# The Operations Evaluation Group

A History of Naval Operations Analysis

By Keith R. Tidman

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# Preface

The prime force behind the writing of this book was Dr. Bernard O. Koopman, who, as a member of the Operations Evaluation Group (OEG) during World War II, left a lasting imprint on operations research through his seminal work in search theory. While visiting the Center for Naval Analyses (CNA) in 1979, to give a talk on the principles of search, Dr. Koopman urged that OEG's history be written as soon as possible. He feared that with the passing of some of the key players, especially those whose affiliation dated back to World War II, a significant slice of OEG's institutional memory would be irretrievably lost.

Dr. Koopman's urgings found a receptive ear in Dr. Phil E. DePoy, the director of OEG, and Mr. David B. Kassing, then the president of CNA. Dr. DePoy and Mr. Kassing believed that, in view of the group's upcoming fortieth anniversary, the time for preparing a history of OEG was particularly ripe. The project was easy to justify on other grounds, too. First, OEG, now a part of the Center for Naval Analyses, is the oldest military operations analysis group in the United States, with its origins in the early days of America's involvement in World War II.

Further, OEG was a pioneer in developing or refining many of the methodologies that have long since become fundamental to operations research. At the time of OEG's founding in early 1942, operations research stood as an embryonic and arcane science. The group's early work—which helped remedy the relative obscurity of operations research, as well as its lack of a formal framework apart from the other sciences—resulted in such classical texts as Morse and Kimball's *Methods of Operations Research* (MIT and Wiley, 1951; originally OEG Report 54, 1946) and Koopman's *Search and Screening* (Pergamon, 1980; orginally OEG Report 56, 1946).

Also, for the first half of its history, OEG served as the navy's main—and, for many years, its only—civilian advisor engaged in operations research. OEG's history has therefore been wedded to the navy's history. Three wars, a variety of large and small crises, the threat posed by potential adversary nations, new technology, and realigned priorities and expectations within the navy itself demanded innovative thinking among OEG's ranks. How the group adjusted to these undulations is described in this book.

Research for the book began in early 1981, with some concern on my part that I would be stymied by yawning gaps in the records. On the contrary, I discovered that the archives at CNA were quite complete. These official records, of both an administrative and scientific nature, were supplemented by the contributions of some long-time members who were inveterate collectors of "paperwork" often not available in the files. In addition, I was made privy to the insights of past and present members who consented to be interviewed in order to provide background information on events.

Access to these various sources was made much easier by my being a member of OEG. Another advantage was my security clearance, which permitted me to search through the classified literature—though I should stress that the material in this book has been thoroughly reviewed for public release. One final advantage of this affiliation was my familiarity with the work OEG does in support of the Navy, which proved inordinately helpful in discriminating, from the outset, between important matters and probable blind alleys or trivia. I would like to underscore, however, that although the book was sponsored and reviewed by OEG, it is not an "official history," in the sense that that term is customarily used.

A few final words are in order concerning the scope of the project. First, because of OEG's historically prominent role in military operations research, the book necessarily represents more than a look at just one organization. A history of OEG is, by its very nature, also a history of a rather major cross-section of naval analysis in general.

Second, the book attempts to trace the scientific as well as the organizational history of OEG. Since the science was the means by which the group could fulfill its charter of helping to improve the effectiveness of naval forces, it merited careful coverage. Analyses that are representative of the operational problems faced by the fleets and that reveal something about how solutions were arrived at are discussed. I tried to keep the narrative as jargon-free as possible, yet substantive enough to interest the professional. This meant "talking around" information that was expressed mathematically in the original analyses—which would have been beyond the scope of this book, anyway—while endeavoring to retain the quantitative flavor of the work. No familiarity with the tools of operations research is required, therefore, to read those portions of the book.

It became apparent from the beginning that an account of OEG's history would have to be related to the many world events—the Battle of the Atlantic, the Korean War, the Soviets' first thermonuclear device, the Cuban missile crisis, the Vietnam War, for example—that had a bearing on the group's operations. In this historical context, it becomes easier to understand changes in the direction of OEG's analysis and in its organizational structure.

One final note is necessary to explain a major administrative change that occurred while this book was in production. In May 1983, the navy notified the University of Rochester that it had elected not to renew Rochester's contract for the management of CNA. Instead, the navy wished to open the contract to competition. Universities (including Rochester) and nonprofit organizations were therefore invited to submit bids. On 4 August, the Department of the Navy announced that the Hudson Institute, a nonprofit research organization founded in 1961, had been awarded the contract for management of CNA, effective 1 October 1983.

I am greatly indebted to many people whose support proved indispensable over the course of writing this book. Foremost is Dr. DePoy, who gave me the opportunity, in the first place, to write the book. Dr. DePoy, along with Dr. Jamil Nakhleh, OEG's deputy director, provided me with the needed encouragement and made it possible to set aside my normal duties so that I could devote myself fully to the history. I would also like to extend a collective thanks to those who took time out of their busy schedules to share their reminiscences with me or to search out material they felt might add an important dimension to the history. Though too numerous to cite by name in their entirety, they include the former directors of OEG: Professor Philip M. Morse (the founder and director of OEG's World War II progenitor, the Antisubmarine Warfare Operations Research Group), Dr. Jacinto Steinhardt, Dr. Joseph H. Engel, Dr. James K. Tyson, Mr. Ervin Kapos, and Dr. Daniel B. Rathbun. (The one name missing from this list is Dr. Erwin Baumgarten, who died in 1972.)

I also wish to acknowledge the assistance provided by Ms. Cynthia Barry, who edited the manuscript; Ms. Durinda Suttle, who did the typesetting; Mrs. Andree Lanser, who drew the illustrations; and Mrs. Delia Hoover, who typed the draft manuscript. A final thanks goes to Mrs. Linda Dennis, who came into OEG in order to perform my regular duties while I was working on the book.

# The Operations Evaluation Group

# Introduction

> Science is contributing so liberally to every department of knowledge . . . that it seems only natural and reasonable that we should call science to our aid to lead us to a clearer comprehension of naval warfare.
>
> Rear Admiral Stephen B. Luce

In February 1942, four U.S. destroyers—*Edison, Nicholson, Lea,* and *Bernadeau*—were instructed to rendezvous with convoy ON-67, just south of Iceland, and escort it westward toward Halifax. What ensued, however, underscored many of the shortfalls bedeviling American antisubmarine operations at that early stage of the war.

Although all four destroyers were outfitted with radar, only the *Nicholson's* was working. It was this one escort that finally located the thirty-five-ship convoy, but only after some difficulty and a full day later than planned. Shortly thereafter, in the early evening of 21 February, the rescue ship *Toward*—not one of the destroyers—monitored the high-frequency signal of a U-boat prowling nearby. The commander of the escort group, Commander A. C. Murdaugh, ordered the *Lea* to run down the bearing. The *Lea* complied for about an hour, whereupon, in accordance with the antisubmarine doctrine of the time, she broke off the search even though she had failed to make contact with the enemy. Ten hours after the *Lea* had rejoined the other escorts, the U-boat's presence was confirmed. Two ships of convoy ON-67 were torpedoed and sunk.

Yet another search for the trailing submarine produced nothing, despite the prevailing feeling that the convoy was still being shadowed. Then, during the night of 23 February, four more merchant ships were sunk. Later the next day, the high-frequency direction finder on the rescue ship *Toward* intercepted more signals, prompting Commander Murdaugh to order the *Lea* and *Nicholson* to search the area. Two U-boats were subsequently spotted idling on the surface, about fifteen miles ahead of the convoy. Standing instructions, however, prevented the destroyers from going after the U-boats, because of the range.

To make matters worse, Commander Murdaugh was required to get permission from Washington before he could alter the disposition of his forces or the direction of the convoy. On 24 February, for example, Murdaugh had to wait seven hours to receive approval from the Chief of Naval Operations on a 68-degree change of course he had requested because of the enemy's relentless pursuit. Even after the radical course change, the U-boats clung to the convoy. In fact, two U-boats were sighted by the *Edison*—one of which was only a couple of hundred yards away—but they were not harmed by the depth-charge attack mounted against them.

ON-67 finally reached Halifax without further losses. Still, it was evident that too much had gone wrong with the entire operation. Only one of four radars worked, and even that failed to make contact with the surfaced U-boats, probably because of inadequate operator training. The *Lea's* initial search, required by set doctrine to last no more than an hour, was far too short. Also, the inability of the destroyers to make contact with the U-boats once their presence had been confirmed by high-frequency intercepts spotlighted the need to use sonar more effectively.

Particularly glaring was the excessive rigidity of the instructions that guided the prosecution of contacts, to the extent that even two sighted U-boats escaped being pursued. The failed depth-charge attack by the *Lea* demonstrated the need for improved attack procedures. Finally, reliance on direction from Washington stifled any hope of ingenuity or quick reaction by the escort commander. A much more aggressive yet flexible antisubmarine doctrine was called for if the U-boat menace was to be beaten back. Furthermore, new equipment was being developed and put in the field all the time, emphasizing the need for new tactics to ensure its most effective use.

Just a month after the harrowing episode involving convoy ON-67, a group of civilian scientists was assembled to help the U.S. Navy deal with the kind of operational problems experienced by Commander Murdaugh's force. The embryonic group flourished during the war and in the years following, to become today's Operations Evaluation Group (OEG). Now an integral part of the Center for Naval Analyses, OEG is the oldest military operations research organization in the United States, and one of the oldest in the world.[1]

Since its inception in April 1942, OEG has been doing analytical studies of naval operations.[2] The key to understanding the role of OEG is to distinguish between the research and development of new military systems and the evaluation of the operational employment of existing systems. OEG is involved in the latter, that is, in helping the navy derive the most effective and efficient use of the forces at hand and on which navy policy makers will have to rely for the next several years.

In short, OEG is engaged in operations research. Specifically, it helps design and analyze fleet exercises on the basis of carefully developed objectives and measures of effectiveness; assesses the capabilities of new equipment in a rigorous operational environment; evaluates actual operations; helps develop and evaluate tactics to improve the operational effectiveness of available systems; and determines force requirements for the near future. In performing these activities, OEG's province spans the spectrum of naval warfare—in the air, on the ocean surface, or under water.

