward movement of the Army's R&D efforts, but in the end the scientists and senior R&D "experts" prevailed and a highly effective, independent Army RDTE structure emerged and made a major contribution to the technological superiority that the U.S. Army still enjoys today.

On 8 April 1950, shortly before he left office, Secretary of the Army Gordon Gray wrote for Army Chief of Staff Gen. J. Lawton Collins a perceptive memorandum in which he critically reviewed the entire Army R&D program and declared that it deserved "a radically greater degree of emphasis than we have heretofore conceived it to warrant."[56] The secretary's concern led to a formal study of Army R&D organization. In August 1950, Assistant Secretary of the Army Karl R. Bendetson assigned the project to Leonard W. Hoelscher.[57] A first draft was completed in November 1950, and the final report was delivered on 12 January 1951. The Kilgo Report, as it came to be called, concluded that the Army R&D program needed stronger leadership at the top and recommended establishing a separate assistant chief of staff (ACS) for R&D with control over R&D funds, and a deputy chief of staff (DCS) for development.[58] The report also noted that there should be a direct link between the Army R&D programs and Army strategic planning, and it proposed that the use of operations research be increased by establishing OR groups in every major Army command.[59] All twenty of the recommendations included in the Kilgo Report were eventually adopted in one form or another, although some took longer to implement than others.[60]

When Secretary of the Army Frank Pace, Jr., circulated the Kilgo Report in the Army Staff, he found that there was strong opposition to the creation of the two proposed senior staff positions. Most of the senior Army Staff officers rejected any proposal for reorganization of Army R&D, although Secretary Pace had made it clear that he favored transferring Army R&D functions from the ACS G-4, Logistics.[61] A compromise was reached (primarily because of the work of Maj. Gen. Maxwell D. Taylor, then the DCS for organization and administration), and pursuant to Department of the Army General Order No. 4 (11 January 1952), on 15 January 1952, the DCS for plans became the DCS for plans and research (DCSPR) and was assigned responsibility for coordinating the Army R&D activities with the Army's assigned missions, plans, and tactical doctrines.[62] General Order No. 4 also established the position of chief of research and development (CRD) within the Office of the Army Chief of Staff. The CRD, a general officer with a civilian scientist as his deputy, was to be the personal assistant of the chief of staff on R&D matters and was designated as program director for Army Primary Program 7 (Research and Development) with responsibility for overseeing Army R&D activities and allocating R&D appropriations within the Army.[63]

In fact, the DCSPR and CRD shared the responsibilities for Army R&D planning formerly exercised by the Research and Development Division in the Office of the ACS G-4, Logistics, but because of severe personnel limitations the new CRD was forced to delegate much of his authority to other elements of the Army Staff, particularly the ACS G-4, Logistics. For the time being, the ACS G-3, Operations, supervised the Operations Research Office (ORO); the ACS G-1, Personnel, oversaw the newly created Human Resources Research Office (HumRRO); and the much-reduced Research and Development Division in the office of the ACS G-4, Logistics, remained responsible for R&D (and thus operations research) activities in the technical services.[64] General Order No. 4 also directed that each of the principal Army Staff agencies have a section responsible for R&D matters in their field of cognizance.[65]

Earlier, in November 1951, Secretary Pace also created the Army Scientific Advisory Panel (ASAP), a group of twelve prominent scientists and businessmen whose function was

> to assist the Secretary of the Army and the Chief of Staff in their joint responsibility to give this country a fighting force as effective, economical, and progressive as our scientific, technological, and industrial resources permit.[66]

Dr. James R. Killian, a leader in the struggle to remove R&D from G-4 control, was the first chairman of ASAP.[67]

Although the changes effected by the Kilgo Report, General Order No. 4, and the creation of ASAP greatly enhanced the status of R&D within the Army Staff, the compromise solution implemented in early 1952 soon proved unworkable in that there was no single agency that could oversee an R&D project from beginning to end, and the production and procurement element in the Army Staff continued to dominate the R&D program.[68]

Renewed interest in Army reorganization on the part of Congress, the press, and the newly installed Eisenhower Administration, as well as the blue-ribbon committee established in February 1953 and headed by Nelson A. Rockefeller to examine the organization and procedures of the Department of Defense prompted the Army Staff to revive the search for a viable R&D organization in March 1952. The need to find a solution was made more urgent by the economy drives of the Eisenhower Administration. As Under Secretary of the Army Earl D. Johnson pointed out, the Army was the only service that had yet to consolidate its R&D organization, and it would be much better for the Army to act before an unacceptable solution was forced upon it by outside agencies.[69]

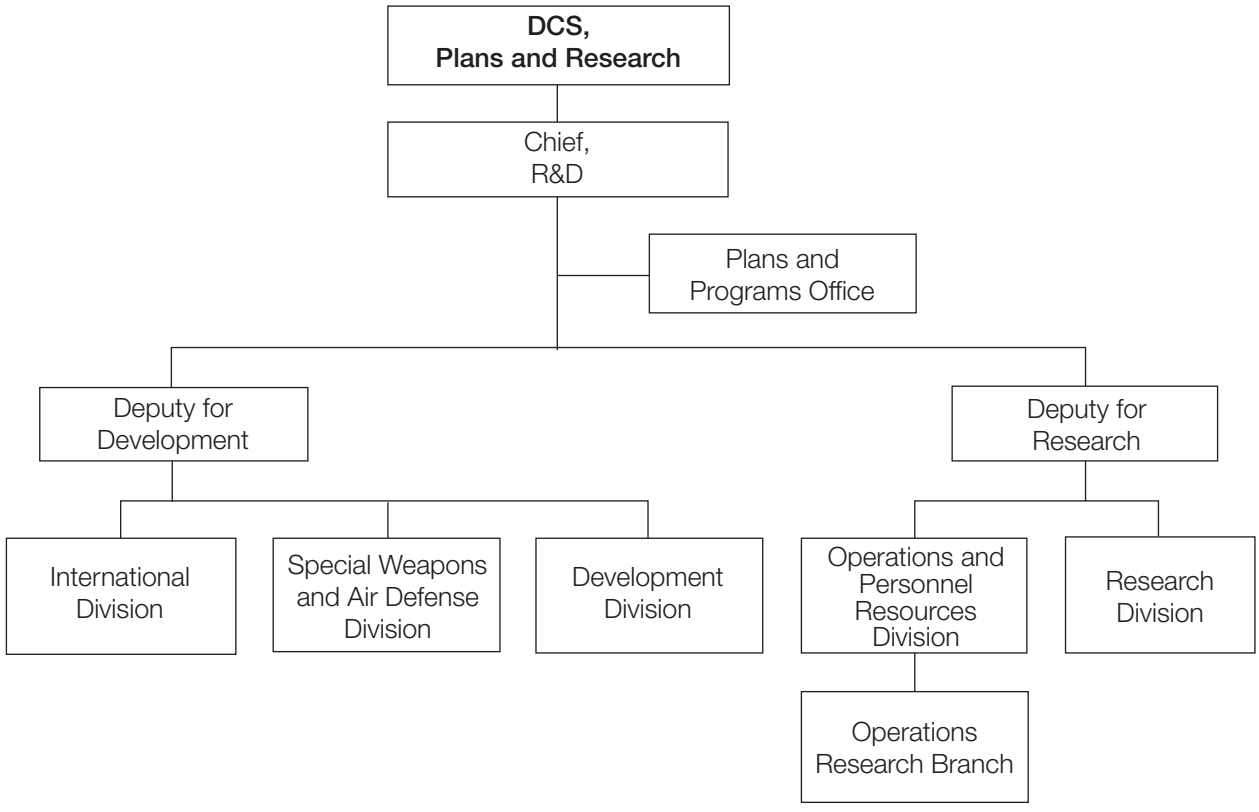
On 18 September 1953, Secretary of the Army Robert T. Stevens appointed the Advisory Committee on Army Organization, headed by Paul L. Davies, to study and make recommendations on Army organization in general.[70] The committee, assisted by Chicago management consulting firm McKinsey and Company, interviewed 129 witnesses, including senior Department of the Army personnel, Army R&D experts, and distinguished civilian scientists such as Vannevar Bush and James R. Killian.[71] The committee rendered its report on 18 December 1953, and recommended, among other changes, the strengthening of the CRD's authority, transfer of the R&D planning functions of the G-4 to the Office of the Chief of Research and Development, expansion of the scope of ASAP to include any and all problems concerning Army R&D, and rejection of suggestions to form an Army Research and Development Command.[72]

In June 1954, Congressional subcommittee hearings on the organization and administration of military R&D programs considered eight principal problem areas: the incompatibility of military organizations and civilian scientists, control and domination by the military, lack of an optimum climate for civilian scientific research, lack of technical and scientific capability in the military, limitations of rotation, the question of civilian control over research, the extent of research functions that should be accomplished by civilian agencies, and the desirability of a civilian organization to administer military R&D programs.[73] During the hearings only Dr. James R. Killian, the chairman of ASAP, raised the subject of operations research, noting that ORO was insufficient, that other university contracts provided research projects rather than analysis, and that the Army needed an organization similar to the RAND Corporation.[74]

The recommendations of the Davies Committee, particularly the creation of an Army Supply Command, were opposed by the new ACS G-4, Lt. Gen. Williston P. Palmer, and others, and their implementation was delayed. After considerable maneuvering and additional studies, the recommendations of the Davies Committee were finally put into effect in June 1954, when Secretary Stevens issued his plan for the reorganization of the Army Staff.[75] Called the Slezak Plan, after the new Under Secretary of the Army, John Slezak, Secretary Stevens' reorganization scheme included the creation of two additional assistant secretaries of the Army, one for civil–military affairs and the other for logistics (including R&D). At the insistence of Lt. Gen. Palmer, the Army Supply Command was dropped and the R&D functions of the ACS G-4 were to be transferred to a DCS for logistics. The position of chief of R&D was strengthened in that the CRD was given the authority to "stimulate, support, and coordinate the planning and operational requirements for research and development."[76]

The new organization left Army R&D subordinate to logistics, and the reactions of key Army R&D personnel and civilian scientists (such as Lt. Gen. Lyman L. Lemnitzer, the new DCS for plans and research; Dr. James R. Killian, the chairman of ASAP, which had been reorganized and expanded in the fall of 1954; and Dr. J. E. Vance, the Army's chief scientist) were negative.[77] Military opponents of the plan argued their case through Lt. Gen. Lemnitzer's office to the Army chief of staff, and ASAP sought through civilian channels to pressure Secretary Stevens to modify the plan.[78] Dr. Killian personally urged Secretary Stevens to separate R&D from logistics and to elevate the CRD to DCS level.[79] As a result, Secretary Stevens agreed that the proposed transfer of R&D functions from the ACS G-4 to the DCS for logistics, the ACS G-1, and the ACS G-3 should be canceled, and, pursuant to Department of the Army General Order No. 88 of 22 December 1954, those functions were centralized in the Office of the DCS for Plans and Research, although the DCS for logistics retained control over the R&D elements of the technical services.[80] The order also provided for the establishment of a new Army Staff division under the chief of R&D to oversee the "planning, supervising, coordinating, and directing" of all Army R&D under the supervision of the Of-

FIGURE C–2—OFFICE, CHIEF OF RESEARCH AND DEVELOPMENT, OFFICE OF THE DEPUTY CHIEF OF STAFF FOR PLANS AND RESEARCH, HEADQUARTERS, DEPARTMENT OF THE ARMY: CIRCA MARCH 1955



Source: Emmette Y. Burton Jr., "The Role of Operations Research in the Army," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1955, Annex 1.

fice of the DCS for Plans and Research.[81] The same general order also transferred the Research and Development Division in the DCS for logistics to the Office of the DCSPR and assigned it to OCRD, thereby concentrating R&D planning and policy responsibilities in OCRD. The resulting organization of OCRD was as shown in Figure C–2.

In March 1955, Lt. Gen. James M. Gavin became the DCS for plans and research and asked Maj. Gen. Kenner F. Hertford, then the CRD, to recommend necessary changes in the R&D area.[82] Maj. Gen. Hertford recommended the creation of a senior Department of the Army civilian position (an assistant secretary or special assistant to the secretary of the Army) to oversee R&D matters.[83] He also recommended that the CRD be raised to DCS level and given the authority to determine the requirements for developing new weapons, equipment, and techniques; to supervise all aspects of Army R&D, including engineering and user tests; to make full use of R&D work performed by the other services and foreign agencies; and to maintain close contact with the DCS for logistics to facilitate the transition from development to production and with the planning and combat development agencies of the ACS G-3 to ensure the integration of R&D with war plans.

No immediate action was taken on Maj. Gen. Hertford's recommendations, but on 3 August 1955, Maj. Gen. Andrew P. O'Meara, the new CRD, formally proposed to the assistant secretary of the Army (logistics and R&D) the establishment of the Office of the DCS for R&D.[84] The concurrence of the Army Staff was obtained, and Secretary Wilbur M. Brucker and Chief of Staff Gen. Maxwell D. Taylor approved the new position. The necessary organizational changes were incorporated in Change 11 (22 September 1955) to *Special Regulations No. 10–5–1*, and later confirmed by Department of the Army General Order No. 57 (6 October 1955).[85] Accordingly, the position of chief of research and development was separated from the Office of the DCS for Plans and Research and made an autonomous agency at the DCS level with the CRD responsible to the chief of staff for planning, coordinating, directing, and supervising all Army R&D.[86] Although the position was considered equivalent to that of a deputy chief of staff, the title of chief was used instead inasmuch as the Army Reorgani-

zation Act of 1950 limited the Army to three deputy chiefs of staff. The CRD was authorized to deal directly with the technical services and technical staff officers, but before issuing any directives he was required to coordinate closely with the DCS for logistics, who retained control over the personnel and funds for R&D in the technical services.[87]

The reorganization became effective on 10 October 1955, and Lt. Gen. James M. Gavin became the Army's first true chief of research and development.[88] Lt. Gen. Gavin subsequently served as the CRD until 31 March 1958, when he was replaced by Lt. Gen. Arthur G. Trudeau, who served as the CRD until 30 June 1962. He was relieved in turn by Lt. Gen. Dwight E. Beach.[89] As part of the October 1955 reorganization, the civilian position of director of research and development was created to provide a principal assistant to the secretary of the Army on R&D matters.[90] Dr. William H. Martin, then deputy assistant secretary of defense for applications engineering, was appointed to the position.[91]

As James E. Hewes, the leading historian of Army staff organization, has noted:

> The emergence of the Office of Chief of Research and Development on 10 October 1955 as an independent General Staff agency ended a strenuous five-year campaign for recognition by civilian scientists both within and outside the Army. It was also part of the continuing struggle for control over the Technical Services because they performed most of the research and development within the Army.[92]

Although the October 1955 reorganization marked the successful separation of R&D from logistics and gave the CRD a direct channel to the chief of staff as well as to the R&D elements of the technical services, the CRD still did not exercise full control over the R&D efforts of the technical services; the DCS for logistics continued to enjoy that authority.[93] It was not until 1960, shortly before the abolition of the technical services, that the chief of R&D finally gained full control over all R&D programs.[94]

APPENDIX C NOTES

[1]The history of Army research and development activities, particularly in the post–WWII period, is well documented, although most of the sources have not been published commercially. Of particular value to this study are Lowell R. Eklund, "Science and the Soldier: The Organization for Research and Development in the Army: Past, Present, and Future" (MS thesis, Syracuse University, 1947); U.S. Army General Staff, Logistics Div, *Research and Development in the Department of the Army* (Washington: Logistics Div, General Staff, U.S. Army, 1948); U.S. DOD, Office of the Asst Sec Def for R&D, Resources Div, *The Growth of Scientific Research and Development*, RDB 114/34 (Washington: OASD [R&D], Resources Div, 1953) (hereafter cited as U.S. DOD, *Growth of Scientific R&D*); U.S. Department of the Army, Office of the Chief of Research and Development, *"Path of Progress": U.S. Army R&D Organizational Changes, 1924–1960* (Washington: OCRD, HQDA, 1960); L. Van Loan Naiswald, *The History of the Army R&D Organization and Program, Part I: Organization* (draft) (Washington: OCMH, DA, ca. 1963); and James E. Hewes, *From Root to McNamara: Army Organization and Administration, 1900–1963* (Washington: U.S. Army Center of Military History, 1975).