Although OEG's scientists are civilians, they work closely with the operational commands of the U.S. Navy. Indeed, over half of OEG's professional staff is assigned to naval commands throughout the United States and abroad. This close relationship with the people conducting the operations has been essential to the group's effectiveness. First, it means that much of the analysis can be done right where it is most needed and can do the most good—not in some ivory-tower setting. Furthermore, it means that essential information—no matter how sensitive—has generally been accessible as needed. Third, proposed solutions to operational problems have more readily been communicated to and implemented by those in command. Finally, the impact of change wrought by OEG's efforts can be evaluated in an operational environment, ensuring greater realism.

Before going on, however, let's turn our attention to events that antedate OEG and, for that matter, the science of operations research in general.

### Science in War

History attests to the fact that scientists were cultivated by military and political leaders long before OEG—or any other formal defense research organization—came into being:

> Science and warfare have always been most closely linked; in fact, except for a certain portion of the nineteenth century, it may fairly be claimed that the majority of significant technical and scientific advances owe their origin directly to military or naval requirements.[3]

In large measure, the application of science to the conduct of war before the twentieth century involved developing new devices or upgrading old ones ("gadgeteering"). Nonetheless, some scientists did touch on what today would be called operations research. A few may even be credited with setting the stage for the kind of operations analyses now taken for granted by governments and defense officials throughout the developed world.

One of the earliest scientists to concern himself with military affairs was the Greek mathematician Archimedes. Although he held his numerous mechanical contrivances in low esteem—refusing, even, to document them—he captured the world's imagination by their ingenious design. His involvement in defense issues centered around a series of devices he designed for Hieron II, king of Syracuse, in the third century B.C. Hieron made use of these devices to help hold the Romans at bay during their three-year siege of Syracuse. The most talked-about device consisted of convex glass mirrors designed to reflect sunlight at the Roman ships, setting them on fire. The effectiveness of the contraption has surely been greatly exaggerated by the more romantic historians. Despite Archimedes' efforts, Syracuse fell to the Roman general Marcellus in 212 B.C. A fate rare to today's defense analysts, Archimedes was stabbed to death during the ensuing rampage, contrary to orders by Marcellus. (The death of Archimedes evoked perhaps the first recorded expression of appreciation from a military man to a scientist, for Marcellus is said to have mourned the loss of Archimedes and paid lavish tribute to him, even though they had opposed one another.)

In the late fifteenth and early sixteenth centuries, Leonardo da Vinci distinguished himself not just by his remarkable artistic skills but also by his science. In a letter to Lodovico Sforza, the ruler of the principality of Milan, he expressed his willingness to satisfy whatever needs Sforza might have for devices of war: mortars, mines, catapults, and "other machines of marvelous efficacy not in common use."[4] Some of the "other machines" for which he is noted include tanks, submarines, and multibarreled guns. At about the same time (in 1529), Michelangelo, renowned today for the considerably more tranquil pursuits of sculpting and painting, was placed in charge of the fortifications of the Florentine Republic, to help defend the city against an attack by the combined forces of the pope and the emperor of Spain.

Many scholars of the Renaissance likewise furthered the cause of science in military affairs. One of these, Sébastien Le Prestre de Vauban, marshal of France, served as a highly influential military engineer during Louis XIV's reign. His contributions were not restricted, however, to new forms of weapons technology; rather (and more important to our purposes), they also profoundly altered tactical doctrine.

France was fighting to strengthen the borders of the territory claimed by the king. Hence, enemy fortresses first had to be taken, and then bolstered (reequipped and redesigned) to deter their being taken back by the enemy. Vauban's talent lay in his ability to devise ways to achieve these two goals. One of his better-known tactics was successfully applied at the siege of Maastricht in 1673. There, he designed trenches that ran parallel to the perimeter of the fortresses and that were linked by other trenches laid out in a zigzag formation. This innovative disposition of attacking forces offered improved protection against the defenders' artillery fire.

Two other ways in which Vauban influenced doctrine are worth noting. First, during attempts by French troops to take Valenciennes in 1677, he persuaded Louis XIV—despite contrary advice from most other royal advisors—to try an assault by day. The suggestion was considered radical at the time because assaults had nearly always been conducted at night. Nighttime operations, however, had often resulted in attacks on their own forces. The advice bore fruit: Valenciennes collapsed and Vauban received another grant. Finally, in 1688, during the war of the Grand Alliance, Vauban proposed a way to make cannonfire more effective. A cannonball was to be fired such that it would richochet forward, hitting several targets before coming to rest—a seventeenth-century version of getting the most out of the forces at hand. Vauban's indefatigable efforts, documented in a series of technical treatises, stand as an early example of what today has become the commonplace role of the scientist at the operational level.

Little more than two centuries later, World War I, largely because of dramatic changes in weaponry, was pivotal in rallying scientists around the military. The value of aircraft, for example, quickly became apparent, despite an insistence by many authorities—among them, the French military leader Marshal Ferdinand Foch—that it was little more than a frivolous machine. Although planes did not attain the importance they were to gain in World War II, they did support army and naval operations by attacking supply lines and reconnoitering. Also, the tank, first seen on the battlefield in the Somme area in September 1916, was soon recognized as at least a partial solution to the barbed wire, gun nests, and trenches that characterized World War I. Then, of course, there was the submarine, skillfully employed by Germany to apply a stranglehold on Britain's overseas supplies through a campaign of unrestricted warfare. Although Britain, at the start of the war, actually owned more submarines than Germany (thirty-six versus twenty-eight), it was Germany that opted to accelerate production of the submarine and to enhance its capabilities.

Also in World War I, true military operations research emerged. At first pursued informally—and with little influence on real operations—operations research began to stir interest in scientific circles on both sides of the Atlantic. In England, Frederick W. Lanchester was exploring ways to express military operations by mathematical means. The kind of resistence he ran into, however, is illustrated in the following lament:

> There are many who will be inclined to cavil at any mathematical or semi-mathematical treatment of the present subject [the practice of warfare], on the ground that with so many unknown factors, such as the morale or leadership of the men, the unaccounted merits or demerits of the weapons, and the still more unknown "chances of war," it is ridiculous to pretend to calculate anything. The answer to this is simple: the direct numerical comparison of the forces engaging in conflict or available in the event of war is almost universal. It is a factor always carefully reckoned with by the various military authorities . . . . Yet such direct counting of forces is in itself a tacit

> acceptance of the applicability of mathematical principles, but confined to a special case. To accept without reserve the mere "counting of the pieces" as of value, and to deny the more extended application of mathematical theory, is as illogical and unintelligent as to accept broadly and indiscriminately the balance and the weighing-machine as instruments of precision, but to decline to permit in the latter case any allowance for the known inequality of leverage.[5]

Undaunted, Lanchester developed interesting quantitative analyses, relating victory to the superiority of numbers and firepower and to the concentration of forces. He is perhaps best remembered for his "square law," from which it can be deduced that a tactical or strategic use of concentration (of forces) may outweigh any advantages acquired from modest improvements in weapons efficiency. As a mark of the times, his efforts had no bearing on the actual conduct of the war then engulfing Europe.

In America, Thomas A. Edison was likewise pioneering military operations research, as chairman of the newly formed Naval Consulting Board. By the time the board was created in July 1915, the United States had already suffered a serious erosion of its sense of security. The situation had worsened on 4 February 1915, when Germany declared that "every enemy merchant ship found in [the waters around Great Britain and Ireland] will be destroyed without its always being possible to warn the crews or passengers of the dangers threatening.... Neutral ships will also incur danger in the war region, where, in view of the misuse of neutral flags ordered by the British Government, and incidents unavoidable in sea warfare, attacks intended for hostile ships may affect neutral ships also." A month later, German submarines summarily sank three merchant ships. Then, on 7 May, the Cunard passenger liner *Lusitania* was torpedoed. Of the 1,198 who perished, more than 120 were Americans, enraging the American public. Protests brought about a calling-off of the unlimited U-boat campaign only temporarily.

It was clear by this time, then, that the United States should improve its defensive capabilities, particularly in light of the role of science and invention in the war. Secretary of the Navy Josephus Daniels decided to form an organization that would serve as a catalyst for inventive ideas on the conduct of the war. The organization was to consist of civilian scientists whose sole responsibility (all previous duties were suspended) would be to conjure up inventive ideas of their own or to assess the practicality of ideas submitted by the general public.

At its organization meeting on 7 October 1915, at the Navy Department, the group became officially known as the Naval Consulting Board of the United States. Secretary Daniels persuaded Thomas Edison to be its head. He emphasized, however, that it was Edison's genius he wished to tap, not his abilities to administer or preside. In addition, he asked the presidents of each of the seven largest engineering societies in the United States to choose two members to join the board, ensuring nonpartisanship and an interdisciplinary flavor. At a meeting on 4 November at India House, New York, the board was divided into several committees: Chemistry and Physics, Aeronautics, Mine and Torpedoes, Submarines, Ordnance and Explosives, Wireless and Communications, and others. This arrangement enabled the scientists to gravitate to their areas of strength and interest and to better organize their efforts.

An Act of Congress on 29 August 1916 (seven months before the United States entered the war) made the board official, granting it $25,000 to run its operations for the fiscal year ending 30 June 1917.

Numerous technical problems were tackled that proved the board's worth. Examples of areas addressed by the board include the navy's switch from coal-fired to oil-fired ships, the need for an improved underwater listening device for use by merchant ships in locating enemy submarines, and improved optics for range finders. Edison's attention, however, soon turned to issues of a clearly operational nature. Specifically, he decided that killing submarines was only one way to help protect merchant shipping and that he would try to suggest safer ways for merchant ships to go about their business.

Edison thought he should begin by analyzing the successes scored by German submarines. He was disappointed to find, however, that the government's data were incomplete; among other shortcomings, the records lacked charts of the sinkings. Undeterred, Edison and three assistants labored around-the-clock in the summer of 1917, to research the information they would need for their studies.

Edison's review of the newly organized data and the accompanying charts revealed several pertinent points. First, merchant ships were using the same routes during the war as they had before the war, even though losses were high.[6] Just as important, at least 94 percent of the losses occurred during the day. This fact was made even more significant by the observation that no ships had been sunk during nighttime transfers of troops between England and France. Finally, Lloyd's Register showed that only a few (4 percent) of Britain's merchant verssels carried up-to-date listening devices to detect U-boats and even fewer carried radios.

Edison concluded that merchant ships would be safer if they made just three changes in their pattern of operations: venture into high-risk regions only under cover of night; use new routes; and take refuge during daylight hours in shallow waters (such as ports) that would prevent the approach of submerged enemy submarines.

To better understand the threat posed by submarines to merchant shipping in waters around Britain, Edison developed a simulation technique. He began by preparing a chart of those waters, which he segmented into forty-mile squares. The size of the squares was dictated by the distance at which a submarine located at the center could see smoke coming from the funnel of a merchant vessel. At the center of each square was a hole in which a peg (representing a ship or a submarine) was placed. One player would use his pegged board to maneuver a given number of vessels into various ports without being detected. An opposing player would use a separate pegged board to position a given number of submarines, with the purpose of thwarting the vessels heading for port. If a vessel entered a square in which a submarine was stationed, it was considered sunk. Use of these boards showed that by far most of the ships could safely reach port. Closely associated work by Edison dealt with assessing the value of zigzag maneuvers by merchant ships in high-risk parts of the ocean. He concluded that such maneuvers were unproductive for ships traveling at less than 10 knots, because they extended the time required to deliver the cargo.

Beyond the actual results of these efforts lies the noteworthy fact that the work may justly be characterized as operations research. It was, after all, analysis conducted on the basis of operational data. Yet, despite the importance of Edison's work to the evolution of operations research, his findings had little influence on naval operations at the time. The foremost reason has to be that Edison, as with all the members of the Naval Consulting Board, had virtually no access to operational personnel, through whom recommendations could have been channeled. This sharply contrasts with the experience of military analysts since World War II (especially those of OEG), who have nurtured close ties with the operational commands. Also, of course, operations research was a little-known and poorly understood science that still lacked credentials.

In spite of what appeared to be a fairly good start to operations research in World War I, little was ventured after the war until Europe again found itself embroiled in conflict. In the interim, the only scientific analysis conducted for the U.S. Navy consisted of whatever scientifically trained officers found time to perform. These officers—notably Admirals Lee, Parsons, and Blandy—contributed in a major way to the navy's preparedness. Yet two circumstances hampered their efforts. First, these officer-scientists were aided by only a handful of volunteers, many of whom were inadequately trained. Second, their other responsibilities as naval officers took priority over analysis.

By the start of the second world war in 1939, the scientific method had attained full acceptance as a military tool, particularly in England. Albert P. Rowe, superintendent of the Bawdsey Research Station, had already demonstrated an interest in the use of civilian scientists to help fill the needs of the military in, for example, radiolocation. To this end, Rowe joined forces with Wing Commander R. G. Hart to form a research group at headquarters of the Fighter Command, RAF, at Stanmore. As it turned out, Bawdsey became the center of radar development and the seminal force behind modern operations research.

The overriding goal at Bawdsey was to find a way to detect enemy air forces earlier and, even more important, to shorten the time between early warning of an enemy raid and the placement of defenses. The network of radar stations being set up to provide early warning of air attacks was to be integrated into the existing Observer Corps that had been responsible for sighting, identifying, and reporting enemy aircraft. Rowe chose G. A. Roberts to study the system. By paying special attention to the efficiency of the communications system that linked the entire network, Roberts assumed the vantage point of someone (such as an executive officer) responsible for the *entire* network. In typical operations research fashion, he took into account the interrelationship of components rather than focus on individual pieces of hardware. At the same time, another scientist, E. C. Williams, analyzed why some of the radar stations performed better than others, even when tested by identical operations. He subsequently uncovered defects in the network and, as an extra measure, proposed improved operator techniques that would provide greater uniformity of efficiency among the ever-increasing number of operators.

Because of the value of Williams and Roberts's work to military operations, Rowe—whose Bawdsey organization had been renamed the Telecommunications Research Establishment—decided to pool the talents of these two scientists, under the direction of H. Larnder. The group immediately broadened the range of problems it was willing to investigate, studying, for example, the effectiveness of fighter aircraft engaging German planes at night. The ground control interception (GCI) system they suggested proved invaluable, making it possible to plot almost instantaneously the positions of a large number of enemy planes and to display the information on a scope. This small group set the tone for analyses by other scientists and prompted the Air Ministry to form many other such groups.

Operations research soon caught on in the British army. Antiaircraft guns at the time were equipped with radar that provided the bearing and slant range of enemy bombers and with sound-locating equipment that provided the altitude. This mix of paraphernalia, however, proved both awkward and inaccurate. Although a modified version of the GCI system was substituted, the accuracy of the guns remained quite poor. Adding to the confusion, the equipment would sometimes operate up to par while being tested, but function disappointingly in the field.

General Sir Frederick Pile, Commander in Chief of the Antiaircraft Command, decided to seek outside scientific help to solve the problem. Several civilian scientists were assembled in September 1940, under the direction of Professor P. M. S. Blackett of the University of Manchester, a Fellow of the Royal Society and former naval officer. To encourage a more rounded assessment of the problem, Blackett selected people of diverse scientific backgrounds—physicists, mathematicians, astrophysicists, physiologists, and so forth—but none of them was a radio specialist. The group, dubbed "Blackett's Circus," demonstrated the wisdom of such a mixed team for handling operational problems.

In March 1941, Blackett switched to the Coastal Command, where he worked in close contact with the Admiralty. With some other members of the Circus, he examined problems connected with the use of airborne radars to detect ships and surfaced submarines. In December, Blackett switched again, this time because of his appointment as director of Naval Operational Research at the Admiralty. In the meantime, other members of the Circus, plus some newly trained people, formed the Operational Research Group of the Air Defense Research and Development Establishment (later called the Army Operational Research Group). This meant that the operations research needs of all three of Britain's services were now being met to one degree or another.

In view of Blackett's enormous contribution to operations research, it is worth noting his paper, "Scientists at the Operational Level," written in 1941. Regarded as the cornerstone of modern operations research, the paper lays out reasons for assigning scientists to operational problems, underscores the value of the scientific method to the study of operations, and discusses the organization of operations research groups.

The civilian defense concerns of the Ministry of Home Security also became the object of operations analysis. Within the ministry was established the Civil Defense Research Committee, consisting of such distinguished scientists as Professor John D. Bernal. Bernal initiated a program to collect and study data on the effects of the heavy bombing being inflicted on Britain. Foreshadowing the way such efforts would be tackled in the future, the people assigned to the project were split between the field and a central office: 120 observers went out to collect the data, while 40 analysts remained at headquarters.

A major study at the time corrected erroneous estimates of the lethality of bomb explosions to human beings. The anatomist Professor Solly Zuckerman used the observed effects of explosions on animals (in experiments) and on people (in actual air raids) to increase fivefold previously accepted figures on the strength of blast a person could survive. He was also able to predict casualty and damage rates, given a particular number of bombs dropped in a specified area. Zuckerman's work was verified by Bernal and Dr. F. Garwood, who forecast the results of a raid by five hundred enemy bombers on a typical English town. Some time afterwards, Coventry was attacked by about five hundred bombers.[7] A survey of the city showed that Bernal and Garwood's estimates were quite accurate. These same predictive techniques were later used to analyze offensive operations, that is, the same kinds of estimates were made about the effects of bombing German sites.

Two other examples of Britain's successful wartime use of operations research should be mentioned. The first concerns the unsatisfactory performance of aircraft in attacks against U-boats. E. J. Williams, who had replaced Blackett at Coastal Command, found that although a submarine was attacked the moment it was spotted—which meant that it was still at or close to the surface—the depth charges being dropped were set to explode at one hundred feet. The submarine was therefore well out of the charge's lethal range. Coastal Command's rationale for the depth setting was that the submarine, upon sighting the plane, would have time to get deep—which, in fact, it did not. Analysis showed that in over half the attacks, the U-boat either was still visible at the time of the depth charge's release or had been submerged for just a few seconds. Given these findings, Williams determined that for maximum effect the depth charge should be set for twenty feet. Even though the charges at the time could be set for no less than thirty-five feet, the new setting at least quadrupled their destructive capability.

The last example deals with the loss of merchant ships, a concern of Thomas Edison twenty-seven years earlier. In 1942, convoys typically were composed of about forty ships, shielded by six escorts. Although losses were heavy, no additional escorts were available to help make screens around the convoys more impregnable. Hence, it was thought that the size of the convoy itself might have a bearing on its vulnerability. Indeed, records showed that between January 1941 and April 1943, convoys of fewer than forty-five ships averaged a 2.6 percent loss rate, whereas those of more than forty-five ships averaged a 1.7 percent rate. Since only the same number of U-boats—usually about ten—could be amassed to conduct a particular attack, no more damage could be inflicted on a big convoy than on a small one. The loss rate, meanwhile, could be reduced.

Britain's experience with operations research just before and early in the war encouraged the organizing of similar groups elsewhere, particularly in the United States. In fact, many of the scientific methods and the organizational philosophy employed by the British were to serve operations analysts for some time to come. Britain's experience demonstrated the superb effectiveness of employing civilian scientists—untrammeled by rank and staff obligations—to solve military problems. Also, the interdisciplinary approach enabled groups to assess problems from various angles. The establishment of field posts for contact with the real world and of a central office for theoretical analyses, consolidation of work done in the field, and administrative purposes seemed to work well. Of considerable significance, too, was that problems were studied not in isolation but in the context of other factors that impinged on the issue. This aspect of the new science of operations research was quite different from the methods that had been the staple of scientific researchers up to that period, as we shall see next.