[2]The term "research and development" first came into official Army usage about the same time (see Naiswald, *History of Army R&D Organization and Program*, p. 1).

[3]Robert W. Coakley, Richard C. Kugler, and Vincent H. Demma, *Historical Summary of Evolution of U.S. Army Test and Evaluation System—World War II to the Present* (draft), 3 vols. (Washington: Histories Division, OCMH, DA 1966), p. 1. The Army Air Corps, Corps of Engineers, and Signal Corps had a dual position as both combat arm and supply service.

[4]Ibid., pp. 1–3. The conduct of service tests was assigned to a board, normally co-located with and connected to the service school. There were five separate combat arms boards in 1940 (infantry, cavalry, field artillery, coast artillery, and armored forces), each under the direct control of the chief of the arm. Seven new boards were added during World War II (tank destroyer, 1941; antiaircraft, 1942; desert warfare and winter warfare, 1942 [discontinued in 1944]; and landing vehicle, airborne, and rocket, 1944).

[5]Ibid., p. 1; Eklund, "Science and the Soldier," p. 13. The small R&D section in G-4 consisted of just one officer (see Naiswald, *History of Army R&D Organization and Program*, p. 5).

[6]Naiswald, *History of Army R&D Organization and Program*, p. 8. On 15 May 1944, the Developments Branch was redesignated the R&D Division (see U.S. Army, *Path of Progress*, pp. 11–12).

[7]Ibid., p. 9.

[8]Ibid., pp. 10–11. Secretary Stimson's other special consultant on scientific matters, Dr. Edward L. Bowles, was also influential.

[9]U.S. War Department Special Staff, New Developments Div, *History of the New Developments Division, War Department Special Staff, 13 October 1943–1 September 1945 and Postwar Planning* (Washington: U.S. War Department Special Staff, 1946), pp. 7–14. In particular, the success of the activities of the Borden group highlighted the need for a new Army General Staff agency to oversee the development and fielding of new weapons and equipment.

[10]Memo, Henry L. Stimson (sec war) to director, New Developments Division, Washington, 13 Oct 43, sub: Organization and Functions, New Developments Division, War Department, College Park, Md., NARA II, RG 107, Entry 113, Box 67, Folder New Developments Division. The establishment of NDD was confirmed by War Department Circular 267, dated 25 October 1943.

[11]Maj. Gen. Henry served as director, NDD, from 23 October 1943 to 17 August 1944. He was replaced by Brig. Gen. (later Maj. Gen.)

William A. Borden, who served from 18 August 1944 to 27 March 1946. Maj. Gen. Borden was replaced by Col. Gervais W. Trichel, who served as acting director from 28 March 1946 to 9 June 1946, when NDD was discontinued and its functions were transferred to the new R&D Division of the War Department General Staff (see Hewes, *From Root to McNamara*, p. 402).

[12]Memo, Stimson, 13 Oct 43.

[13]Eklund, "Science and the Soldier," p. 33.

[14]Brig. Gen. William A. Borden (then director, NDD), draft article titled "Army Research and Development," pp. 7–8, attached to Memo, Harvey H. Bundy to Brig Gen William A. Borden, Washington, 15 Jan 45, sub: Comments on Borden's draft article, RG 107, Entry 113, Box 67, Folder New Developments Division.

[15]U.S. DOD, *Growth of Scientific R&D*, p. 12, Table III.

[16]U.S. DOD, Office of the Secretary of Defense, *Second Report of the Secretary of Defense and the Annual Reports of the Secretary of the Army, Secretary of the Navy, and Secretary of the Air Force for the Fiscal Year 1949* (Washington: USGPO, 1950), p. 58.

[17]Naiswald, *History of Army R&D Organization and Program*, p. 2.

[18]Ibid., p. 10.

[19]U.S. DOD, *Growth of Scientific R&D*, p. 11, Table II; *Second Report of the Sec Def*, p. 58.

[20]U.S. War Dept, *History of New Developments Division*, pp. 179–82; Naiswald, *History of Army R&D Organization and Program*, pp. 12–13. General Handy later became a key consultant and staff member of the Army ORO.

[21]U.S. War Dept, *History of New Developments Division*, p. 182–83.

[22]Ibid., p. 184.

[23]Memo, Col Gervais W. Trichel (asst director, NDD) to commanding generals, Army Ground Forces, Army Service Forces, and Army Air Forces, Washington, 3 Apr 46, sub: War Department Research Council (reproduced in Eklund, "Science and the Soldier," Tab 28).

[24]U.S. War Department General Staff, Research and Development Div, *Research and Development Annual Report, Fiscal Year 1947*, (Washington: Research and Development Div, U.S. War Department General Staff, 30 Jun 47), p. 9, NARA II, RG 319, Entry 153. Box 434, Folder R&D Annual Rpt, FY 47.

[25]U.S. Army, *R&D in the Department of the Army*, p. 1.

[26]Ibid., pp. 1–3.

[27]Memo, Gen of the Army Dwight D. Eisenhower (Army chief of staff) to directors and chiefs of War Department General and Special Staff divisions and bureaus and the commanding generals of the major commands, Washington, 30 Apr 46, sub: Scientific and Technological Resources as Military Assets, U.S. Army CMH, HRC–020—R&D, Fort McNair, Washington; also reproduced in Eklund, "Science and the Soldier," Tab 18.

[28]Ibid., pp. 1–2.

[29]Ibid., pp. 2–3.

[30]Ibid., pp. 3–4.

[31]Memo, Brig Gen Henry I. Hodes (asst deputy chief of staff) to commanding generals of Army air forces, Army ground forces, Army service forces and chiefs of all War Department General and Special Staff divisions, Washington, 29 Apr 46, sub: Creation of Research and Development Division, U.S. Army CMH, HRC–321 R&D, Fort McNair, Washington. The 29 April directive was confirmed by Executive Order 9722 of 13 May 1946, which reorganized the War Department, effective 11 June 1946. NDD was officially redesignated as the R&D Division by War Department Circular 138, dated 14 May 1946, and on 11 June 1946, the R&D Division absorbed the R&D functions of Headquarters, Army Service Forces, which was abolished by Executive Order 9722.

[32]Lt. Gen. Aurand took office on 10 June 1946 (see press release, War Department Public Relations Div, Washington, 13 Jun 46, sub: General Aurand Named to Head General Staff Research Group, U.S. Army CMH, HRC–020 R&D, Fort McNair, Washington). A 1915 graduate of West Point, Lt. Gen. Aurand was originally commissioned in the Coast Artillery but had been engaged in Ordnance work since 1917. In WWII he had commanded logistical units in the United States, France, and China.

[33]Press release, War Department Public Relations Division, Washington, 18 Sep 46, sub: Dr. Marvin Named Deputy Director, Research and Development Division U.S. Army CMH, HRC–020 R&D, Fort McNair, Washington). Dr. Marvin had served as a captain in the Army Aviation Service in WWI.

[34]Ltr, Col Gervais W. Trichel (acting director, R&D Div) to Dr C. C. Lauritsen (California Institute of Technology), Washington, 3 May 46 (reproduced in Eklund, "Science and the Soldier," Tab 3).

[35]U.S. Army, *Path of Progress*, p. 4.

[36]Marvin, extract from 24 Sep 47 report to the Secretary of the Army, pp. 9–10 (reproduced in Eklund, "Science and the Soldier," Tab 41). See also U.S. Army, *Path of Progress*, pp. 4–5; and Eklund, "Science and the Soldier," p. 121.

[37]Marvin, extract from 24 Sep 47 report to the Secretary of the Army, p. 3.

[38]Memo, Dr Cloyd H. Marvin to the Secretary of the Army, Washington, 26 Nov 47, sub: Army Research and Development (reproduced in Eklund, "Science and the Soldier," Tab 40).

[39]Ibid. In essence, Dr. Marvin was recommending the creation of a functionally organized Army Combat Developments Command quite similar to that formed in the early 1960s.

[40]U.S. Army, *Path of Progress*, p. 5. The R&D Division was abolished by *DA Circular 73*, dated 19 December 1947. The R&D Group was again designated the R&D Division on 1 March 1950, concurrent with the redesignation of the Logistics Division as the Office of the Assistant Chief of Staff, G-4, Logistics, pursuant to *DA Circular 12*, dated 28 February 1950.

[41]U.S. Department of the Army, Office of the Secretary of the Army, *Report of the Secretary of the Army for Fiscal Year 1949*, in *Second Report of the Secretary of Defense*, p. 160; U.S. Army, *R&D in the Department of the Army*, p. 13.

[42]U.S. Army, *Path of Progress*, p. 5.

[43]U.S. Department of the Army, *Semiannual Report of the Secretary of the Army, January 1 to June 30, 1950*, in U.S. DOD, *Semiannual Report of the Secretary of Defense and the Semiannual Reports of the Secretary of the Army, Secretary of the Navy, and Secretary of the Air Force, January 1 to June 30, 1950* (Washington: USGPO, 1950), p. 67.

[44]*Semiannual Rpt of the Sec Def, Jan 1–Jun 30, 1950*, pp. 48–49.

[45]U.S. DOD, *Semiannual Rpt of the Sec Def, January 1 to June 30, 1951*, in U.S. DOD, *Semiannual Report of the Secretary of Defense and the Semiannual Reports of the Secretary of the Army, Secretary of the Navy, and Secretary of the Air Force, January 1 to June 30, 1951* (Washington: USGPO, 1951), p. 6. The services were instructed to include at least $30 million in their FY51 R&D program for basic research.

[46]U.S. DOD, *Semiannual Report of the Secretary of Defense, January 1 to June 30, 1956*, in U.S. DOD, *Semiannual Report of the Secretary of Defense and the Semiannual Reports of the Secretary of the Army, Secretary of the Navy, and Secretary of the Air Force, January 1 to June 30, 1956* (Washington: USGPO, 1957), p. 29.

[47]U.S. DOD, *Semiannual Report of the Secretary of Defense, January 1 to June 30, 1957*, in U.S. DOD, *Semiannual Report of the Secretary of Defense and the Semiannual Reports of the Secretary of the Army, Secretary of the Navy, and Secretary of the Air Force, January 1 to June 30, 1957* (Washington: USGPO, 1958), p. 30.

[48]U.S. DOD, *Annual Report of the Secretary of Defense for FY 1962*, in U.S. DOD, *Annual Report of the Secretary of Defense and the Annual Reports of the Secretary of the Army, Secretary of the Navy, Secretary of the Air Force, for Fiscal Year 1962* (Washington: USGPO, 1963), p. 33.

[49]U.S. Department of the Army, Office of the Under Secretary of the Army, *Annual Report of the Office of the Under Secretary of the Army for the Period of 1 July 1950 to 30 June 1951* (Washington: DA, 1952), p. 8.

[50]Ibid., pp. 8–9.

[51]Ibid., p. 14; U.S. Department of the Army, *Semiannual Report of the Secretary of the Army, January 1 to June 30, 1951*, in *Semiannual Report of the Secretary of Defense . . . January 1 to June 30, 1951*, p. 86. The FY52 Army R&D budget included funds for OR (for example, ORO).

[52]*Annual Report of the Secretary of the Army for Fiscal Year 1961*, in U.S. DOD, *Annual Report of the Secretary of Defense and the Annual Reports of the Secretary of the Army, Secretary of the Navy, Secretary of the Air Force, for Fiscal Year 1961* (Washington: USGPO, 1962), p. 137.

[53]The controversy is discussed by Hewes in *From Root to McNamara*, pp. 242–58 *passim*. See also Naiswald, *History of Army R&D Organization and Program*; and U.S. Army, *Path of Progress*.

[54]The focal point of R&D in the Army logistics system was the Research and Development Group created within the Service, Supply, and Procurement Division of the Office of the Assistant Chief of Staff G-4 in 1947. The Research and Development Group was redesignated as the Research and Development Division (RDD) pursuant to *DA Circular 12*, dated 28 February 1950.

[55]Hewes, *From Root to McNamara*, pp. 217, 258.

[56]Naiswald, *History of Army R&D Organization and Program*, pp. 27–28.

[57]Ibid., p. 29.

[58]Ibid. Marvin M. Kilgo of the Army Comptroller's Office did most of the work of compiling the data for the report. At the time, responsibility for R&D was split between the ACS G-4, Logistics, and the DCS for Plans per *Army Special Regulations No. 10–5–1*, dated 11 April 1950.

[59]Ibid., pp. 29–30. See also Hewes, *From Root to McNamara*, p. 245; and Lorna Jaffe, *Quantitative Analysis and Army Decision Making* (Alexandria, Va.: U.S. Army Materiel Development and Readiness Command Historical Office, 1984), p. 10.

[60]U.S. Army, *Path of Progress*, p. 6.

[61]Ibid.

[62]Hewes, *From Root to McNamara*, p. 247; U.S. Army, *Path of Progress*, pp. 6–7.

[63]U.S. Department of the Army, *Semiannual Report of the Secretary of the Army, January 1 to June 30, 1952*, in U.S. DOD, *Semiannual Report of the Secretary of Defense and the Semiannual Reports of the Secretary of the Army, Secretary of the Navy, and Secretary of the Air Force, January 1 to June 30, 1952* (Washington: USGPO, 1952), p. 85; Hewes, *From Root to McNamara*, pp. 247–48; U.S. Army, *Path of Progress*, p. 7.

[64]Hewes, *From Root to McNamara*, p. 248.

[65]U.S. Army, *Path of Progress*, p. 7.

[66]*Semiannual Report of the Sec Army, Jan 1– Jun 30 52*, p. 85.

[67]Hewes, *From Root to McNamara*, p. 248.

[68]U.S. Army, *Path of Progress*, p. 8.

[69]Ibid.

[70]Ibid.; Hewes, *From Root to McNamara*, p. 223. Davies was then vice president of the Food Machinery and Chemical Corporation and director of the American Ordnance Association. Other committee members included Harold Boeschenstein, president of Owens-Corning Fiberglass; C. Jared Ingersoll, director of the Philadelphia Ordnance District in WWII and president of the Midland Valley Railroad; Irving A Duffy, a retired Army colonel and vice president of Ford Motor Company; and Lt. Gen. Lyman L. Lemnitzer, the DCSPR.

[71]Hewes, *From Root to McNamara*, p. 224.

[72]Ibid., pp. 224–27. The Davies Committee also recommended the creation of the position of assistant secretary of the Army for financial management, the establishment of a Continental Army Command to assume responsibility for training from the ACS G-3, and the establishment of a Supply Command that would relieve the ACS G-4 of responsibility for the direction and control of the technical services as well as all R&D operating responsibilities.

[73]John C. Schermerhorn, "The Role of Operations Research in the Army," student individual study, U.S. Army War College, Carlisle Barracks, Penn., 1956, Appendix D, p. 74 (based on U.S. Congress, 83d Cong, 2d Sess, *Organization and Administration of the Military Research and Development Programs*, pp. 2–3).

[74]Ibid., Appendix D, p. 75 (based on U.S. Congress, *Organization and Administration*, p. 436).

[75]Ibid., p. 9; Francis T. Julia, Jr., *Army Staff Reorganization, 1903–1985*, CMH Historical Analysis Series, Pub 93–6 (Washington: USGPO for Analysis Branch, U.S. Army CMH, 1987), pp. 24–26. The plan was announced on 14 June 1954, and approved by the secretary of defense on 17 June.

[76]Schermerhorn, "Role of OR in the Army," p. 9.

[77]Ibid., pp. 9–10.

[78]Ibid., p. 10.

[79]Hewes, *From Root to McNamara*, p. 252.

[80]U.S. Army, *Path of Progress*, p. 10.

[81]Hewes, *From Root to McNamara*, p. 252. Brig. Gen. Andrew P. O'Meara was named chief of research and development.

[82]U.S. Army, *Path of Progress*, p. 10.

[83]Ibid.

[84]Hewes, *From Root to McNamara*, p. 253.

[85]U.S. Department of the Army, Change 11 to *Special Regulations No. 10–5–1: ORGANIZATION AND FUNCTIONS, DEPARTMENT OF THE ARMY* (Washington: HQ, DA, 22 Sep 55).

[86]Hewes, *From Root to McNamara*, p. 238. Simultaneously, the DCS for Plans and Research was redesignated the DCS for Plans.

[87]Change No. 11 to HQ, DA, *Special Regulations No. 10–5–1: ORGANIZATION AND FUNCTIONS, DEPARTMENT OF THE ARMY* (Washington, 22 Sep 55), para. 29.1.

[88]U.S. Army, *Path of Progress*, p. 11.

[89]Hewes, *From Root to McNamara*, pp. 396–97. During most of Lt. Gen. Gavin's term as the CRD, his deputy was Maj. Gen. Andrew P. O'Meara, the chief scientist was Dr. Ragnar Rollefson, the director of research was Brig. Gen. Theodore J. Conway, and the Operations Research Division (which oversaw ORO) was headed by Col. Roland P. Carlson and then Lt. Col. L. Fritter.

[90]U.S. Army, *Path of Progress*, p. 11. The position was titled director of R&D rather than assistant secretary of the Army for R&D for the same reason the CRD was not given the DCS designation.

[91]Hewes, *From Root to McNamara*, p. 253.

[92]Ibid., p. 242.

[93]Ibid.

[94]Annual Report of the Secretary of the Army for Fiscal Year 1961, in Annual Rpt of the Sec Def, FY 61, p. 136.

Glossary

AAF	United States Army Air Forces
AAFAC	AAF Anti-Submarine Command
AAORG	Anti-Aircraft Operations Research Group (Navy)
ACS	Assistant Chief of Staff
ADCSOPS	Assistant Deputy Chief of Staff for Operations
AFR	Air Force Regulation
AGARD	Advisory Group on Aeronautical Research and Development (NATO)
ALCLAD	ORO study on individual protective equipment and measures
AMEDS	Army Medical Service
ANALAA	ORO study on air defense
AORE	Army Operational Research Establishment (Britain)
AORG	Army Operational Research Group (Britain)
AR	Army Regulation(s)
ARMOR	ORO study on the role of armor in future warfare
ARO	Army Research Office
ARO (Durham)	Army Research Office, Durham, North Carolina
ASAP	Army Scientific Advisory Panel
ASW	antisubmarine warfare
ASWORG	Anti-Submarine Warfare Operations Research Group (Navy)
ATLAS II	commercial version of the Remington Rand UNIVAC electronic computer, 1952
ATTACK	ORO study on the employment of atomic weapons in Army operations
AU	American University
BALANCE	ORO study on the optimum weapons systems for ground warfare
BRAND	ORO section dealing with continuous evaluation of Army research and development
BRL	Ballistic Research Laboratories
BuOrd	Bureau of Ordnance (Navy)
CAA	United States Army Concepts Analysis Agency; Center for Army Analysis (after 1998)
CAG	Combined Arms Group, Fort Leavenworth, Kansas
Cal Tech	California Institute of Technology
CAORE	Canadian Army Operational Research Establishment
CAPWAR	ORO study on the relationship of ground warfare requirements to available resources
Carmonette	ORO computerized wargame
CCORG	Chemical Corps Operations Research Group
CDC	United States Army Combat Developments Command
CDEC	United States Army Combat Developments Command Experimentation Command/ Center
CDTEC	Combat Developments Test and Experimentation Center
CENTAUR	STAG computerized land warfare model/game
CGSC	United States Army Command and General Staff College
CINC	Commander in Chief

CINCPAC	Commander in Chief, Pacific
CJCS	Chairman, Joint Chiefs of Staff
CMH, HRC	Center of Military History, Historical Reference Collection
CmlC	United States Army Chemical Corps
CMR	Committee on Medical Research
CNO	Chief of Naval Operations
COA	Comptroller of the Army
COBRA	ORO study on chemical, biological, and radiological warfare
"Cocky Ken"	Man-shaped pop-up target used for marksmanship training
"Colossus"	First all-electronic computer, housed at Bletchley Park, England, World War II
COMINCH/CNO	Commander in Chief, U.S. Fleet, and Chief of Naval Operations
COMPLAB	Computing Laboratory (ORO)
COMPLETE	ORO study on the defense of the United States as a strategic problem
CONARC	United States Continental Army Command
CORG	Combat Operations Research Group
CPA	Central Pacific Area
CRD	Chief of Research and Development
CSA	Chief of Staff, U.S. Army
CSO	Chief Signal Officer
DA	Department of the Army
DAME	ORO study on the cost of NATO forces
DCS	Deputy Chief of Staff
DCSLOG	Deputy Chief of Staff for Logistics
DCSOPS	Deputy Chief of Staff for Military Operations (1956–74)
DCSPER	Deputy Chief of Staff for Personnel
DCSPR	Deputy Chief of Staff for Plans and Research
DOD	Department of Defense
DONKEY	ORO study on the use of surface-to-surface missiles in support of Army operations
DOUGHBOY	ORO study on infantry weapons systems
DRB	Defence Research Board (Canada)
ENIAC	Electronic Numerical Integrator and Calculator (early computer, 1946)
ETO	European Theater of Operations
EUSA	Eighth United States Army
EUSAK	Eighth United States Army, Korea
EVANAL	ORO study on the operation of equipment under various environmental conditions
FABMDS	Field Army Ballistic Missile Defense System (wargame)
FAME	ORO hand-played wargame
FASD	Foreign Area Studies Division
FEC	Far East Command
FY	fiscal year
GHQ	General Headquarters
GHQ SWPA	General Headquarters, Southwest Pacific Area
GRO	General Research Office
Group M	Early name for World War II Navy antisubmarine warfare group
GWU	George Washington University
HQ	Headquarters
HQ ETOUSA	Headquarters, European Theater of Operations, United States Army
HQ EUSAK	Headquarters, Eighth United States Army, Korea
HRAF	Human Relations Area Files
HumRRO	Human Resources Research Office
IBM	International Business Machines Corporation
ICR	Institute for Cooperative Research (The Johns Hopkins University)
INDIGO	ORO hand-played intelligence wargame
INFORMS	Institute for Operations Research and Management Sciences
JCS	Joint Chiefs of Staff
JHU	The Johns Hopkins University
JNWEC	Joint New Weapons and Equipment Committee
JORSA	*Journal of the Operations Research Society of America*
LEGATE	ORO study on civil affairs and military government
LEGION	STAG theater-level computerized wargame
LOGSPIEL	ORO logistical wargame
LOI	Letter of Instruction
LORAN	long-range navigation system
MAID	ORO study on military aid to foreign countries
MIT	Massachusetts Institute of Technology
MORS	Military Operations Research Symposium

MORU	Military Operational Research Unit
MWORG	Mine Warfare Operations Research Group (Navy)
NACA	National Advisory Committee for Aeronautics
NARA	National Archives and Records Administration
NAS	National Academy of Sciences
NATO	North Atlantic Treaty Organization
NDD	New Developments Division
NDRC	National Defense Research Committee
NDRE	Norwegian Defence Research Establishment
NME	National Military Establishment
NOL	Naval Ordnance Laboratory
NRC	National Research Council
NSA	National Security Act
NSF	National Science Foundation
OA	operations analysis
OAD	Operations Analysis Division (HQ, USAAF)
OAO	Operations Analysis Office
OAS	Operations Analysis Section
OASD (R&D)	Office of the Assistant Secretary of Defense for Research and Development
OCAFF	Office of the Chief of Army Field Forces
OCMH	Office of the Chief of Military History
OCNO	Office of the Chief of Naval Operations
OCRD	Office of the Chief of Research and Development
OCSigO	Office of the Chief Signal Officer (Army)
ODF	Operational Development Force (Navy)
OE	organizational effectiveness
OEG	Operations Evaluation Group (Navy)
OFS	Office of Field Service (OSRD)
OMA	Operations and Maintenance–Army appropriation
ONR	Office of Naval Research
OOR	Office of Ordnance Research
"Op Annie"	operations analyst (USAAF, World War II)
Operation STARVATION	World War II mining campaign against Japan, 1945
OPSEARCH	ORO section dealing with basic operations research methods and techniques
OR	operations research
ORB	Operational Research Branch (Britain)
ORC	Operations Research Center (Navy)
ORG	Operations Research Group (Navy)
ORO	Operations Research Office
ORSA	Operations Research Society of America
ORS POA	Operations Research Section, Pacific Ocean Area
ORTAG	Operations Research Technical Assistance Group
OSRD	Office of Scientific Research and Development
OTA	Office of Technical Assessment, U.S. Congress
P&O	plans and operations
PAG	Project Advisory Group
PARABEL	ORO study on paramilitary warfare
PASD	Project Analysis and Synthesis Division
PISGAH	Series of ORO-sponsored OR conferences
POA	Pacific Ocean Area
POWER	ORO study on the application of nuclear power by the Army
POWOW	ORO study on psychological warfare operations
Project AGILE	SORO counterinsurgency study
Project CAMELOT	SORO study of revolution and insurgency
Project MICHIGAN	Study of Army long-range surveillance
Project PINPOINT	CDEC study of antitank weapons that evolved into study of experimentation methods
PSD	Project Studies Division
PSYOPS	psychological operations
PSYWAR	psychological warfare
R&D	research and development
RAC	Research Analysis Corporation
RAF	Royal Air Force (Britain)
RDB	Research and Development Board
RDD	Research and Development Division
RDF	radio direction finding (early name for radar)
RDTE	Research and Development/Test and Evaluation

REDLEG	ORO study on artillery support
RG	Record Group
ROEC	Research Office Experimentation Center
ROTEC	Research Office of the Test and Experimentation Center
SADTC	SHAPE Air Defence Technical Center
SADU	Sea Search and Development Unit
SBC	Service Bureau Corporation
SCEAG	United States Army Signal Corps Evaluation and Analysis Group
SHAPE	Supreme Headquarters Allied Powers Europe
SHOP	ORO study on human factors in military operations
SITE	ORO study on Army training and education
SORG	Submarine Operations Research Group (Navy)
SORO	Special Operations Research Office
STAG	United States Army Strategy and Tactics Analysis Group
STRATSPIEL	ORO strategic wargame
SWPA	Southwest Pacific Area
SYNTAC	STAG synthetic tactics wargame system
TACIT	ORO study on combat intelligence
TACSPIEL	ORO tactical wargame
TC	United States Army Transportation Corps
TEAM	ORO study on human behavior and interpersonal relationships
TEAR	ORO study on air support of ground operations
TELLSPIEL	ORO intelligence wargame
THEATERSPIEL	ORO theater-level wargame
TIME	ORO study on the use of strategic intelligence to determine the imminence of hostilities
TIMS	The Institute of Management Sciences
TOE	Table of Organization and Equipment
TRADOC	United States Army Training and Doctrine Command
TRAINFIRE	Army rifle marksmanship training program
TREMABASE	ORO study on the logistical support of Army operations
U.K.	United Kingdom
UN	United Nations
UNIVAC	early Remington Rand electronic computer (1950s)
U.S.	United States
USA	United States Army
USAAF	United States Army Air Forces
USACDCIAS	United States Army Combat Developments Command Institute for Advanced Studies
USACGSC	United States Army Command and General Staff College
USACMH	United States Army Center of Military History
USAFFE	United States Army Forces Far East
USAFICPA	United States Army Forces in the Central Pacific Area
USAFMIDPAC	United States Army Forces in the Mid-Pacific Area
USAFPOA	United States Army Forces Pacific Ocean Area
USAIAS	United States Army Institute for Advanced Studies
USAREUR	United States Army Europe
USGPO	United States Government Printing Office
USMA	United States Military Academy
USMC	United States Marine Corps
USN	Untied States Navy
USNA	United States Naval Academy
USNR	United States Naval Reserve
USSBS	United States Strategic Bombing Survey
VISTA	Project study of Army research and development/combat developments
WAC	Women's Army Corps
WDGS	War Department General Staff
WSEG	Weapons Systems Evaluation Group
WSL	Weapons Systems Laboratory
WWI	World War I
WWII	World War II