## Operations Research: The Discipline

Operations research has perhaps best been described as a "scientific method of providing executive departments [in OEG's case, decision makers in the navy] with a quantitative basis for decisions regarding the operations under their control."[8] Two parts of this definition warrant further discussion. One is the phrase "scientific method," implying that operations research involves methodologies that scientists use to make sense of information that they or others have gathered regarding the systems and events of their interest. The raw ingredients are normally the observations of operations, recorded as unbiasedly and as quantitatively as possible. Once the data have been assembled in some scientifically palatable form, the analytical phase can begin. The process has been summarized as follows:

> The operational research worker must use both ingenuity and discrimination in seeking out his information and he must find some means of assessing the degree of certainty or the significance of every piece of information. He then submits this information to an exhaustive series of analyses to determine whether any patterns can be identified, or whether there is any interdependence or relationship between various quantities; here the mathematical methods of statistical analysis are frequently used.[9]

Part of this process involves modeling, by which the analyst constructs a mathematical representation of some operation. The aim is to model the way things work in the real world. The model is constructed to enable the analyst to substitute values for the different parameters, representing alternative conditions within the operation being studied. The analyst thus gains insight into how and why events occur as they do, and how changes might improve the conduct of a particular operation. Once this step has been achieved, it is then desirable to validate the conclusions by means of controlled tests that permit the analyst to check whether proposed improvements do indeed work in the real world.

This brings us to the second important component of our definition of operations research, namely, the decision makers. They are the critical link between the analyst's proposals and their implementation. In effect, they have the prerogative either to give life to the analyst's work or, alternatively, to consign the work to the files where it may never again see the light of day. Because the purpose of the effort is, of course, to improve (some say to "optimize"[10]) how things are done, it must inspire action. But this can be achieved only if scientists convey their analyses coherently and intelligibly and at a technical level appropriate to the ultimate users of the work. That is, scientists must communicate in such a way that decision makers (often nonscientists) are able to grasp immediately what needs to be done—and why—to make future operations more efficient. An operations research scientist, "unlike the fundamental researcher, cannot wait for posterity to prove him right. He cannot . . . spell out his ideas, as it were, over the heads of his contemporaries, hoping that they would be hailed . . . later."[11]

One other point fundamental to an understanding of operations research is that the operations analyst is concerned with the *overall* system, or at least with the interactive features of the system even if not every feature is explicitly examined. (Here, *system* means any mix of people, machines, and methods of operation whether in industry, business, government, or the military.) Predecessor sciences seldom adopted this tack to problem solving, preferring instead to isolate and focus on individual components of the system. Although the whole-system approach is the ideal of analysts, it is not always practical, especially when the system in its entirety is just too large or the problem too far reaching.

The generally broader perspective, however, means that much may be at stake when operations researchers make recommendations. Typically, they might propose that decision makers commit themselves to fundamentally different ways of running their operations for a long time to come; at times, they might suggest that expensive equipment be brought on-line or old equipment modified. A serious error could jeopardize, for instance, the ability of our armed forces to fulfill some critical aspect of national defense. Of course, analysts cannot remove all uncertainty from their proposals, because even the best assumptions may prove somewhat deficient in light of future developments. Nonetheless, the methodical use of operations research tools[12] offers planners much greater reassurance than could the trial-and-error approach of the past.

Several considerations must be taken into account by analysts faced with an operational problem. First is the objective that some decision maker—say, a commanding officer—wishes to achieve. That objective must be clear before much else can be done; after all, only by chance would a desired solution spring from the "wrong" problem. One example of an uncertain objective involves a response to the loss of British merchant ships in the Mediterranean Sea during World War II. Enemy aircraft were sinking or damaging such large numbers of ships that it was decided to arm some of the ships with antiaircraft guns and crews. Although this entailed considerable expense, few aircraft (about 4 percent) were shot down. The guns and crews, it seemed, were not paying off, which aroused considerable consternation because of the scarcity of resources and their need elsewhere in the war effort. Later, however, a study of operational data showed that despite few kills, the guns were indeed effective in protecting the convoys. Only 10 percent of the protected ships were lost to attacks (because the guns decreased the accuracy of the enemy planes) versus 25 percent of the unprotected ships for the same period. Determination of the success or failure of the effort therefore depended on clearly defining the proper objective. Was the goal to shoot down large numbers of enemy planes or to minimize ship sinkings?

The second consideration is the identification of alternative courses of action available to accomplish the objective. All sorts of factors may influence the number of courses of action that deserve the analyst's closer attention, once all conceivable options have been spelled out. For example, if a problem must be solved immediately, as in wartime, only a stopgap measure—rather than the best of all possible solutions—might be feasible. Other factors to be weighed include the availability of equipment and personnel, constraints on tactics imposed by the resources at hand, and political and economic ramifications. Beyond that, the analyst's own ingenuity and experience become factors.

Yet another consideration is the variables that will play upon the alternative courses of action. Some of the variables may be quantifiable, such as the availability of a particular type of asset (for example, the number of destroyers available to screen a convoy of merchant vessels). Others may be less tangible, such as the benefits of a particular training program. Also, some variables have known values, whereas others (such as the enemy's tactics or intentions) have to be estimated, perhaps from intelligence reports. The degree to which these variables contribute to the success or failure of a course of action in attempts to achieve the objective depends on the sensitivity of that course of action to the variables. A sensitivity analysis can be done to determine this. Listing the variables helps the analyst to understand the data that are required, the difficulty of the task, the analytical methods to be employed, the range of factors to be considered, and the quantities essential to computing the measure of effectiveness.

The measure of effectiveness (MOE), the last of our considerations, is a quantitative way of assessing results. The MOE is measured for each alternative course of action so that a decision can be made concerning which course of action best meets the planner's expectations. If the objective were to detect a target, the MOE might be the "probability of detection" or "time to detection." An MOE used to evaluate the performance of a plane patrolling a confined region, such as a strait, to oppose enemy submarines might be the probability that an enemy submarine passing through the strait is sunk. The MOE, then, is closely tied to the objective. As seen in the example of Britain's decision to arm merchant ships in the Mediterranean, the wrong MOE can sometimes be emphasized. In that instance, the MOE was initially thought to be the number of attacking aircraft shot down by those ships armed with antiaircraft guns

Later, the more appropriate MOE was shown to be the reduced number of armed ships sunk.

The solution to an analyst's operational problem may be derived from weighing the values determined for the MOE for all alternative courses of action that warrant attention. Let's say that we are considering four plans that allow for searching of enemy submarines by patrol aircraft and that the MOE is the probability of detection. The solution to the problem, then, would call for calculating the probability of detection for each plan and seeing which is best. Not all quantitative comparisons of courses of action, however, lend themselves to complete accuracy, largely because nonquantitative factors cannot be easily accounted for. A certain threshold is therefore necessary; that is, the results should show that alternative tactics differ by at least a factor of two or three, or else the alternatives should be regarded as effectively the same. Furthermore, conditions in the real world are always changing. Hence, solutions that attempt to predict the outcome of future operations, on the basis of knowledge about past operations, may be invalidated by the state of flux to which the real world is subjected.

Whether the problem and proposed solution be simple or complex, the decision maker's (commander's) burden of responsibility is only lightened, not removed, by operations analysis. The onus of a miscalculation—as with the kudos derived from success—remains mostly with the decision maker and only secondarily with the supporting analyst. Operations analysts cannot replace executives, for their aim is to provide understanding rather than decisions. It is the role of the decision maker to consider the results of analysis in light of his or her own judgment, based on his experience, knowledge, and intuition. The roles of the analyst and decision maker are by nature functionally separate, even though they are complementary:

> If ever there was a world in which situations do not repeat themselves like some mass-production model, it is the military world. If we are to avoid the imposition or arbitrary limits to the exercise of judgment and control, we must be careful not to create in a mathematical vacuum situations which are based neither on past experience of affairs, nor on any conception of the innumerable variables and factors that determine social decision either today or tomorrow . . . . True scientific method should be used as an aid to human judgment—and not as a hindrance. Science *is* human experience; it is not an alternative to judgment, and it is certainly not something that can operate outside human experience.[13]

The commander's decision to conduct an operation one way rather than another can thus be made with a fuller awareness of realistic options and their consequences.

The preceding discussion touches on some of the major elements of operations research, which should suffice for the purposes of this book. Other elements that have a particularly direct bearing on OEG's circumstances, especially as they relate to the group's pioneering efforts during World War II and in the years after the war, will be taken up in later chapters.

# 1

# The Group's Formative Years during World War II

## The U-boat Menace

We have already seen that a major concern of Britain's operations research scientists during World War II was the German U-boat and its successes against merchant shipping. It was clear from the outset that Germany placed great stock in the submarine, as it immediately implemented a campaign of unrestricted U-boat warfare. By the end of 1940, the efficacy of the campaign was evident. During some months, U-boats were sinking about two and a half times the amount of shipping the Allies were able to build.