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INDEX

AR15 (rifle): 102
AAF. *See* U.S. Army Air Forces
AAFASW. *See* U.S. Army Air Forces Anti-Submarine Command
Abajian, Henry: 37
ABC Discussions on Army Operational Research: 127*n185*
Aberdeen Proving Ground: 34, 35, 63, 112, 159*n2*
Research Division: 35. *See also* U.S. Army Ordnance Department
Advisory Committee on Bombardment: 27
Advisory Group on Aeronautical Research and Development (AGARD): 106
exchange program: 128*n198*. *See also* NATO
AGARD. *See* Advisory Group on Aeronautical Research and Development
Air Defense Command: 45*n74*
Air Defense Technical Center (NATO): 106
Air Evaluation Boards: 26, 27
Air Force Regulation 20-7: Operations Analysis: 58, 59
establishes Operations Directorate of Air Force: 59
establishes Operations Analysis Office (OAO): 59
and staffing: 59
Air Force Regulation 20-9: Air Force Policy for the Conduct of Project RAND: 60
and Project RAND Military Advisory Group: 60
Air Warfare Operations Research Group: *47n132*
Airborne Instruments Laboratories: 122
Aircraft in Warfare: The Dawn of the Fourth Arm (Lanchester): 5
Akin, Maj. Gen. Spencer B., USA: 37, 53*n382*
requests OR analysts: 38
Alexander the Great: 4
Alexander, Archibald: 69
Alexander, James: 19, 51*n302*
Alexander, Col. William, USA: 38
Alvarez, Luis: 125*n94*
Ambrose, W. A.: 47
American Association for the Advancement of Science: 161
American Chemical Society: 156*n192*
American Institute of Research: 126*n129*
American Kriegsspiel, The (Livermore): 114
American Power Jet Company: 71
American University: and OR as a discipline: 107
Special Operations Research Office at: 110
Analysis of the ORO Research Program with Respect to Timeliness (Flory): 103
Analytics, Inc.: 64
Andrews, Lt. Gen. Frank M., USA: 49*n226*: suggests use of civilian OR analysts: 24
Anti-Submarine Warfare Operations Research Group (ASWORG): 21-23, 29, 57
Columbia University contract: 17, 28, 51*n280*
personnel: 21, 22, 48
sponsored by Office of Field Service: 17

Antisubmarine Warfare in World War II (Sternhell and Thorndike): 58
AORE. *See* Great Britain, Army Operational Research Establishment
AORG. *See* Great Britain, Army Operational Research Group
Appleton, E. V.: 43*n4*
Archambault, Bennett: 15
Archimedes: 3, 6
Armalite Company: designs AR 15 (rifle): 102
Armed Forces Security Agency: 112
Army Operations Research Symposium: 158, 161
Army Regulation No. 15-14: and STAG mission: 116
Army Regulation No. 15-480: establishes mission of Operations Research Office: 87
Army Regulation No. 70-32: Special Warfare Non-Materiel Research: 111
Army Table of Distribution No. 89-9826: and STAG personnel: 117
Arneson, Robert W.: OR analyst killed in action: 32
Arnold, Lt. Gen. Henry H., USAAF: 15, 30, 32, 36
forms Advisory Committee on Bombardment: 27

Arnold, Lt. Gen. Henry H., USAAF—*Continued*
aerial mining of Shimonoseki Straits: 20
establishes Air Evaluation Boards: 26
and formation of OAD on Air Staff: 25
and postwar R&D for Air Force: 59
orders review of U.S. air defenses: 24
ARO. *See* U.S. Army Research Office
Arps, Leslie H.: 51*n302*
ASWORG. *See* Anti-Submarine Warfare Operations Research Group
Atkins, Emery L.: and Project EVANAL: 72
Atlantic Fleet: 21
ASWORG: personnel attached to: 48*n173*
ATLAS II (computer): for Armed Forces Security Agency: 112
Aurand, Lt. Gen. Henry S., USA: 64
Australian National Academy: 11
Aydelotte, Dr. Frank: 28

Babbage, Charles: and computers: 111
Bacher, Robert T.: and Project VISTA: 135
Bacon, Lt. Col. John A., USA: 150
Baker, Rear Adm. Wilder D., USN: 15
recommends OR element for Atlantic Fleet: 21
Ball, George W: 26
Ballistic Research Laboratories (BRL): 34, 63, 147, 159*n2*
Advisory Council: 35
ENIAC developed for: 112
mission of: 35
multidisciplinary approach: 35
studies of: 63, 147
Terminal Ballistics Laboratory at: 63
Weapons System Laboratory (WSL): 81*n109*, 147
See also under individual arsenals; U.S. Army Ordnance Department
Bardeen, John: 19
Nobel Prize: 48*n167*
Barton, Carlyle: 92
Bath, Carl C.: 34
Battelle Memorial Institute: 64, 71, 83*n212*
Battle of Britain: 10, 12
Battle of the Atlantic: 13, 22
Bawdesy Research Station: 10, 44*n9*, *n11*
radar development: 10, 14
Baxter, James: *Scientists Against Time*: 45*n77*
Beach, Lt Gen. Dwight E., USA: 123, 157
Becich, J. P.: 38
Bell Telephone Laboratories: 15, 46*n79*, 48*n167*, 53, 122
Bell, Maurice E.: 21, 47n167
Bennett, Ralph D.: 19
Bergstein, Svend, Lt. Col. (Denmark): 3
Besson, Gen. Frank S., Jr., USA: 157
Best, Robert J.: 67, 72
Biggin Hill: radar development at: 10, 14
Bitter, Cdr. Francis, USN: 19, 47*n132*
Blackett, P.M.S.: 10, 11, 13, 19, 21, 43*n4*, 44*n25*
Nobel Prize: 11

Blackett, P.M.S.—*Continued*
"A Note on Certain Aspects of the Methodology of Operational Research": 13 defining OR and codifying scientific rules of: 11
forms Operational Research Club: 107
"Recollections of Problems Studied, 1940-1945": 12
"Scientists at the Operational Level": 11, 15
on Tizard Committee: 10
Bletchley Park: uses computer for code-breaking: 111
Bode, Dr. Hendrik W.: 122
Bombing accuracy: 42
Booz Allen and Hamilton: 83*n212*
Booz-Allen Applied Research, Inc.: development of CENTAUR: 119
STAG contract: 117
Bothwell, Dr. F. E.: 118
Bowen, Ralph: 15
Bowker, Lt. Col. A., USA: 150
Bowles, Dr. Edward L.: 59
Bowman, Dr. Isaiah: 65
Bradley, General of the Army Omar T., USA: 122
Bramhall: Dr. Ervin H.: and Project ANALAA: 71
BRAND: reviews Army R&D: 88, 92. *See also* Operations Research Office
Brattain, Walter: Nobel Prize: 48*n167*
Brewerton, Capt. Douglas: *War Chess, or The Game of Battle*: 130*n305*
British Air Ministry Center of Operational Research: 26
Menzies heads: 12, 26
British Army Munitions Inventions Department, Anti-Aircraft Experimental Section: 5
British Central Scientific Office (Washington, D.C.): 15
British Commonwealth: OR organizations: 62
British Ministry of Home Security Research and Experiments Department, Princes Risborough: 15, 17, 46
BRL. *See* Ballistics Research Laboratories
Bronk, Detlev: 69, 76, 84*n250*, 92
Bronowski, Jacob: contacts British OR analysts: 15
Brooke Army Medical Center: 151
Brookhaven National Laboratory: 47*n165*, 136
Brooks, Dr. Franklin C.: 140, 154*n73*
Brothers, LeRoy A.: 15, 58
relationship with Air Staff: 59
Brown, Arthur A.: 21, 22, 128*n218*
Brown, Bonnar: 128*n218*
Bulova Watch Company: 122
Bundy, Harvey H.: 18, 24, 36, 44*n21*, 53*n378*, 58
and Leach-Davidson Report: 25
Buonarotti, Michangelo: 4
Burchard, John E.: 17, 39, 46*n97*
Combat Scientists: 45*n77*
NDRC Division 2: 17, 53
Bureau of Applied Social Science Research (Columbia University): 126*n129*

Bureau of Ordnance Research Division: 19, 20. *See also* Mine Warfare Operations Research Group
Bureau of the Budget: 56
Bush, Vannevar: 24, 28, 30, 38, 40, 70
and autonomy of American scientists: 16, 17, 29, 43, 64
heads Joint New Weapons and Equipment Committee (JNWEC): 61
creates Office of Field Service: 17
on OA for ground forces: 36, 37
and OR in Army and Navy: 25
chairs National Advisory Committee for Aeronautics: 14
chairs National Defense Research Committee: 14
relations with Navy: 29
chairs Research and Development Board: 61

California Institute of Technology: Project VISTA: 135
and Institute for Defense Analyses: 61
Cameron, Dr. Robert H.: 147
Camp, Glen D.: 106
Canada: 105, 157, 158
Canadian Army Operational Research Establishment (CAORE): 105
at Royal Military College, Kingston: 62
and Tripartite Conferences: 62
CAORE. *See* Canadian Army Operational Research Establishment
Caribbean Defense Command: 24
uses ASWORG: 49*n226*
Caribbean Sea Frontier: and ASWORG: 48*n173*
Carmonette (wargame): 115, 130*n340*
Carnegie Institution: 14
Case Institute of Technology: and Institute for Defense Analyses: 61
and OR as a discipline: 107, 120
Casebook on Revolutionary Warfare, A: 111
Casey, Maj. Gen. Hugh J., USA: 38
Castra (field camp): 4
Catapults: 3
Cavity magnetron: 14, 45*n68*
CCORG. *See* U.S. Army Chemical Corps Operations Research Group
CDEC. *See* U.S. Army Combat Developments Experimentation Center
CDTEC. *See* U.S. Army Combat Developments Test and Experimentation Center
CENTAUR (wargame): development of: 119
Center for Army Analysis: 131*n393*
Center for Naval Analyses: administered by Franklin Institute: 122
contract with University of Rochester: 132*n443*
CGSC. *See* U.S. Army Command and General Staff College
Chadsey, Charles P.: 107
Charles, Archduke: 4
Chase, Dr. Martin N.: 154*n73*
Chennault, Maj. Gen. Claire L., USAAF: 50*n257*
Chess: as wargame: 113
Churchill, Winston: scientific collaboration with the U.S.: 14
Circular error probable: 5, 7*n18*, 51*n330*
Civil Defense Administration: 91
Clark, Dr. Dorothy Kneeland: 67, 97
Clark, Gen. Mark W., USA: 139, 154*n65*
Clarke, Gen. Bruce C., USA: 154*n65*
Clarkson, James A.: and bombardment accuracy: 32
Clausen, Svend: 3
Clausewitz, Carl von: 3, 4, 5
The Principles of War: 7*n10*
On War: 7*n10*
Cockcroft, John: 45*n66*
Cody, Donald D.: 21
Cole, Dr. Hugh M.: 41, 92, 97
Cole, I. H.: 10
Collbohm, Franklin: and RAND Corporation: 60
and Project RAND: 59
Collins, Gen. James Lawton, USA: 76, 108:
orders formation of Combat Development Group: 135
and study of Negro manpower in Army: 101
"Colossus" (computer): at Bletchley Park: 111
Columbia Research and Development Corporation: 83
Columbia University: 107
contract with ASWORG: 28, 51*n280*, 57
contracts with Navy: 21, 42, 57
contract with OSRD: 28, 48*n197*
and OR as a discipline: 107
Combat Developments Command: 122, 148, 151, 155*n14*
Combat Developments Element: structure: 135-36: *See also* Office of the Chief of Army Field Forces; Combat Development Group
Combat Developments Group: established, 135: renamed: 136. *See also* Combat Development Special Section
Combat Developments Planning Guide (OCAFF): 135
Combat Developments Special Section: projects of: 136
Combined Intelligence Office Survey: 34
Commission on Organization of the Executive Branch of the Government. *See* Hoover Commission
Committee for the Scientific Study of Air Defence: *See* Tizard Committee
Committee for the Scientific Survey of Air Warfare: 43*n5*
Committee on Medical Research: 15, 56
Committee on Operations Research: 107
Committee on Postwar Research (Wilson Committee): 56
COMPLAB. *See* Computing Laboratory
Compton, Dr. Karl T.: 16, 33, 53*n378*
creation of OSRD: 17, 37
on OR sections and field research groups: 17-18, 29
visits Headquarters, Southwest Pacific Area: 38
and Pacific Branch-OSRD: 38, 46*n97*

Computer Concepts, Inc: development of CENTAUR: 119
develops FORTRAN: 119
Computers and wargaming: 85, 111-119
development of: 111-13
linear programming: 112
matrix generation: 112
and Operations Research Office: 114, 115
simulations: 112, 115
and wargames: 115
Computing Laboratory (COMPLAB): part of Strategic Division, ORO: 114-15
Conant, Dr. James B.: 15
establishes American office for scientific research in London: 15
leads delegation to Great Britain: 14
chairs National Defense Research Council: 14
supports OR program in U.S.: 16
CONARC. *See* U.S. Continental Army Command
Concentration, principle of: 5
Concept Analysis Agency: 131*n393*
Connor, John T.: 122
Contribution to the War Game, A (von Verdy du Vernois): 113
Copell, D. F.: 38
CORG. *See* U.S. Army Combat Operations Research Group
Council of National Defense: 14
Covington, O. M.: 34
Craig, A. T.: 47*n167*
Crawford, Dr. Meredith Pullen: 108, 109, 129*n236*,*n238*
Crawford, Lt. Col. Roscoe C., USA: 49
CRD. *See* Department of the Army, Chief of Research and Development, Army Staff
Crozier, William J.: 32
Curtiss-Wright Corporation: 71-72

Da Vinci, Leonardo: 4
Dahl, Norman: 39
Daley, Lt. Gen. John P., USA: 145, 157
Daniels, Josephus: 5, 6
Danish Defense Research Establishment: 3
Darlington, Dr. Sidney: 37, 38, 53*n387*
Darwin, Dr. Charles G.: 15
Davidson, Dr. Ward F.: 11, 18, 30
prepares Leach-Davidson report: 25, 36, 48*n169*
Davies, Max: 107
Davis, Robert N.: first combat radar pictures: 32
Davison, Maj. Gen. Garrison H., USA: 138
DCSOPS. *See* Deputy Chief of Staff for Military Operations
Decision theory: 115
Decker, Gen. George H.: 116
Defense Dynamics: 3
Defense of the US Against Attack by Aircraft and Missiles: 100
Defense Research and Development Board: 64, 65
Defense Research Board (DRB): Canadian OR agency: 62
Defense Systems Division, General Motors Corp.: 118
Degaussing: 20, 46*n121*
Density method: 13, 42
Department of Defense: OR programs in: 60-62, 157
established: 56, 60, 61
funding: 85, 123*n4*
forms Joint Operations Research Group: 62
shift from ORO to RAC: 122
and Weapons Systems Evaluation Group (WSEG): 85, 105
Department of the Air Force: 62
Department of the Army: Ad Hoc Advisory Committee: 66
Advisory Committee for the Operations Research Office: 94
Army Regulation 15-480 defines Advisory Committee: 94
Office of the Chief of Research and Development: 94
Project Advisory Groups for the Operations Research Office: 94
Department of the Army Memorandum 3-50-2: creates Department of the Army Ad Hoc
Advisory Committee: 66
establishes General Research Office: 66
defines work program of Operations Research Office: 70
Deputy Chief of Staff for Military Operations (DCSOPS): 116
DeQuoy, Col. Alfred W., USA: chief of STAG: 116
Devers, Lt. Gen. Jacob D., USA: 37, 70
Dickins, Dr. B.G.: 10, 30
Directorate of Air Defense: 51*n281*
Directorate of Logistics Liaison: 145
Directorate of Plans and Operations, 145
Directorate of Technical Services: 25
DOD. *See* Department of Defense
Dolan, Col. W. C., USA: 21
Donovan, Grace: 67
Doolittle, Maj. Gen. James, USAAF: commander, Eighth Air Force: 51*n308*
Douglas, Donald: supervises Project RAND: 59
Douglas Aircraft: and establishment of RAND Corporation: 60
and Project RAND: 59, 64
Dowding, Air Chief Marshal Sir Hugh: 10, 12; OR study of aircraft transfer: 12, 45*n40*
Dowker, Clifford H.: develops position firing: 32
DRB. *See* Defense Research Board
Druckenbrod, W. F.: 83*n212*
Dubridge, Dr. Lee A.: 70, 135
Duggan, Stephen P., Jr.: 26
Duke University: and U.S. Army Office of Ordnance Research: 147
Dunlap and Associates: 72