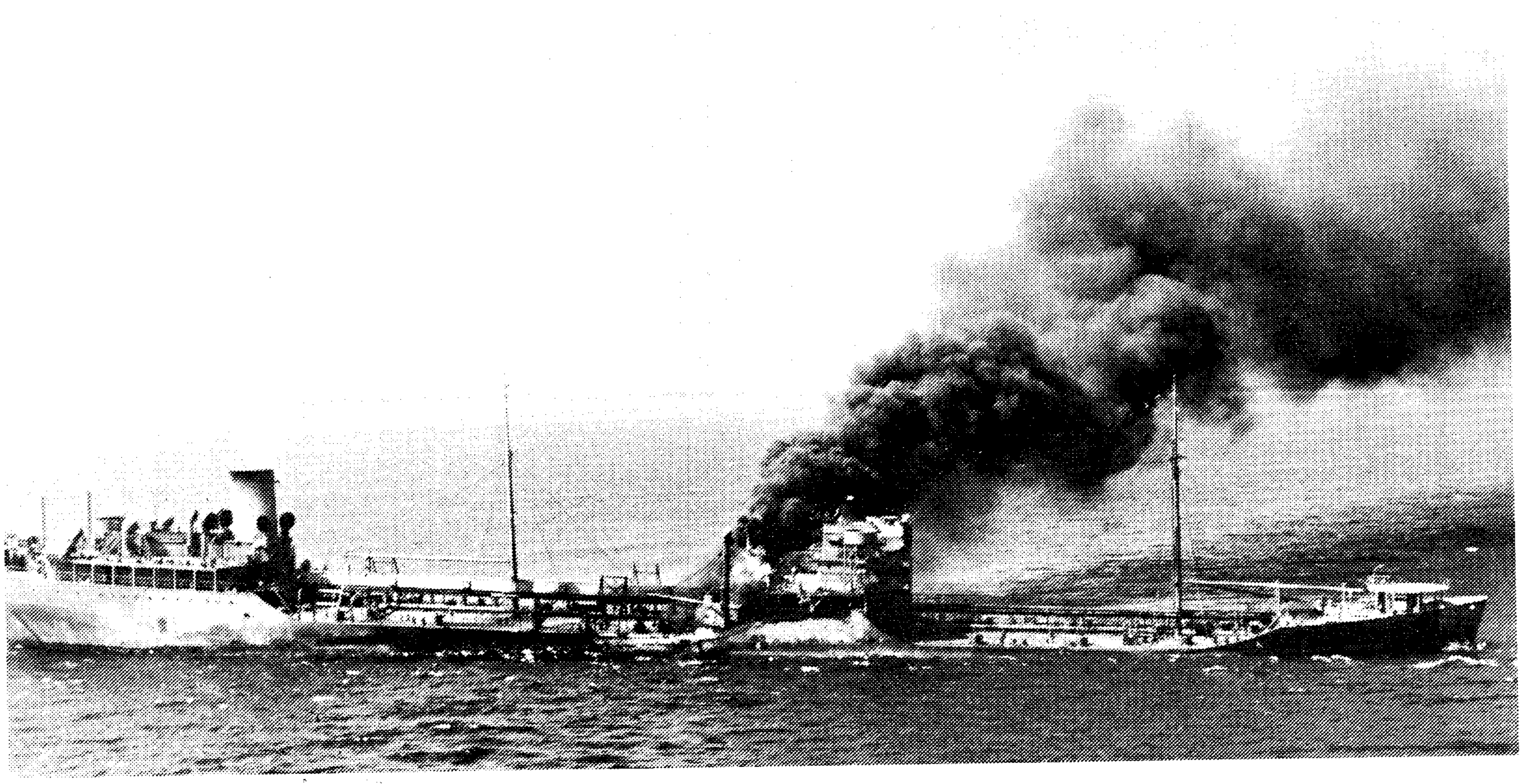
The successes scored by the U-boats against combatants and merchant ships resulted from a considerable expenditure of resources to increase the size of the force and to perfect equipment and tactics. In September 1939, the German order of battle included a modest sixty-submarine fleet; by early 1941, however, as many as twenty U-boats a month were being commissioned. By the time the United States entered the war, about two hundred were already prowling the oceans. These submarines were made strong enough to resist much more powerful detonations than ever before, quiet enough to test the limits of new listening devices, tight enough to reach depths that made it difficult for searchers to detect them, and fast enough on the surface to outmaneuver a great many merchant ships on which they preyed. They were armed with the newly developed electric torpedo that left no visible wake, making it harder for the target ship to observe the torpedo's approach and turn to avoid it.

Additionally, U-boat Command developed an extensive body of bold tactical doctrine. One tactic, designed to reduce the effectiveness of daytime counterattacks on submerged submarines, involved a change to night attacks conducted on the surface. The U-boat was to trail the convoy until nightfall, close its target for a surface attack, then leave the area at high speed while still on the surface. This procedure, enabling individual U-boats to exploit weaknesses in Britain's merchant shipping system, remained a favorite of the Germans for much of the war.

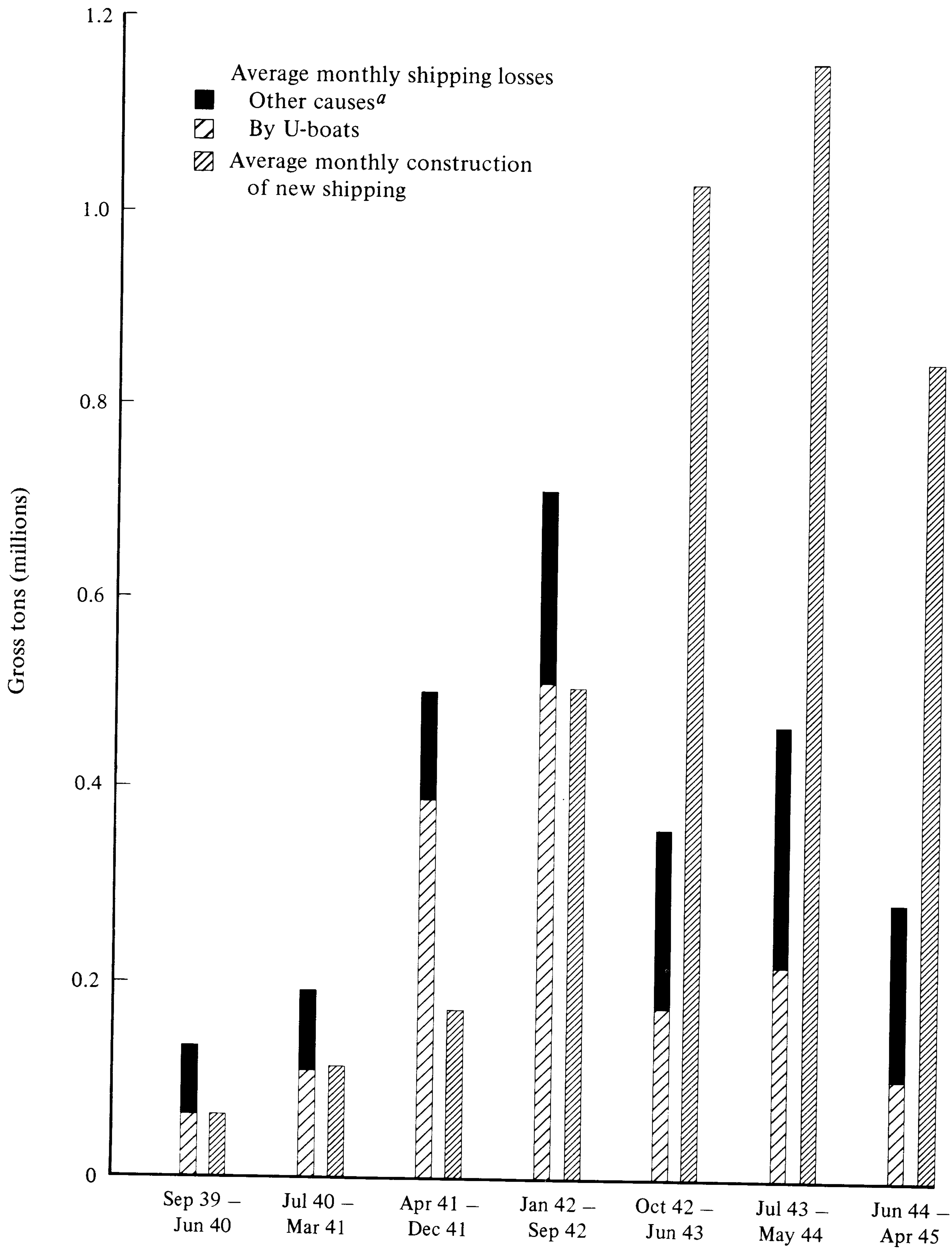
Another tactic, adopted in the spring of 1941, called for U-boats to gather in packs ("wolf packs," as they became known) before attacking a convoy. The chief aim was to overwhelm the escorts and to sink as many of the ships in the convoy as possible. Central to this scheme was a communications system linking all the U-boats with base control. The procedure was for the U-boat that first sighted a convoy to shadow rather than attack the vessels, then provide up-to-date information on the convoy's position to permit other U-boats to assemble and coordinate their thrust. Because U-boats were fairly slow, and thus inefficient, searchers, they benefited considerably by sharing each other's contacts. Also, the grouping of submarines enabled many captains and crews, who had been sent to sea with minimal training, because of the rapid expansion of the U-boat force, to operate in company with others of more experience.

As Germany's armies defeated the nations of Western Europe, a great expanse of coastline was opened up for supporting U-boat operations. The advantages reaped from these territorial gains were enormous from the point of view of the submarine fleet. For example, the ports around the Bay of Biscay, acquired as a result of the June 1940 victory over France, shortened the transit time of the U-boats and enabled them to penetrate deeper into the Atlantic than they could before. Thus, for a period, the U-boats were able to chalk up impressive gains[1] while sustaining tolerable losses. The price to the Allies of this U-boat offensive is illustrated in Figure 1-1, which shows shipping losses and ship construction by Allied and neutral nations.

Owing to the urgent situation in the Atlantic, Allied efforts to counteract the submarine threat were intense. However, it took a while for



The dense column of black smoke rolling up from this tanker shows where a German torpedo struck almost amidship on the port side. (Official U.S. Navy photo.)