Eaker, Lt. Gen. Ira C., USAAF: 30, 31, 32, 50*n258*, 51*n308*, 58

Earle, Dr. Edward M.: 27, 50*n253*
Eastern Sea Frontier: ASWORG personnel attached to: 48*n173*
Eckert, Dr. J. Presper, Jr.: designs ENIAC: 112
  designs UNIVAC: 112
Eddison, Roger T.: 107
Edgewood Arsenal: 149, 156*n192*
Edison: Thomas Alva: 7*n20*
  tactical board game: 6
  zigzagging: 6
Edlefson, Niels E.: 39
EDVAC (computer): 112
Eighth Air Force: 29, 30-31, 32, 51*n308*
  VIII Bomber Command: 26, 30, 31, 49*n266*
  VIII Fighter Command: 31, 32
Eighth United States Army (EUSA) in Korea: 86, 117-18
Eisenhower, Dr. Milton S.: 121
Eisenhower, General of the Army Dwight D., USA: 64, 70
Electronic Numerical Integrator and Calculator. *See* ENIAC
Electronics Laboratory: 114
Elmore, Lt. Col. Vincent M., Jr., USA: 82
Elwell, Lt. Col. R.E., USA: 37
Ely, Maj. Gen. William J., USA: 122
Engineer Development Board of the Chief of Engineers: 136
ENIAC: 112, 130*n280*
Enlightenment: 4
Ennis, Brig. Gen. William P., USA: 135
Ennis, Malcolm E.: 21
Epaminondas: 3, 6, 7*n14*
ERA (UNIVAC) 1103: 114
EUSA. *See* Eighth United States Army
Everitt, Dr. William Litell: 33, 34, 52*n337*, 150
Executive Order 8807: establishes Office of Scientific Research and Development: 15
Executive Order 9913: abolishes NDRC and Committee on Medical Research and Office of Field Service: 56

FABMDS. *See* Field Army Ballistic Missile Defense System
Fairchild Engine and Aircraft Corporation: 102
Fairchild, Brig. Gen. Muir, USA: 25
FAME (wargame): 115
Far East Command: and OR in Korea: 86
  and psychological warfare, 87
Farkas, Lucien: 34
Farmer, Lt. Col. W. C., USA: 66, 68, 82*n166*
Farwell, J. W.: 38
FASD. *See* Special Operations Research Office, Foreign Area Studies Division
Fell, Maj. Charles F.: 33
Fermi, Dr. Enrico: 70
Field Army Ballistic Missile Defense System (FABMDS): STAG develops wargame for: 118
"Field Manual 30-27: Regulations for Civilian Operations Analysts, Scientific Consultants, and Technical Observers Accompanying U.S., Army Forces in the Field": 27
Fields of Knowledge and Operations Research: 96
Fifteenth Air Force: 32
5th Infantry Division: 143
Firestone Tire and Rubber Company: 122
First Army: 34
First Ordnance Conference on Operations Research: 148
Floberg, John F.: 122
Flood, Dr. Merrill M.: 148
Flory, Brig. Gen. Lester DeLong, USA: 67, 82*n158*, 96-97, 103
Food and Container Institute: 109
Forbush, Scott: 19
Ford Foundation: and RAND Corporation: 60
Foreign Economic Administration: 82*n157*
Forrestal, James V.: 57, 77, 79*n67*
  first Secretary of Defense: 60
Fort Leslie McNair: houses Operations Research Office: 66, 97
FORTRAN: development of: 119
Foulis, Ronald J.: 26
Fourteenth Air Force: 32, 50
14th Anti-Aircraft Command: 37
Fowler, Ralph: 45*n66*
Fowler, William A.: and Project VISTA: 135
Fox, Robert A.: 34
France: OR groups: 128*n189*
Frankford Arsenal: 63, 147, 148, 159*n2*
Franklin, Benjamin: 4
Franklin Institute Laboratories for Research and Development: 72, 122
Free Kreigsspiel: 113, 114
Furer, Rear Adm. Julius A., USN: 21, 46*n113*
Furnas, C. C.: and Project VISTA: 135

Gadsby, G. Neville: 105, 106
Galilei, Galeileo: 4
Gaming Strategic Logistics: 116
Gardner, Dr. John H.: 72
Gates, Maj. Gen. Byron E, USA: 25, 27
Gates, Thomas S., Jr.: 85
Gavin, Lt. Gen. James M., USA: 102, 148
Gay, Herman: at Terminal Ballistics Laboratory: 63
General Research Office (GRO): 56, 65, 66
George Washington University: forms HumRRO: 108
"Get That Fighter": 32
Gilman: Col. Seymour I., USA: and Project ANALLA: 71
Glennan, Capt. J. B., USN: 19
Goggin, K. M. M.: 11
Goodeve, Sir Charles: 12
  forms Operational Research Club:107
Goodwin, Herbert F.: 38

Gordon, Dr. Cecil: develops planned flying: 11, 12-13
develops planned maintenance: 11, 13
forms Operational Research Club: 107
Great Britain: Admiralty: 11
air defense: 9
Air Ministry: 11
Army Operational Research Establishment (AORE): 106
Army Operational Research Group (AORG): 62
Ministry of Home Defense: 11
Operational Research Section, British Army of the Rhine: 106
Operational Research Unit, Far East: 106
operations research: 11-14, 107
radar: 9
Greece: 106
Green, Alexander: 32
Green, J. W.: 87
Griggs, H. P.: 83*n212*
GRO. *See* General Research Office
Gross, Dr. Paul M.: 161
Grubbs, Frank: 35
Guadalcanal: mining operations at: 20
Guerlac, Henry: 4
Gulf Sea Frontier: ASWORG personnel attached to: 48*n173*

Hafstad, Kay: 67
Hall, Capt. John M., USA: 28, 49*n232*: on training of analysts: 50*n270*
Haller, Raymond and Brown, Inc.: 150, 156*n205*
Handy, Gen. Thomas, USA: 97, 125*n73*
Hardick, Col. William L., USA: 139, 140
Harlan, John M.: 51*n302*
heads Eighth Air Force OA section: 29, 30, 50*n271*
Harlow Committee: and psychological warfare: 110
Harmon, Lt. Gen. Willard F., USA: 37, 53*n376*
Harrington, Maj., USA: 53
Harrison, Dr. George R.: 37, 53*n383*
Hart, Squadron Leader Raymund G.: 10
Harvard Mark I (computer): 111
Haworth, Dr. Leland J.: 136
Haworth Report: 136-37, 140, 155*n142*
and field experimentation: 142
and Project VISTA: 136
Hayward, Roger: develops position firing: 32
Hazleton, Sgt. Eileen, USA: 51*n311*
Headquarters, Allied Air Forces Central Europe: 106
Headquarters, Combat Developments Experimentation Command: 139
Headquarters, Commander SOUTH: 106
Headquarters, Eighth United States Army, Korea (HQ EUSAK): 86
Headquarters, Twelfth Air Force: ORO field office at: 106
Headquarters, U.S. Air Force Europe: Office of Operations Analysis at: 106
Headquarters, U.S. Army Europe: 106

Helwig, Master of Pages: and wargames: 113
Henderson, Lt. Col., USA: 39
Hennington, Howard H.: 21
Henry, Dr. James H., USA: and Project ANALAA: 71
Henry, Maj. Gen. Stephen G.: 36, 41, 46*n113*
Herring, Dr. Pendleton: 70
Hill, Brevet Major Archibald Vivian: 5, 6, 44*n25*
Nobel Prize, 7*n19*, 43*n4*
Tizard Committee: 10, 14
Hill, Dr. Floyd: 63
Hitch, Charles J.: 15, 60
Hobbs, Dean Marcus E.: 148
Hodge, Gen. John R., USA: 135, 154*n65*
Hoelscher, Leonard W.: and Project 80: 145
Hoffman, George: 128*n198*
Hoisington, Dr. Laurence E.: 19
Holley, I. B.: 59
Holst, Helge: 39
Hoover, Dorothy: 82*n147*
Hoover, Herbert: 79
Hoover Commission: 60, 61, 79*n68*
second: 79*n68*
Horne, Vice Adm. Frederick J., USN: involvement of civilians in sensitive military work: 19
Horvath, William J.: 128*n218*
Housner, George W.: 32
Hovde, Frederick L.: 15, 45*n70*
Howard, Royal V.: 34
Howze Board: 161
HRAF. *See* Human Relations Area Files
Hubbard, E.B.: 37
Hull, Capt. George D., USN: 20
Hull, Lt. Gen. John E., USA: 61
Hulme, H. R.: studies Atlantic convoys: 13
Human Relations Area Files (HRAF): Army contract with: 110
Human Resources Research Office (HumRRO): 108-10, 121, 122, 129*n236*, 152, 157
and *AR 70-8: RESEARCH AND DEVELOPMENT—Human Factors and Social Science Research*: 109
and *AR 70-31*: 109
creation of: 133
field research laboratories: 109
financing: 109
at George Washington University: 108, 109
"An Integrated Program in Human Resources Research" 108
mission of: 108-109
organization of: 109
personnel: 109, 120
Project DESERT ROCK: 109
publications of: 109
supervision of: 108
and TRAINFIRE I AND II: 110
and university contracts: 158

HumRRO. *See* Human Resources Research Office
Hunsaker, Jerome C.: 46*n79*
Hutchinson, Dr. Miller Reese: 7*n20*

I Bomber Command: 21, 49*n226*
IBM: 111
  model 1401: 119
  model 7090: 119
ICR. *See* Johns Hopkins University Institute for Cooperative Research
Illinois Institute of Technology: and OR as a discipline: 107
Imperial College of Science and Technology: 10
INDIGO (wargame): 115
INFORMS. *See* Institute for Operations Research and Management Sciences
Institute for Operations Research and Management Sciences (INFORMS): 108
Institute for Defense Analyses: 61, 118
Institute of Management Sciences, The: 107, 108
Institute of Radio Engineers: 52*n337*
Instructions for the Representation of Tactical Maneuvers under the Guise of a War Game (von Reisswitz the Younger): 113
Integrated Combat Development Systems: 133, 134
"Integrated Program in Human Resources Research, An": 108
Interior lines: principle of, 5
International Business Machines Corporation . *See* IBM
International Public Opinion Research, Inc.: 72, 126*n129*
International Symposium on Military Operational Research: 128*n216*
Italy: 4, 106

Janney, Stuart S.: 92
Jansky, Cyril Moreau, Jr.: 24, 26, 30, 33, 34, 49*n206*
  defines operational analysis: 24
  "Memorandum on Operational Analysis in the War Department": 24
  recommends OA include land forces: 36
Japan: defeat of Imperial Navy: 32: wargaming at Total War Research Institute: 113
Jewett, Dr. Frank B.: 17, 24, 33, 46*n79*, 52*n337*
JNWEC. *See* Joint New Weapons and Equipment Committee
Johns Hopkins University, The: 75, 86
  Committee on Sponsored Research: 70
  and Department of the Army: 64-66, 69, 70, 86, 87
  Institute for Cooperative Research: 65, 66, 67, 92
  and Navy's Applied Physics Laboratory: 65
  and OR as a discipline: 107, 120
  and Operations Research Office: 46n121, 56, 68, 92-94, 97-98, 105, 120, 122
  forms trustees committee for ORO: 92
Johnson, Dr. Ellis A.: 70, 72, 74, 82*n147*, 92, 107, 128*n218*, 134, 139
Johnson, Dr. Ellis A.—*Continued*
  and Army Operations Research Office: 46*n121*, 63, 73-75, 76, 97-98, 104
  and basic research: 83
  and computers: 118
  relationship with Johns Hopkins: 121
  and Korea: 86
  and mining: 19, 20, 21, 74, 130*n316*
  "murder boards": 102
  naval commission of: 20, 47*n144*
  and growth of OR: 86, 106, 107, 123, 142
  personality of: 87
  and Plans and Operations Division: 76
  formation of Review Committee: 70
  and XXI Bomber Command operations: 47n160
  and need for interaction between military and civilian OR analysts: 94, 96
  on wargames: 115
Johnson, James W.: 87
Johnson, Louis A.: 79*n67*
Johnson, Lt. Gen. Harold K., USA: 138
Johnstone, Dr. J. H. L.: 62
Joint Chiefs of Staff: 16
  and Vannevar Bush: 18
Joint New Weapons and Equipment Committee: 16, 18
  and Joint Operations Analysis Committee: 26
  Weapons Systems Evaluation Group (WSEG): 47*n165*
  Bush heads: 61
  members: 18
  and OR: 18: 25
  and coordination of OSRD and military: 18
Joint Operations Research Group: 62, 76
Joint Research and Development Board: 81
Jomini, Baron Antoine-Henri: 4, 5, 6: *Précis de l'art de la guerre*: 7*n10*
Journal of the American Chemical Society: 156*n192*
Journal of the Operations Research Society of America, The: 107, 125*n64*

Kane, Col. T. J., USA: 148
Kant, Immanuel: 4
Karman, Dr. Theodore von: 59
Katcher, David: 19
Kelly, Maj. Edward G., USA: 124*n15*
Kendall, Willmoore: 73
Kendrew, John C.: 11
Kennedy, John F.: 161
Kepner, Maj. Gen. W.E., USAAF: 32
Kilgore, Senator Harley: 78*n7*
Killian, Dr. T. J.: 148
Kimball, George E.: 57, 128*n218*
  Methods of Operations Research: 58
  and search theory: 22
King, Fleet Admiral Ernest J., USN: 22, 57
King, Robert W.: 36

"King's Game" (wargame): 113
Kip, Arthur F.: 47*n167*
Kissinger, Henry A.: 97
Klopsteg, Dr. Paul E.: 37, 39
Knott, Widnell D.: analyst killed in action: 32
Knox, Frank: 22
Koopman, Bernard O.: and search theory: 22
"A Quantitative Aspect of Combat": 48
Search and Screening: 58
Kroeger, Dr. William J.: 64

Laboratories for Applied Sciences, University of Chicago: 118
Lamar, Edward J.: 22
Lanchester, Frederick William: 3, 5, 6, 7*n14*
principle of concentration: 5
N^2 Law: 5, 48*n191*
Lanchester Prize: 107
Lane, Lt. Col. Jack F., USA: 150
Lang-Brown, Hilary: 11
Larnder, Harold: 10, 12, 44*n16*, 45
Larsen, Finn J.: 122
Larson, Brig. Gen. Westside T., USAAF: 21
Lathrop, John B.: 128*n218*
Lauristen, Charles C.: and Project VISTA: 135
Lawrence, Dr. E. O.: 70
Leach, Col. Walter Barton, USAAF: 12, 18, 25, 30, 31, 34, 36, 37, 39, 44*n31*, 73
serves on Advisory Committee on Bombardment: 27
availability of information: 27
and OAD: 26, 49*n234*, 58
personnel and salaries: 27-28, 29, 30, 43, 47*n166*
views on postwar OA: 58
Leach-Davidson Report: 24-25
on British OR sections: 44
on civilian analysts: 28
employment policies for analysts: 49*n208*; 50*n276*
recommendations of: 25, 26, 49
Lee, Rear Adm. W. A., Jr, USN.: on Joint New Weapons and Equipment Committee: 16, 18
Leet, Dr. L. D.: and Moreland mission: 53*n392*
LEGION (wargame): 119
and Booz-Allen Applied Research analysts: 119
and Computer Concepts Inc.: 119
FORTRAN: 119
IBM 1401: 119
Leibler, Dr. Richard A.: on STAG Advisory Council: 118
LeMay, Lt. Gen. Curtis, USAF: and low-level night bombing: 47*n160*, 59, 60
LEO (computer): 112
Levinson, Dr. Horace: 107, 128*n218*
Livermore, Maj. W. L., USA: *The American Kriegsspiel*: 114
LOGSPIEL Group (Logistics Division, ORO): 115-16
Gaming Strategic Logistics Studies: 116
Londonderry, Lord: 9
"Lord Tiverton's system of Bombing": report to Air Board: 5
Louis XIV: 4
Louisiana Polytechnic Institute: 71
Lowry, Philip H.: 118
Lusitania: 5

MacArthur, Gen. Douglas, USA: 40, 53*n389*
offensive mining operations: 20
requests research section: 37
Macdonald, Charles B.: 92
Machiavelli, Niccolò: 4
Magnuson, Senator Warren: 78*n7*
Mahan, Dennis Hart: 5
Management Control Division, Air Staff: OAD created in: 25, 26
Marcellus, Marcus Claudius, 3
Maris, Maj. Gen. Ward H., USA: 94
on Ellis Johnson: 74
Marquat, Maj. Gen. W.H., USA: 37
Marquis, Dr. Donald: 70
Marsh, Harold N.: establishes Special Services, Inc.: 28
Marshall, Dr. Lauriston: 39, 40
experience with Vannevar Bush: 40
Marshall, Gen. George C., USA: 27, 97
Army reorganization: 78*n32*
and OA for ground forces: 36, 37
Marshall, S. L. A.: 87
Pork Shop Hill: 87
The River and the Gauntlet: 87
Marshall, Sam W.: 124*n15*
Mason, Dr. Edward: 70, 71
Massachusetts Institute of Technology. *See* MIT
"Mathematics and War" (conference): 3
Mauchly, Dr. John W.:
designs ENIAC: 112
designs UNIVAC: 112
McAuliffe, Gen. Anthony, USA: 71, 149, 156*n192*
and development of Army R&D program: 64, 65
on basic research and operations research: 65
R&D experience of: 81n116
McCain, Adm. John S., USN: 47*n132*
McCarthy, Phillip J.: 47*n167*
McClelland, Brig. Gen. Harold M., USAAF: 21, 25, 30
McCloskey, Joseph F.: 21
on density method: 13
McCormack, Gen. James, Jr., USA: 122
McIntyre, J. T.: 83
McKeehan, Cdr. L. W, USN.: 19
McKibben, Wayne E.: 72
McNamara, Robert S.: 146, 161
Project 80: 145
Meade, Col. Frank C., USA: 33
Meals, Dr. Donald W.: 154*n73*
Medical Department Field Laboratory: 109
Meffling: Field Marshal: and wargames: 113
"Memorandum on Operational Analysis in the War Department" (Jansky): 24

Menzies, Wing Commander A. C.: 12, 26
Merck & Company: 122
Merriam, Col. Lauren W., USA: 140, 154*n74*
Merton, T. R.: 43*n4*
Methods of Operations Research (Morse and Kimball) 58
Michels, Dr. Walter: 19, 47*n132*
Midwest Research Institute: 72
Militaire (Wilhelm): 130*n305*
Military District of Washington: 94
Military Operations Research Society: 82*n155*, 108, 120
Military Systems Engineering, Bell Telephone Laboratories: 118
Millikan, Clark B.: and Project VISTA: 135
Milly, Dr. George H.: 150, 156*n192*
Mine Research Unit. *See* Naval Ordnance Laboratory
Mine Warfare Operations Research Group (MWORG): 18-21, 47
  and Bureau of Ordnance Research Division: 18, 19
  degaussing: 20
  mines: 19, 20, 21
  and Naval Ordnance Laboratory: 19
  personnel: 48*n197*
Ministry of Aircraft Production (Great Britain): Telecommunications Research Establishment: 11
Ministry of Home Defense (Great Britain): operations research: 11
Miser, Hugh J.: 159, 159*n20*
MIT: 122
  contract with Navy: 57, 64
  and Institute for Defense Analyses: 61
  and OR: 107, 120
  Radiation Laboratory at: 15
  Sloan School of Management: 128*n220*
  contract with WSEG to provide scientific personnel: 61
Model, Field Marshal Walther: and wargaming: 113
Mogensen, A. H.: 38
Moltke, Count Helmut von, the Elder: and wargames: 113
Montague, Maj. Gen. Robert M., USA: 139, 140, 142, 154*n66*
Montgomery, Field Marshal Bernard Law: 14, 36
Moreland, Dr. E. L.: on state of Japanese science: 38
Moreland mission: 53*n392*
Morganstern, Oskar: *Theory of Games and Economic Behavior*: 130*n312*
MORS. *See* Military Operations Research Symposia
Morse, Dr. Philip M.: 21, 22, 47*n165*,*n167*, 57, 80*n74*, 148, 158
  heads ASWORG: 21, 29
  heads Operations Research Group: 57
  president Operations Research Society of America: 47*n156*, 107, 128*n218*
  and WSEG: 61
MORU. *See* Great Britain
Moses, Brig. Gen. Raymond, USA: 16, 18
Mottley, Charles M.: 128*n218*
Mutual Defense Act of 1949: 72
MWORG. *See* Mine Warfare Operations Research Group
N^2 Law: 5
NAS. *See* National Academy of Sciences
National 4-H Club: and Operations Research Office: 97
National Academy of Sciences (NAS): 15, 46*n79*, 52, 56*n337*
National Advisory Committee for Aeronautics (NACA): 14, 15, 46n79
National Bureau of Standards: 107
National Defense Research Committee (NDRC): 14, 15-18, 23, 32
  abolished: 56
  Applied Mathematics Panel of: 17, 30, 36
  Vannevar Bush chairs: 14
  created by Council of National Defense: 15
  data access: 18
  divisions: 15, 17, 21, 32, 156*n192*
  London liaison office: 15
  and Office of Scientific Research and Development: 15
  personnel: 15, 21, 29, 30, 43
  training relationship with ORB OCSigO: 34
National Military Establishment: 60
National Physical Laboratory (Great Britain): 10, 15
National Research Council (NRC): 28, 46*n79*, 147
  Committee on Operations Research: 56, 78*n10*, 107
National Science Foundation: 56: proposed: 78*n7*
National Security Act of 1947: 77
  and Air Force: 78*n32*
  creates Central Intelligence Agency: 60
  creates Department of Defense: 55-56, 60
  recognizes Joint Chiefs of Staff: 60
  creates National Military Establishment: 60
  creates National Security Council: 60
  establishes Research and Development Board: 61
National Security Act of 1949: 61
National Security Council: 60
National War College: 57
NATO: Advisory Panel on Operational Research: 128*n191*,*n216*, 157
  Advisory Group on Aeronautical Research and Development (AGARD): 106
  members establish OR organizations: 106
  RAND Corporation representatives to: 106
Naumann: *Das Regiments-Kreigsspiel*: 113
Naval Consulting Board: 5, 6, 7*n20*
Naval Ordnance Laboratory (NOL): 15, 47*n132*
  hosts military operations research symposium: 108
  Mine Research Unit: 19
  mine warfare: 130*n316*
  and wargaming: 19
Naval Postgraduate School: 107
Naval Special Projects Office: 118
Naval War College: 57, 114
Navy Special Devices Center: Army element at: 109
NDRC. *See* National Defense Research Committee
Nettleton, Douglas: 41
Neumann, Dr. John von: 19, 112, 130*n312*

Newmark, Nathan: 26, 39
Ney, Virgil: CORG analyses: 142
Nichols, Thomas S.: 92
Nicholson, George E., Jr.: 128*n218*
Nimitz, Adm. Chester A., USN: 20, 38
Ninth Air Force: 31, 32
Ninth Army: 34
IX bomber Command: 32
NME. *See* National Military Establishment
NOL. *See* Naval Ordnance Laboratory
Nolan, Joseph E.: 26
Norstad, Gen. Lauris, USAF: on OR: 106
"Note on Certain Aspects of the Methodology of Operational Research, A" (Blackett): 13
North Atlantic Treaty Organization. *See* NATO
Norway: OR groups: 128*n200*
Noyes, Dr. William Albert, Jr.: 149, 156*n192*, *n195*
NSA 1947. *See* National Security Act of 1947

O'Connell, Lt. Gen. James D., USA: 151
O'Meara, Brig. Gen. Andrew P., USA: 104
OAD. *See* United States Army Air Force, Operations Analysis Division
OAO. *See* Operations Analysis Office
Oblique order: 3, 7*n14*
OCAFF. *See* Office of the Chief of Army Field Forces
OCNO. *See* Office of the Chief of Naval Operations
OCRD. *See* Office of the Chief of Research and Development
ODF. *See* Operational Development Force
OEG Report 51. See Antisubmarine Warfare in World War II
OEG Report 54. See Methods of Operations Research
OEG Report 56. See Search and Screening
OEG. *See* Operations Evaluation Group
Offensive mining: 20
Office of Defense Mobilization: 91
Office of Field Service (OFS): 29, 38, 37
  demobilization of: 55, 56
  established: 17, 29, 46
  mission of: 17
  and Navy: 17
  personnel: 17, 18, 29
  projects of: 17
  and Signal Office, Southwest Pacific Area: 38
Office of Naval Research: 129*n232*
  and military OR symposium: 108
  and Operations Evaluation Group: 57
Office of Scientific Research and Development (OSRD): 16, 18, 23, 29, 30, 37, 46*n97*
  Administrative Order No. 1: 15
  Advisory Council: 18
  contract with Columbia University: 22
  demobilization of: 55, 56
  established: 14, 15
  and Office of Field Service: 17, 46
Office of Scientific Research and Development (OSRD)—*Continued*
  Pacific Branch: 38, 40
  personnel: 15, 18, 42, 43
  role in development of OR: 15-18
Office of the Chief of Army Field Forces (OCAFF): 64, 86, 133, 136, 139, 140
  defines combat developments: 134
  Combat Developments Group: 135
  Combat Developments Planning Guide: 135
  personnel: 153*n26*, *n38*
  and U.S. Continental Army Command (CONARC): 137
Office of the Chief of Naval Operations (OCNO): 19, 20, 62
Office of the Chief of Ordnance: 148
Office of the Chief of Psychological Warfare: 129*n254*
Office of the Chief of Research and Development (OCRD): and Army Research Office: 94, 111, 148, 157, 159*n2*
Office of the Chief of Special Warfare: 129*n254*
Office of the Chief Signal Officer: 150
Office of the Deputy Chief of Naval Operations for Fleet Operations and Readiness: New Developments and Operational Evaluation Subsection of: 57
Office of the Deputy Chief of Staff for Military Operations: and Foreign Area Studies Division, Special Operations Research Office: 111
Office of the Deputy Chief of Staff for Operations: Special Warfare Directorate: 129*n254*
Office of the Deputy Chief of the Air Staff for Research and Development: supervises Project RAND: 59
Office of the Director of Special Weapons Development: 135
Office of the Quartermaster General: 94, 109
Office of the Secretary of Defense: 62
Office of War Information: 82
OFS. *See* Office of Field Service
Olmstead, Maj. Gen. Dawson, USA: 33
On War (Clausewitz): 7*n10*
101st Airborne Division Artillery: 81
OOR. *See* U.S. Army Office of Ordnance Research
Op Annies. *See* Operations Analysis Division
Operation BARBAROSSA: and wargaming: 113
Operation Research Branch, Office of the Chief Signal Officer (ORB OCSigO): 33-34
Operation SEALION: and wargaming: 113
Operation STARVATION: 20, 21, 47*n158*
Operational Analysis Branch, Signal Section, HQ European Theater of Operations: 34 Operational Development Force (ODF): 57
"Operational Research" (Blackett): 107
Operational Research Club: 107
Operational Research Quarterly: 107
Operational Research Section Air Defense of Great Britain. *See* Operational Research Section Royal Air Force Fighter Command