[a]*By other enemy action (aircraft, ships, mines, etc.) and natural marine casualty.*

Figure 1-1. Average Monthly Shipping Losses versus Ship Construction by Allied and Neutral Countries

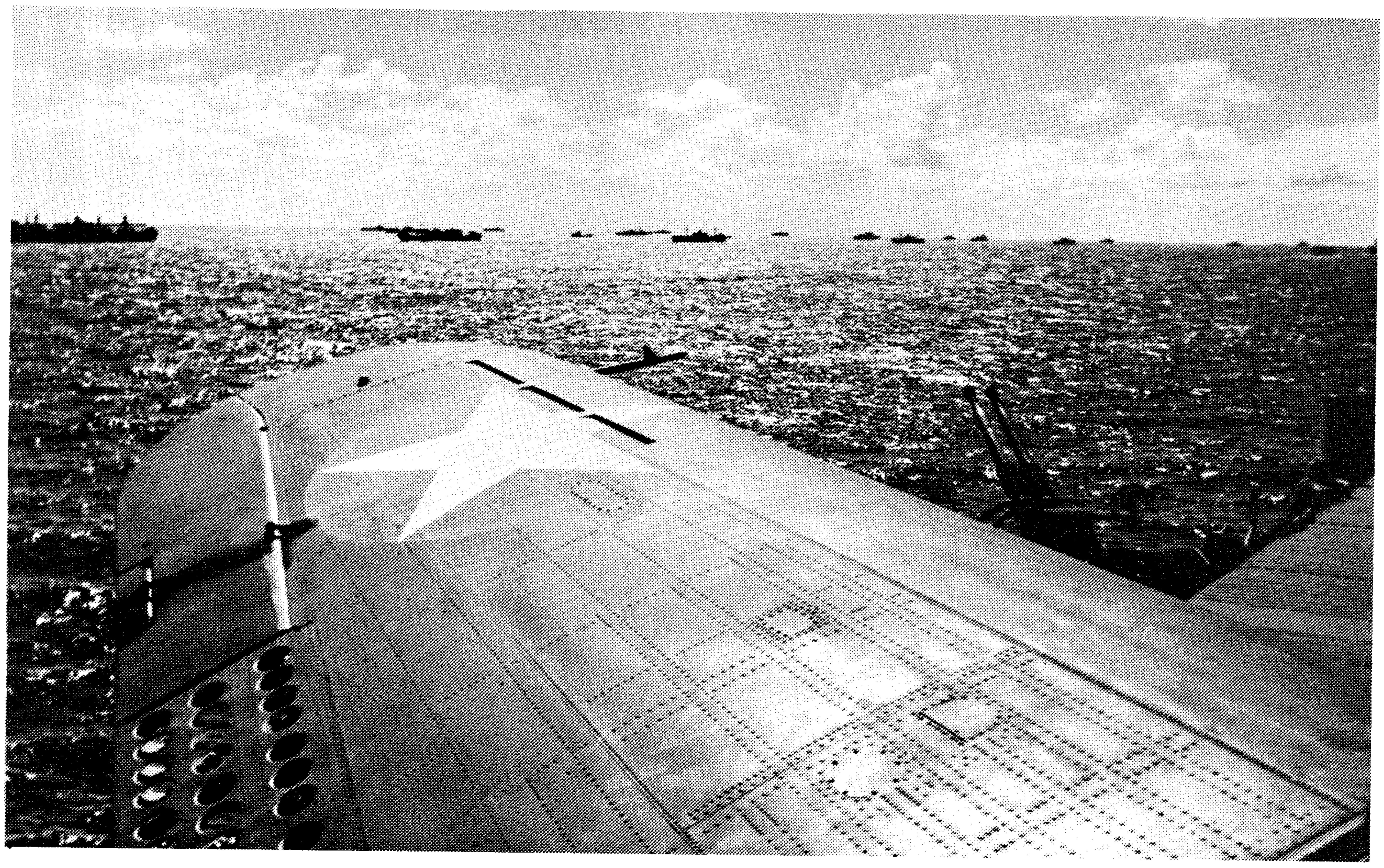
Britain—the country most immediately threatened—to overcome its early deficit in antisubmarine preparedness. At the start of the war, it had only 220 vessels properly fitted for antisubmarine warfare: 165 destroyers, 35 patrol craft (sloops, frigates, and corvettes), and 20 trawlers. (The total stands in sharp contrast to the 3,000 antisubmarine vessels the Allies had on hand at the close of World War I.) By the end of June 1940, the total had reached 450, with most of the increase in small craft, especially trawlers, rather than in the more important destroyers. Various antisubmarine weapons became available for use by these ships. If a U-boat were on the surface, the ship, of course, could simply fire guns or rockets; if a U-boat were submerged, the ship could lay a barrage of depth charges off the stern or throw explosives—such as the Hedgehog, Mousetrap, or Squid—ahead of its own course.

One immediate countermeasure to U-boats was the convoy system, introduced more than twenty years earlier in 1917. The British had learned during World War I that convoys were highly effective in the open ocean, where evasive maneuvers were possible. If the position of enemy submarines could be reliably estimated, captains could select routes that would likely reduce the chance of contact. Alternatively, shipping routes could simply be widely dispersed, forcing enemy forces to thin out rather than remain concentrated. The British also knew that the ability to detect and track nearby U-boats was essential to the convoy system, and that adequate protection depended on the availability of properly armed escorts.

From the very beginning of World War II the convoy system was again put to the test, and passed. During September 1939, not a single ship was lost among the nine hundred that transited via escorted convoys. Of the ships that had to make their way through dangerous waters before the convoy system was fully in place, thirty-nine were lost. A quarter of these casualties resulted from gunfire by surfaced submarines rather than from torpedoes. This convinced the British of the necessity to arm their merchant ships so they could at least fight back, no matter how modest the means.

Of course, as tactics and equipment changed on both sides, convoying procedures changed, too. In November 1940, for example, when U-boats were achieving a high percentage of hits in night attacks, Britain quickly moved to separate convoy columns by one thousand yards instead of the customary four hundred yards. After only a month, the spacing between columns for daytime convoys was reduced to six hundred yards, in response to heavy air attacks. The system had to remain elastic if it were to bend and not break under the stresses applied to it by the enemy.

The convoy system remained an effective countermeasure throughout the war in helping to stave off the U-boat offensive. For example, only 7 of the 169 ships sunk by U-boats during the first six months of the war were



A giant convoy moves across the Atlantic under the protective escort of a U.S. aircraft carrier. (Official U.S. Navy photo.)

part of a convoy, despite the fact that about half of all merchant shipping traveled in convoys during those same six months. Indeed, the early successes of escorted convoys using evasive maneuvering were sufficiently outstanding to force the Germans to reconsider their tactics and, beginning in April 1941, they resorted to wolf-pack attacks. Even so, convoyed ships continued to enjoy a greater degree of safety than independent vessels.

Another major effort to thwart the U-boat campaign involved aircraft. Despite some early shortcomings, planes were eventually shown to be far more effective in antisubmarine warfare than anticipated, both in chalking up sinkings and in forcing U-boats away from otherwise vulnerable targets. Obvious advantages of aircraft over surface ships were their speed,[2] relative inexpense, large field of vision, and ability to appear from nowhere to surprise a surfaced submarine. In fact, from the fall of 1942 until the end of the war, planes often sunk more U-boats per month than did surface ships.

This must surely have come as a surprise to Admiral Karl Doenitz, who once commented that "an aircraft can no more kill a U-boat than a crow can kill a mole."[3] Doenitz's lack of confidence in aircraft as an antisubmarine weapon—a sentiment shared by others at the time—may partly be explained by the little chance any antisubmarine planes had had to prove their value. Planes had seen very little action against U-boats during World War I, and at the beginning of World War II antisubmarine planes carried only conventional bombs which, even if they did hit the deck of a submarine, seldom penetrated the hull. Consequently, in the early phase of the war, their ability to sink submarines—rather than just harass them—was severely restricted. In a major way, then, the antisubmarine role of aircraft was made possible by the development of depth charges suitable for dropping from planes and the ability to detonate the charge at appropriate depths. It was also made possible by the German tactic of operating submarines on the surface until they were about to attack or until they had to escape pursuit. Aircraft could therefore be used either to locate U-boats (if destroyers were to be called to the scene) or to attack them with their own depth charges. In short, aircraft hindered U-boat operations by slowing down their transits, preventing refueling, breaking up wolf packs, and making it difficult to trail convoys.

Beginning in 1941, Germany was able to mitigate the threat of antisubmarine aircraft by operating its U-boats mostly in the mid-Atlantic, along the northern convoy routes. By doing so, the U-boats could stay beyond the few-hundred-mile range of the land-based planes Coastal Command was using at the time. In the spring of 1943, this mid-Atlantic gap in air coverage was plugged, to some extent, by a limited number of carrier-based aircraft. The planes, however, flew mostly in offensive operations and only occasionally in escort.

Developments in equipment also profoundly influenced the antisubmarine effort. Without doubt, the main technical advance was the placing of radar on surface ships and aircraft, thus providing antisubmarine forces with the opportunity to "see" targets even at night and in bad weather. In good weather, radar bettered visual search because it offered continuous scanning (that is, without gaps in its coverage), a considerably greater scan rate, and a longer range (in effect, to the horizon). Radar's most successful application was as an instrument of search and early warning, although it also proved useful in fire control, navigation, altimetry, and so forth.

Ships first began to be equipped with radar in November 1940. By the following April, about forty destroyers of the Western Approaches Command had received radar. The early models enabled ships to detect a surfaced U-boat up to three miles away; those on aircraft boasted a range of 15 miles against the same target, if the plane was at an altitude of twenty-five hundred feet. Over the course of the war, radar was modified to increase its range, to detect smaller targets, and to lessen its vulnerability to search receivers designed to alert a U-boat commander to the presence of a switched-on radar set.

A submerged submarine posed a different search problem from a surface submarine. Not only were visual searches impossible, but radar was ineffective because of the virtual inability of electromagnetic waves to pass through the ocean. Sonar was the solution. Two types of gear were available for sonar detection. One was a simple underwater listening device (consisting of a receiver and amplifier) capable of picking up sounds emitted by the target, such as by the propeller of a U-boat or from machinery within the hull (see Figure 1-2a). It was particularly effective for classifying targets, because of the distinctive sounds made by submarines as opposed to whales or some other underwater object. It was also helpful in determining the bearing to the target, although (and significantly) not the range. Eventually, the system was made capable of supersonic frequencies, to improve its directionality.