Operational Research Section, British Army of the Rhine: 106
Operational Research Section, Headquarters Pacific Ocean Area: 38-40
Operational Research Section, Royal Air Force Anti-Aircraft Command (Blackett's Circus): 13
Operational Research Section, Royal Air Force Bomber Command : 11, 13
Operational Research Section, Royal Air Force Coastal Command: 11, 12, 15, 22
  planned flying: 12-13
  planned maintenance: 13
  studies: 12, 13
Operational Research Section, Royal Air Force Fighter Command: 11, 12, 13, 24
Operational Research Society: membership: 107
  publishes *OR Insight*: 107
Operations Analysis Division (OAD): 23, 25, 26-27, 58
  civilian analysts (Op Annies): 26, 28
  formation of: 25-26, 29
  functions of: 26, 27
  independent of OFS: 29
  organization: 29
  personnel: 27-29, 55
  relations with OSRD: 29-30
  technical training for: 30; *See also* United States Army Air Forces
Operations Analysis Office: 59
Operations Directorate of the Air Force: 59
Operations Evaluation Group (OEG): 22-23, 57, 62, 105
  contract with Columbia University: 42
  established: 57
  mission of: 57
  contracts with MIT: 55
  postwar staff reductions: 55
  personnel: 57
  projects of: 57-58
  publishes reports: 58
  postwar reductions, 55
  and Second Tripartite Conference: 62
  supervision of: 57
Operations Research Group (ORG): 22-23, 57
  subgroups: 57. *See also* Anti-submarine Warfare Operations Research Group
Operations Research Office (ORO): 62, 64, 66, 85, 86-92, 94, 96-97, 101, 105, 110, 120
  and Army Ad Hoc Advisory Committee: 70
  balanced program: 98, 99
  BRAND: 88, 92, 99
  closing: 120-22
  computers: 114, 115
  finances: 68-70, 98, 101
  and The Johns Hopkins University: 56, 87, 88, 92-94, 120
  role of E. Johnson: 66, 67, 73-75, 86
  methods: 133
  mission: 66, 87
Operations Research Office (ORO)—*Continued*
  organization: 67-68, 88-92
  personnel and training: 66-67, 94-97, 105, 119-20, 124*n27*, 127*n184*
  physical facilities: 97-98
  project advisory group (PAG): 70, 83*n179*
  projects of: 66, 70-73, 86, 87, 90, 98-104
  and STAG: 117
  quality of studies: 102-104
  search studies (PISGAH conferences): 99, 105
  and wargaming: 99, 115. *See also* under individual projects
Operations Research Society of America (ORSA): 47*n165*, 78*n10*, 107, 108, 120, 128*n218*, 157, 159*n20*
  publishes *Journal of the Operations Research Society of America*: 107
Operations Research Steering Committee: 148
Operations Research Technical Assistance Group (ORTAG): 148
Operations Research: 128*n220*
Oppenheimer, J. Robert: and Project VISTA: 135
OPSEARCH Group (Strategic Division ORO): 115, 126*n117*
  develops value theory: 115
ORB OCSigO. *See* Operation Research Branch, Office of the Chief Signal Officer
ORG. *See* Operations Research Group
ORO. *See* Operations Research Office
ORS RAF. *See* Operational Research Section, Royal Air Force
ORSA. *See* Operations Research Society of America
ORTAG: *See* Operations Research Technical Assistance Group
OSRD. *See* Office of Scientific Research and Development

Pace, Frank, Jr.: 99, 108, 135
Pacific Warfare Board: 53*n390*
PAG. *See* Operations Research Office, Project Advisory Group
Page, Dr. Thornton L.: 15, 47*n144*, 82*n155*, 106, 107, 125-26*n94*, 128*n218*
  and mine warfare: 19, 20, 130*n316*
  and NATO: 106
  and unidentified flying objects: 97
Palembang Harbor, Sumatra: mining of: 20
Panama Canal Zone: defense of: 24
Parker, Charles A.: 24
Parker, Frank A., Jr.: 122
Parmenter, Dr. Richard: 96
Paxson, Edward: 128*n198*
Payne, Dr. Wilbur B.: 97
Pearman, J. P. T.: and ASWORG: 22
PEGASUS (computer): 130*n286*
Pellam, John R.: 47*n167*
Pennsylvania State University: and OR as a discipline: 107
Pentomic army: 101, 151, 157
Perera, Col. Guido R.: 27

Pettee, Dr. George S.: 67, 82, 96, 100
Phalanx: 3
Phillip II of Macedon: 3, 4, 6
Physical Review: 15
Picatinny Arsenal, 147, 159*n2*
Pickering, J. H.: 122
Piedem, Margaret: 41
Pinkerton, John: 112
PISGAH Conferences: 99, 105
Pittman-Dunn Laboratories: 63, 64
Planned flying: 11, 12-13, 42, 45*n44*
Planned maintenance: 11, 13, 42, 45*n44*
Planning Research Corporation: 158
Plans and Operations Division, Army General Staff: 76, 83
Pogue, Forrest C.: 92
Popper, Karl, 3
Pork Chop Hill (Marshall): 87
Position firing: developed: 32
Powell, Gen. Herbert B., USA: 154*n65*
Pratt, Edmund T., Jr.: 134
  "Challenges in Army Operations Research": 161
Précis de l'art de la guerre (Jomini): 7
Preliminary Design of an Experimental World-Circling Spaceship (RAND Corp.): 60
Priestley, Joseph: 4
Princes Risborough. *See* British Ministry of Home Security Research
Princeton University: Institute for Advanced Studies: 27, 28
  Station: 30
Principles of War, The (Clausewitz): 7*n10*
Project 80: recommends United States Army Combat Development Command: 145
Project ALCLAD: 72, 101
PAG for: 83*n179*
Project ANALAA: 71, 98
Project ARMOR: 73, 98
Project ATTACK: 73, 98
Project BALANCE: 98
Project CAPWAR: 98
Project COBRA: 98
Project DESERT ROCK: 109
Project DONKEY: 73
Project DOUGHBOY: 98
Project EVANAL: 71, 72
Project EXPLOIT-USSR: 111
Project GUNFIRE: 72
Project LEGATE: 98
Project MAID: 71, 72, 84, 110, 126*n108*
  and Mutual Defense Act of 1949: 72
Project MICHIGAN: 153*n37*
  and Combat Development Special Section: 136
Project PARABEL: 98
Project PINPOINT: 141
Project POWOW: 71, 73, 98, 110, 129*n234*
Project PROPIN: 111
Project PROSYMS: 111
Project RAND: 59-60, 62
  converted to RAND Corporation: 55
  divisions: 59
  and Douglas Aircraft: 59, 64
  established: 55
  financing: 69
  Military Advisory Group: 60
  staff of: 59
Project REDLEG: 72, 98
Project SALVO: 102
Project SHOP: 98
Project SITE: 73, 129*n234*
Project TACIT: 98
Project TEAM: 73, 98, 129*n234*
Project TRAINFIRE I and II: 110
Project TREMABASE: 73, 98
Project VISTA: 134-35
  calls for development of Combat Development Group: 135
  and field experimentation: 142
  studies land and tactical air warfare: 134
  and U.S. Army Combat Developments Command: 145
psychological warfare: 87, 98, 101, 110, 124*n27*

"Quantitative Aspect of Combat, A" (Koopman): 48
Quartermaster Climatic Research Laboratory: 109
Quimby, Lt. Cdr. Shirley, USN: 19, 20, 47*n144*

RAC. *See* Research Analysis Corporation
Radar: 9, 12, 14, 45*n43*
  National Defense Research Committee Division on: 14, 15
  and origins of operational research, 9-10
Radar Operators and Maintenance School: 34
Radiation Laboratory, MIT: 34, 37, 45*n68*
  contractor for National Defense Research Committee Division: 15
  and training for OAD personnel: 30
Radio Research Laboratory, Harvard University: 30, 34
RAF. *See* Royal Air Force
RAND Corporation: 60, 77, 80*n74*, 105, 147
  and Air Force OR program: 122
  areas of research: 60
  divisions: 60
  establishment of: 60
  and NATO: 106, 128*n198*
  critique of ORO: 100
  personnel: 60
  develops SAWSPIEL wargame: 115
  and Second Tripartite Conference: 62
  and ZIGSPIEL: 115
Rau, Erik Peter: 17, 24, 25, 29, 43
RDB. *See* Research and Development Board
Readiness Division, Headquarters, Commander-in-Chief: 22

"Recollections of Problems Studied, 1940-1945" (Blackett): 12
Redstone Arsenal: 147
Regiments-Kreigsspiel, Das (Naumann): 113
Reinke, Leonard H.: and target analysis: 32
Reisswitz the Younger: and charts for wargames: 113
  Instructions for the Representation of Tactical Maneuver under the Guise of a *War Game*: 113
Reisswitz, Baron von: and sand tables for wargames: 113
Remington Rand: produces UNIVAC 1103: 112
Rendel, James M.: 11
Renola, Lt. Col. Raymond, USA: 82*n166*
Research Analysis Corporation (RAC): 82*n158*, 85, 118, 152, 157, 159*n2*
  expands OR applications: 133
  formation of: 86, 87, 120, 122
  funding: 157
  refines methods: 133
Research and Development Board (RDB): coordinates military R&D programs: 61
Research Office Experimentation Center (ROEC): 152, 157, 159*n2*
  liaison with OR agencies: 144
  personnel, 144, 145
  responsibilities of: 144, 145. *See also* United States Army Combat Developments Experimentation Center
Research Section, General Headquarters, Southwest Pacific Area: 37-38, 53*n392*
Review of a Battalion of Infantry (Smirk): 130*n305*
Richardson, Lt. Gen. Robert C., USA: 38, 40, 53*n396*
  and "balanced team" of OR and OFD experts: 39
Rigid Kreigsspiel: 114
Rinehart, Robert F.: 47*n167*, 128*n218*
River and the Gauntlet, The (Marshall): 87
Rives, Col. Thomas C., USA: 33
Roberts, G.A.: 10
Robertson, Dr. H. F.: 106
Robertson, Howard P.: 51*n302*, 80, 125*n94*. 153*n17*
  and Project VISTA: 135
Robertson, John M.: 11
Rock Island Arsenal: 147, 150
ROEC. *See* Research Office Experimentation Center
Roosevelt, Franklin: scientific cooperation with Great Britain: 14
Root, Elihu, Jr.: 27
Rowe, A.P.: 9, 10, 11
Royal Air Force: Air Ministry: 9, 10, 13. *See also* under individual units
Royal Army: 11, 13
Royal Australian Air Force: 20, 44
Royal Canadian Air Force: 44, 62
Royal Canadian Navy: 62
Royal Military College (Canada): 62
Royal Navy: 21
  anti-submarine warfare studies: 13
Royal Navy —*Contiuned*
  Atlantic convoy studies: 13
  Blackett and: 13
  civilian analysts: 13
  operations research: 11
  studies of: 13
Royal Society: 11, 107
Ruark, Dr. Arthur E.: 65
  on Operations Research Office: 68-69, 82,150
Ruffner, Maj. Gen. Clark L., USA: 40
Rumbaugh, Lynn H.: 19, 67, 82, 99, 121, 130*n316*
Rumbough, Maj. Gen. William S., USA: 34
Ruppenthal, Roland: 92
Russell, J. A.: 38
Rutherford, Lord: U-boat campaign: 5

SADU. *See* Sea Search and Development Unit
Sargeaunt, H. Anthony: 106, 127*n184*
Sarissa: 3
Saville, Col. Gordon Philip, USAAF: 24, 25, 45*n74*
  observed OR and Battle of Britain: 15
SAWSPIEL (wargame): 115
SCEAG. *See* Signal Corps Evaluation and Analysis Group
Schechter, George: 63, 64
Schlieffen Plan: and wargaming: 113
Schonland, Brig. B. F. J., USA: 21
"Science in World War II": 45*n77*
Scientists Against Time (Baxter): 45*n77*
"Scientists at the Operational Level" (Blackett): 11, 15
Sea Search and Development Unit: unit of Army Air Forces: 21
Search and Screening (Koopman): 58
Search theory: 22, 42, 48*n190*
Second Air Division: 32
Second Allied Tactical Air Force: 106
Secretary of War Administrative Order No. 50: 29
Selected Bibliography on Counter-Unconventional Warfare A: 111
Service Bureau Corporation: 118
Service Squadron Six, Pacific Fleet: 20
Seventh United States Army: 81
SHAPE. *See* Supreme Headquarters Allied Powers Europe
Shimonoseki Straits: aerial mining of: 20
Shockley, Dr. William Bradford: 19, 21, 22, 47-48*n167*
Shortley, Dr. George H.: 67, 148
Signal Corps Evaluation and Analysis Group (SCEAG): 151, 156*n207*
  and Combat Operations Research Group: 151
  directed by Haller, Raymond and Brown, Inc.: 150
  and Plans and Operations Division: 150
  and pentomic Army: 151
Simon, Lt. Col. L. E., USA: 35
Simplified War Game, A (von Verdy du Vernois):114
Sixth U.S. Army: 143
Skifter, Dr. Hector R.: 122
Smallwood, Hugh M.: 128*n218*

Smeby, Lynne C.: 34, 52*n343*
Smirk, Robert: *Review of a Battalion of Infantry*: 130*n305*
Smith, Rear Adm. William Strother, USN: 7*n20*
Snow and Schule: 72
Social Relations of Science Movement: 44
Solandt, Omand: 127*n1*
SORO. *See* Special Operations Research Office
Southwest Pacific Area. *See also* Research Section, General Headquarters, Southwest Pacific Area
Spaatz, Lt. Gen. Carl: 3, USAAF1: commander, Eighth Air Force: 30
Spangenberg, Karl R.: 34
Sparrow, Col. Herbert G., USA: 154*n74*
Special Operations Research Office (SORO): 108, 109, 110-11, 121, 122, 152, 157, 159*n2*
  American University: 110
  and *Army Regulation 70-8*: 111
  and *Army Regulation 70-32: Special Warfare Non-Materiel Research*: 111
  establishment of: 133
  nonprofit: 110
  organization: 110-11
  personnel: 120
  and psychological warfare: 101
  supervision of: 111
  university contracts, 158
  work program of: 111. *See also* under individual projects
Special Regulations No. 705-5-5: Research and Development—Operations Research Office: 66
Special Services, Inc.: 28
Speier, Hans: 60
STAG. *See* U.S. Army Strategy and Tactics Analysis Group
Stanford Research Institute: 71, 72, 83*n212*, 122
  contract with CDEC: 144, 146
  funding: 157-58
  personnel 145
Stanmore Research Section: 10-11, 12, 13
  radar development at: 14: *See also* Operational Research Section, Royal Air Force
  Fighter Command
Stark, Adm. Harold, USN: 15
STEADFAST: reorganization: 155n178
Stearns, Robert L.: 53*n376*
Stein, Arthur: on Ballistics Research Laboratories: 35
Steinhardt, Jacinto: 57, 128*n218*
Stephan, Frederick: 128*n218*
Stephens, Roderick: 39
Stephenson, Dr. H. Kirk: 37, 38
Sternhell, Charles M.: *Antisubmarine Warfare in World War II*: 58
Stevens, Robert T.: 110, 136
Stimson: Henry L.: 18, 24, 27, 36
Strategic Air Command: OAO at: 59
Strategic bombing study: 5
Strategos (wargame): 114
STRATSPIEL Group (Strategic Division ORO):115
  and SAWSPIEL wargame: 115
Street, W. G.: 83*n212*
Supreme Headquarters Allied Powers Europe: 106
Swift, Maj. Eben, USA: and wargaming: 114
Synthetic Tactics system (SYNTAC): wargames: 118, 142