The second type of sonar device centered on echo ranging. Echo ranging involves transmitting sounds under water at above-audible frequencies and

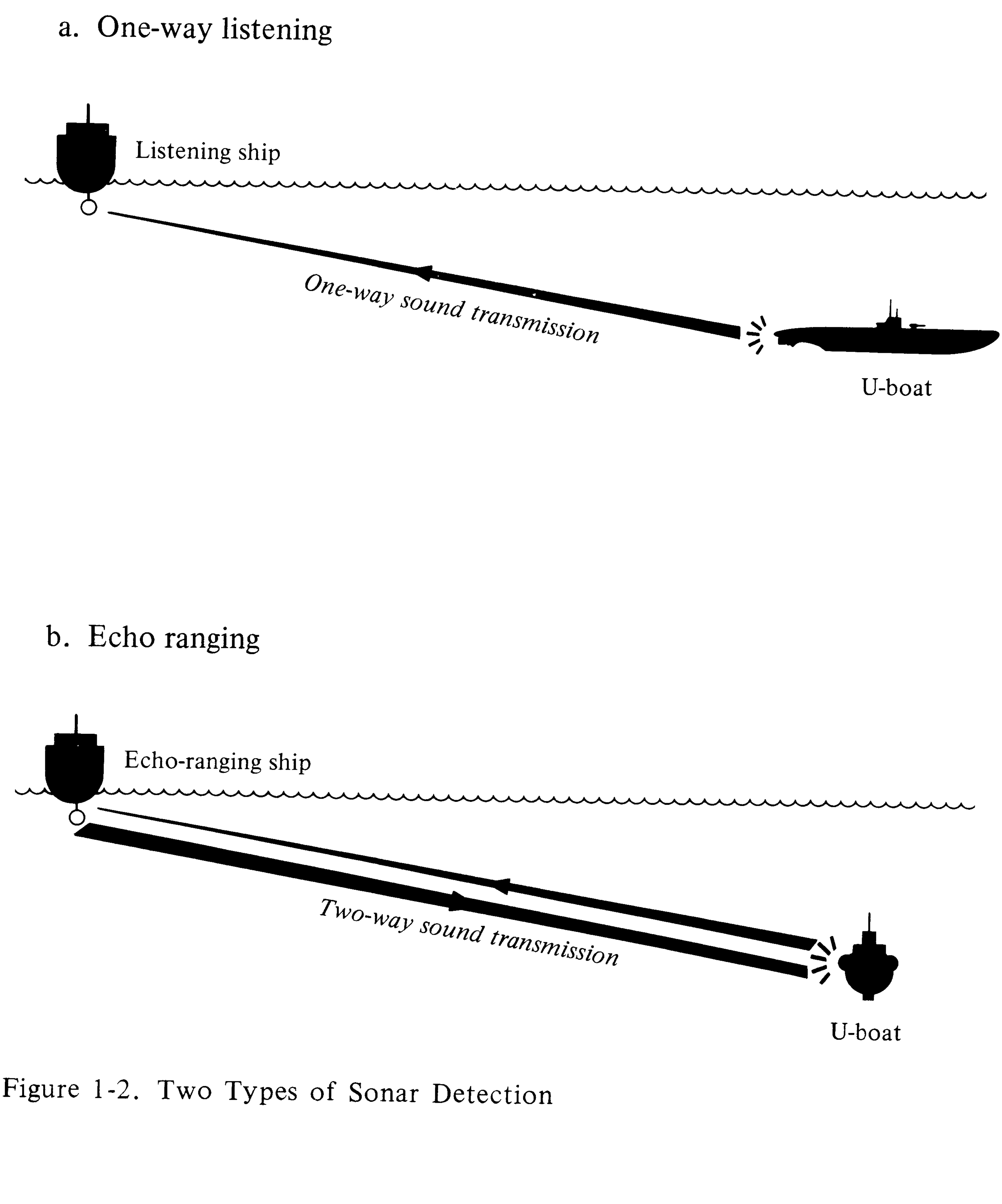



Figure 1-2. Two Types of Sonar Detection

timing the echo, that is, the sound reflected back by the hull of the submarine (Figure 1-2b). The sonar operator could then measure the range to the target, its bearing, and, because of Doppler shifts in frequency, its relative speed. Unlike the passive sonar described above, echo ranging would not be fooled by a U-boat trying to be still and quiet to avoid detection. There were, however, difficulties, such as the need to distinguish a submarine from a school of fish or patch of seaweed, the need to contend with reverberation, and the need to adjust for the bending of sound waves because of changes in water temperature with depth. Nevertheless, under favorable conditions, the device could locate submarines several thousand yards away. The British version was known as Asdic, from the initials for the Anti-Submarine Division International Committee, a small body of British scientists formed in 1918 and credited with developing an experimental model of the device. Asdic was vastly improved on in the 1930s and quite surprised the Germans at the start of the conflict.[4] (The American name of *sonar,* from *so*und, *na*vigation, and *r*anging, was not adopted until 1943.)

Two other devices aided in the detection and attack of U-boats by Allied planes. The first of these was the magnetic anomaly detector (MAD), designed to detect distortions in the earth's magnetic field caused by the presence of a submarine. Because MAD was capable of making detections only at short ranges—no more than a few hundred feet, depending on the plane's altitude—its principal value was in restricted waters, such as a strait. Within a two-month period, planes equipped with MAD were successful in tracking and bombing three U-boats that were passing through the Strait of Gibraltar to the Mediterranean. The results sufficiently demoralized the U-boat commanders that none attempted the passage for another six months.

The other device was the expendable radio sonobuoy, to be dropped by a patrol plane in an area where a submerged U-boat was suspected or known to be. The buoy picked up the sounds of a submarine and transmitted them via radio to the circling aircraft. Several buoys dropped in a pattern would enable the aircraft to track a U-boat by means of changes in the relative intensity of the sound from one location to another. Because a U-boat was capable of crash-diving quite fast—in just one hundred seconds it could be more than two hundred feet deep and anywhere within a radius of one thousand feet—the expendable buoy proved an invaluable asset.

Over the course of the war, the array of Allied countermeasures, whether in the form of tactics or equipment, took an enormous toll on the U-boat force. Figure 1-3 shows monthly U-boat losses, with the type of craft that caused the U-boat sinking indicated.

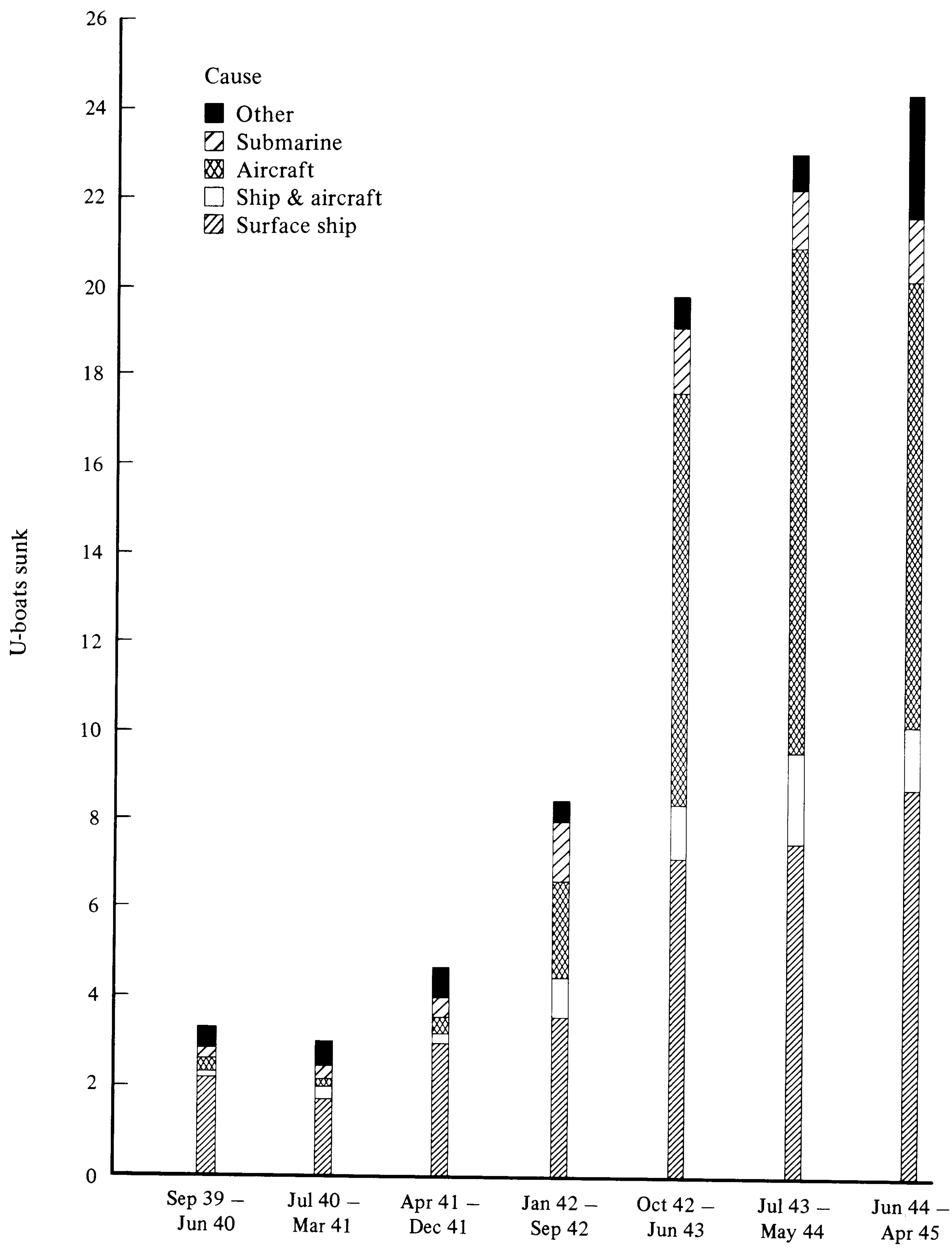
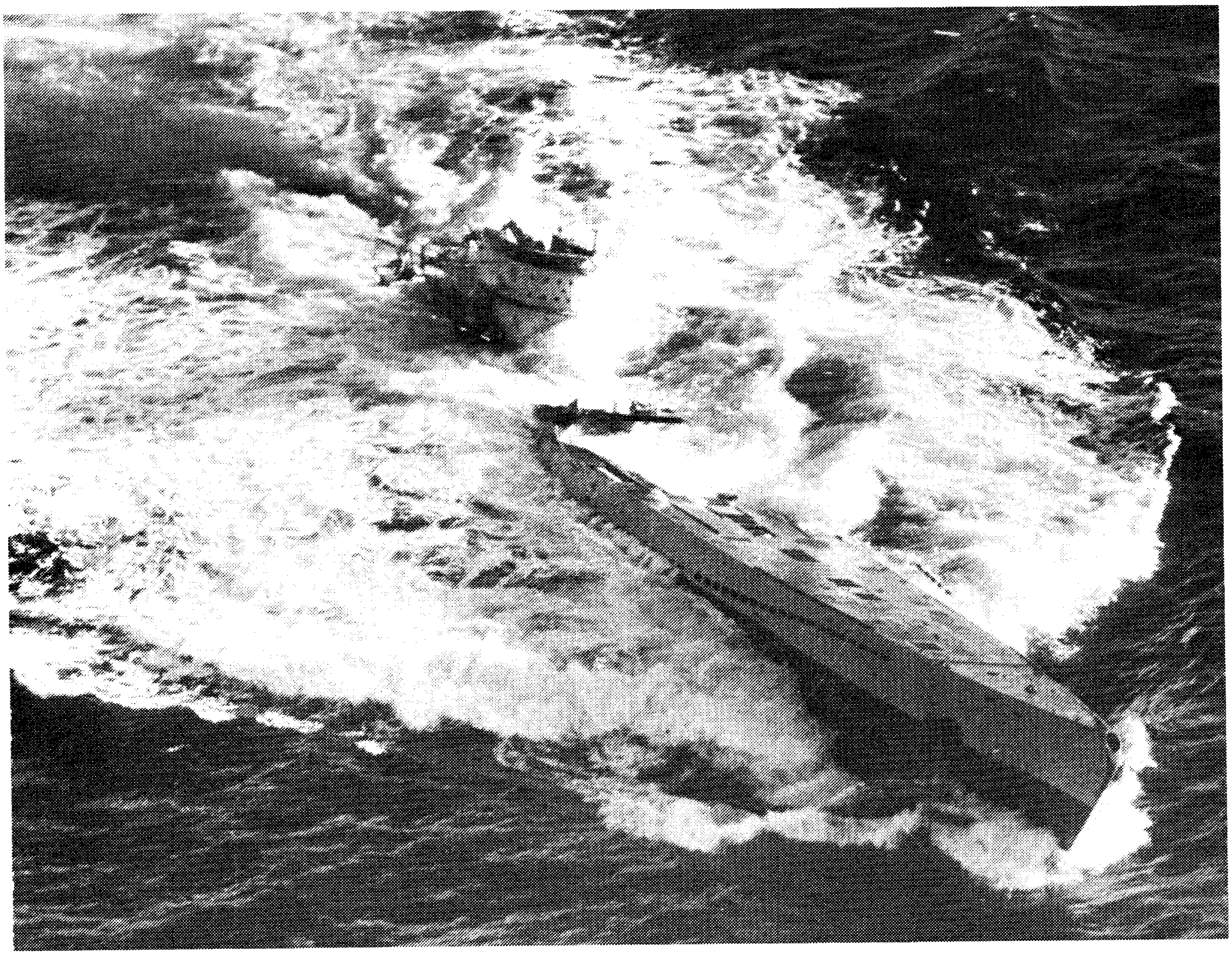