TACSPIEL Group (Tactics Division, ORO): Carmonette: 115
  FAME: 115
  and tactical battle simulation: 115
Tannewald, Theodore, Jr.: 27, 50*n251*
Tate, Dr. John T.: 15, 21
Taylor, Col. George W., USA: 148: develops position firing: 32
Taylor, Jean G.: 67
Taylor, Lauriston S.: 31, 55
Technical Council, 124*n37*
Technical Operations, Inc.: 122, 144
  runs Combat Operations Research Group: 121, 140
  funding: 157
Teeter, John: 34
Telecommunications Research Establishment: 44
TELLSPIEL Group (Intelligence Division ORO): INDIGO (wargame): 115
Tenth Fleet: supervises ASWORG: 22
10th Regimental Combat Team: supports Combat Developments Test and Experiment Center: 143
Terminal Ballistics Laboratory. *See* Ballistics Research Laboratories
Test and Evaluation Command: 148
Tevis, Graham L.: 24
Theory of Games and Economic Behavior (von Neumann and Morganstern): 130*n312*
Theory of mining: 21
Thiesmeyer, Lincoln R.: *Combat Scientists*: 45*n77*
Third Army: 34
Thirteenth Air Force: 32, 53*n376*
Thompson, Dr. L. T. E.: 118
Thorndike, Alan M.: *Antisubmarine Warfare in World War I*: 58
Thorndike, Albert: 47*n167*
Thrall, Dr. Robert M.: 148
Tiverton, Lord: 5, 6
Tizard, Sir Charles: forms Operational Research Club: 107
Tizard, Sir Henry E.: 10, 11, 14, 16, 43*n4*, 44*n25*, 45, 66
Tizard Committee on Air Defense: 10, 14
Tizard Scientific Mission: 14
Totten, Lt. C. A. L., USA: develops Strategos: 114
TRADOC. *See* U.S. Army Training and Doctrine Command
TRAINFIRE System: 101-102, 127*n141*
  I and II: 110
Transportation Board: 139
Transportation Combat Development Group: 139
Transportation Corps (TC): 151
  combat developments in: 139

Transportation Corps (TC)—*Continued*
Office of the Chief of Transportation: 139
and Transportation Research and Development Command: 139
and Transportation Research and Engineering Command: 139
and Transportation School: 139
and Transportation Training Command: 139
Tripartite Agreements on Army Operations Research: 62
Tripartite Conferences on Army Operations Research: 105, 127*n185*
first: 62
second: 62
fourth: 154*n73*
Trudeau, Lt. Gen. Arthur G., USA: 155*n176*
on lack of timeliness of OR studies: 103
Truman, Harry: prohibits racial discrimination: 101
Tufts University: and OR as a discipline: 107
Tulane University: and Institute for Defense Analyses: 61
Turkey: 106, 128*n198*
Tuttle, W. Norris: 51*n302*
Twelfth Army Group: 34
XX Bomber Command: 20, 32
mines Palembang Harbor, Sumatra: 20
21st Army Group (RA): OR section of: 14, 36
XXI Bomber Command: 47*n160*
Tyson, James K.: 47*n167*

U.S. Air Force: 55, 58-60, 91
U.S. Army Ad Hoc Advisory Committee: 70
U.S. Army Adjutant General's Office: commissioning of analysts: 50
Marshall Reorganization creates Service Forces: 32
Operations Research: 32-36, 62-77
pentomic organization: 101, 157
Personnel Research Section: 109
U.S. Army Air Defense: 157
U.S. Army Air Forces: 23-32
1st Anti-submarine Squadron: 22
aerial mining program: 20
airborne ASW: 21
Directorate of Air Defense: 21, 24, 26, 30, 36, 51*n281*
establishes Project RAND: 55
I Bomber Command: 21
Operations Analysis Division (OAD): 23, 25-32, 105
origins of OR in AAF: 24
personnel: 24, 50
retains most wartime analysts: 55
2d Anti-submarine Squadron: 22
Table of Organization and Equipment (TOE) for OA sections: 27
Watson-Watt recommendations: 24
U.S. Army Air Forces Anti-Submarine Command (AAF ASW): 21, 22
U. S. Army Air Forces Directorate of Air Defense: 21, 24, 26, 30, 33, 36, 51*n281*
U.S. Army Air Forces Operations Analysis sections: 21: accomplishments of: 31-32
U.S. Army Air Forces School of Applied Tactics: 34
U.S. Army CBR Combat Developments Agency: 159*n2*
U.S. Army CBR Operations Research Group: 159*n2*
U.S. Army Chemical Center. *See* U.S. Army Chemical Corps
U.S. Army Chemical Corps: 32, 35, 149-50, 152, 156*n192*
Chemical Board: 150
Chemical Corps Advisory Council: 149
Chemical Corps Operations Research Group (CCORG): 118, 149, 150, 157
Chemical Corps Research and Engineering Command: 149
Chief Chemical Officer: 149, 150
offices of: 150
Research and Development Program: 81n116, 150
U.S. Army Chemical Warfare Service. *See* U.S. Army Chemical Corps
U.S. Army Combat Developments Command: 138, 157
creation of: 145-46
mission of: 145
Research Office Experimental Command: 146
U.S. Army Combat Developments Experimentation Center (CDEC): 142-45
and CONARC General Order No. 39: 143-44
contractors from Technical Operations, Inc.: 144
Experimental Project Team: 145
mission: 143
personnel: 145
Research Office: 144
role of: 145. *See also* U.S. Army Combat Developments Command
U.S. Army Combat Developments Test and Experimentation Center (CDTEC): administered by Sixth U.S. Army: 143
established: 142, 143
10th Regimental Combat Team test unit for: 143
Research Office Experimentation Center (ROEC): 144
Research Office of the Test and Experimentation Center (ROTEC): 144
See also U.S. Army Combat Developments Experimentation Center
U.S. Army Combat Operations Research Group (CORG): 121, 122 139-42, 152, 152, 157, 159*n2*
departments: 140
Military Advisor Team: 140
mission of: 140
personnel: 140
Project PINPOINT: 141
publication of results: 142
reorganization of: 140
sections: 140
and Technical Operations, Inc: 121, 122, 140
work program: 140-41
wargaming: 142. *See also* U.S. Army Combat Developments Command

U.S. Army Combined Arms Group: 159*n2*
U.S. Army Command and General Staff College (CGSC): 138
Departments: 135, 138
study of very-long-range combat developments, 138
Office of the Chief of Doctrine: 138
U.S. Army Corps of Engineers: 151
U.S. Army Enlisted Scientific and Professional Personnel program: 150
U.S. Army Institute for Advanced Studies (USAIAS): and combat developments: 138
U.S. Army Intelligence Center: 153*n60*
U.S. Army Limited War Laboratory: 159*n2*
U.S. Army Logistics Management Center: 153*n60*
U.S. Army Material Command: 148, 155*n178*, 157
U.S. Army Medical Department. *See* U.S. Army Medical Service
U.S. Army Medical Service (AMEDS): 32, 36, 151
Combat Developments group: 151
Medical Research and Development Command: 156*n215*
U.S. Army Munitions Command: 150
U.S. Army Office of Assistant Chief of Staff: G-4, Logistics: 94
U.S. Army Office of Ordnance Research (OOR). *See* U.S. Army Ordnance Corps
U.S. Army Operational Research Group: 13
U.S. Army Operations Research Office: 63
U.S. Army Operations Research Symposium: 134, 148, 157
U.S. Army Ordnance Corps: 19, 32, 34-35, 52*n355*, 63, 109, 146, 152
Ballistics Research Laboratories (BRL), Aberdeen Proving Grounds: 34, 35, 147
and conferences: 105
contract with National Research Council: 147
Research Office: 105
establishes U.S. Army Office of Ordnance Research (OOR): 147, 148
Weapons Systems Laboratory: 35
U.S. Army Personnel Research Office: 159*n2*
U.S. Army Quartermaster Corps: 151
U.S. Army Reorganization Act of 1950: 101, 149
U.S. Army Research and Development Field Office. *See* U.S. Army Research Office (ARO)
U.S. Army Research and Development/Test and Evaluation: funds Special Operations Research office: 111
U.S. Army Research Office (ARO) 122
and *Army Regulations No. 1-110*: 148
disbanded: 155*n176*
established: 128*n2*, 148, 155*n176*
missions: 148
forms Operations Research Technical Assistance Group (ORTAG): 148
Research Planning Division of: 148
sponsors OR symposia: 148
U.S. Army School of the Line and Staff College: and wargaming: 114
U.S. Army Scientific Advisory Panel: 136, 148
U.S. Army Security Agency Board: 153n60
U.S. Army Signal Corps: 32, 109, 146, 150-51, 157
Operational Analysis Branch, Signal Section, HQ European Theater: 34
Operation Research Branch, Office of the Chief Signal Officer: 33-34
Radar Division: 33
Signal Supply Service: 33
training: 34
U.S. Army Staff of the Office of the Chief of Psychological Warfare: establishment of: 110
U.S. Army Strategy and Tactics Analysis Group (STAG): 117-18, 121, 122, 123, 157, 159*n2*
Advisory Council: 118
Booz-Allen Applied Research, Inc. contract with: 117
Field Army Ballistic Missile Defense System (FABMDS) wargame: 118
formation of: 116, 133
IBM 7090: 118, 119
Implementation Plan: 131*n353*,*n393*
mission: 116
Office of the Chief: 116
organization: 116
personnel: 117
and Service Bureau Corporation: 118
Staff Management Office: 116
wargames: 118, 119
U.S. Army Training and Doctrine Command (TRADOC) System Analysis Agency: 97
U.S. Army Transportation Corps Combat Developments Detachment: 139
sections within: 139. *See* Transportation Combat Development Group
U.S. Army War College: 104
Doctrine and Studies Division: 138
and very-long-range combat developments: 138
U.S. Army Weapons Command: 147, 159*n2*
U.S. Combat Developments Command: 157
U.S. Continental Army Command (CONARC): 117, 133, 137-38, 140
Combat Developments Section: 137
Combined Arms Agency: 138
Combined Arms Group (CAG): 138
and CORG study program: 149
established: 137
field experimentation center: 142
Material Development Section: 138
responsibilities: 137
hosts symposia: 108
and U.S. Army Combat Development Experimentation Center (CDEC): 143
U.S. Eighth Air Force: 21-22, 25, 29, 46*n89*
U.S. Element, Allied Commission in Austria: 97
U.S. European Command: 124*n49*
U.S. Army Finance Corps Field Service Board: 153*n60*

U.S. Naval Academy: 108
U.S. Navy: 41, 94
  Applied Physics Laboratory: 65
  contracts with MIT: 55
  Operations Research Group: 57
  personnel: 48*n173*
U.S. Navy Bureau of Ordnance: 15
U.S. Office of Scientific Research and Development: 41
U.S.S. *Hornet*: and mining operations: 20
U.S.S. *Terror*: and mining operations: 20
UCLA: and OR as a discipline: 107
Ulug, Col. Fuat: 106
United States Strategic Bombing Survey: works with Air Evaluation Boards: 27
UNIVAC: model 1103: 112, 114,130*n320*
  model 1103A: 114
  model I: 112
University of California-Los Angeles. *See* UCLA
University of Chicago: 73
University of Pennsylvania, Moore School of Engineering: OR training: 120
University of Rochester: contract for Center for Naval Analyses: 132*n443*
University of Washington: 72
USAIAS. *See* U. S. Army Institute for Advanced Studies
USSBS. *See* United States Strategic Bombing Survey
Utilization of Negro Manpower in the Army: 101

Value theory: 115
Vandiver, E. B., III: 82*n155*
Variable-time fuze: 14
Vauban, Sébastien Le Prestre de: 4, 6
Vernois, Col. Von Verdy du: *A Contribution to the War Game*: 113
Veth, Lt. Kenneth L., USN: 20
Vietnam War: 161
Vigneras, Marcel: 92
Vinturinus, Georg: and wargames: 113
VULCO: field experiments; 142

Waddington, Conrad H.: 11
Wallace, Lt. (jg) William F., USN: 20
Walter Reed Army Medical Center: 94, 151
Wansborough-Jones, Owen: 127*n184*
"War Can Be Calculated" (Clausen): 3
"War Cannot Be Calculated" (Bergstein): 3
War Chess, or The Game of Battle (Brewerton): 130*n305*
War Department: issues "Field Manual 30-27
  New Developments Division: 36, 40, 41, 46*n113*
  "Regulations for Civilian Operations Analysts, Scientific Consultants, and Technical Observers Accompanying U.S. Army Forces in the Field": 27
  Operations Division: 36, 49*n323*
War Plans Division, ODCSLOG: 159*n2*
War Production Board: 56, 82*n157*
Wargames: 19, 85, 113-16, 133, 158
Warner, Charles: 150
Waterman, Dr. Alan T.: 17, 29, 46
Watson, Alfred N.: 128*n218*
Watson, Henry H.: 106
Watson-Watt, Sir Robert: 10, 11, 24, 32, 44*n25*
Weapons Operations Research Division: 147
Weapons System Evaluation Group (WSEG): 56, 61, 62, 77, 80, 85, 88
Weapons Systems Laboratory (WSL): 147. *See also* individual arsenals
Weaver, Warren: 17, 30
Weikhmann, Christopher: and wargames: 113
Wein, Dr. Lawrence: 128*n220*
West, Gerald M.: 32
West, Julian N.: 118
Whitehead, J. H. C.: studies Atlantic convoys: 13
Whitmore, William W.: 26
Whitson, Dr. William: 67, 72, 139, 140
Wilbur B. Payne Memorial Award for Excellence in Analysis: 97
Wilcox, Dr. H. A.: 118
Wilhelm III of Prussia: and wargames: 113
Wilhelm, Prof. J. O.: 62
Wilhelm, Rev. *Militaire*: 130*n305*
Wilkinson, Roger I: 32
Williams, Eric: study of aircraft transfer to France: 10, 12
Williams, Evan J.: 11, 21
depth charge study: 13
Williams, John D.: and RAND Corp.: 60
Williams, Robert W.: 70: 92
Wilson, Caroll: 15
Wilson, Charles E.: heads Committee on Postwar Research: 56
Wilson, Dr. J. T.: heads Royal Canadian Army Operational Research Group: 62
Wilson Committee. *See* Committee on Postwar Research
Wimperis, H.E.: 9, 10, 43*n4*
Woodforde, J.: 10
Woodward-Nutt, A. E.: 45*n66*
World War I: 5
Wright Field Air Development Center: teaching OR: 107
WSEG. *See* Weapons Systems Evaluation Group
WSL. *See* Weapons Systems Laboratory
Wyman, Gen. William G., USA: 142, 143, 154*n65*

Yamato: 32
Yarnold, Kenneth W.: 73
Youden, W. John: 32, 51*n302*
Young, Dr. Donald: 70
Young, Lloyd A.: 128*n218*

ZIGSPIEL Group (Home Defense division, ORO): 115
Zimmerman, Richard E.: father of Army combat modeling: 97
  develops Carmonette: 130*n340*
Zornig, Col. H. H., USA: director, BLR: 35