Figure 1-3. Average Monthly U-boat Sinkings (by Cause of Sinking)

## America's Early Antisubmarine Experience

As soon as the United States entered the war, German submarines began to patrol the East Coast and American shipping lanes. U-boat attempts to attack escorted shipping in the Atlantic had been yielding steadily less impressive results. In fact, only one ship was being sunk for each U-boat



A U-boat begins to settle by the stern, her bow rising, as the result of a depth-charge attack by a U.S. Navy Avenger. (Official U.S. Navy photo.)

month at sea. An attack against convoy HG-76 in December 1941 was especially expensive to the Germans, as four U-boats were sunk compared with only two merchant vessels. Eager to find weak spots in Allied defenses, German submarines naturally turned to America's coastal shipping. In January 1942, about twenty U-boats began to operate in the area, including the waters off Nova Scotia and Newfoundland. Lamentably, coastal shipping was dense and accustomed to the absence of order. As a consequence, the U-boats succeeded in getting off to a quick start, sinking fourteen ships in January in the Eastern Sea Frontier alone.

American efforts to establish convoys immediately got under way (Figure 1-4), and operators of merchant vessels studied the special techniques of coastal convoying. Shipyards were building escorts as fast as possible, as most of the larger escorts were allotted to the more critical transatlantic shipping and Pacific operations. To help reinforce American coastal defenses, Britain assigned twenty-four antisubmarine trawlers to operate off our coast and handed over ten corvettes to the U.S. Navy. But the paucity of escorts meant that for the first few months—until 14 May, anyway, when escorted coastal convoys started between Norfolk, Virginia, and Key West, Florida—the navy had to resort to patrols to cover the entire length

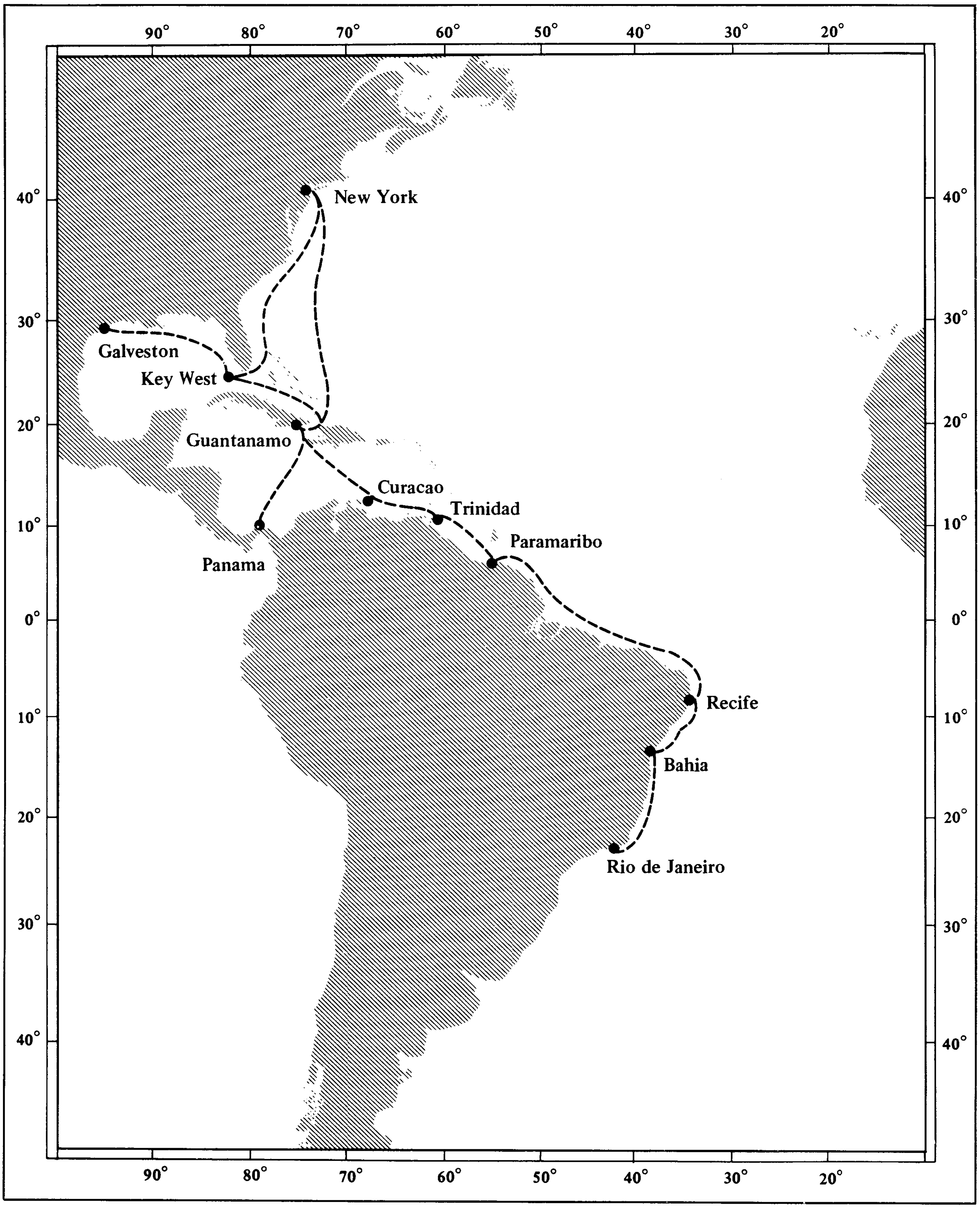



Figure 1-4. Regularly Scheduled U.S. Coastal Trade Convoys

of coastline. Aircraft, too, were employed to patrol the coastal waters. The First Bomber Command of the Army Air Forces added to the number of planes assigned to this antisubmarine mission.

Control over these diverse forces was placed in the hands of the Commander in Chief, U.S. Fleet (CominCh), whose staff was responsible for organizing and routing convoys and for deciding on tactics, training, and equipment. U.S. escorts from the Atlantic Fleet protected the transatlantic convoys for the western half of the journey (this being designated the U.S. Strategic Area), whereupon British escorts took over. Coastal shipping, meanwhile, became the responsibility of the various sea frontiers: the Eastern Sea Frontier (covering the region from Maine to Florida), the Gulf Sea Frontier, the Panama Sea Frontier, and the Caribbean Sea Frontier (covering the northern portions of South America and the Antilles). The sea frontiers operated local patrol craft, planes supplied by Commander Aircraft Atlantic Fleet, and land-based bombers from the First Bomber Command. Each frontier kept its own plot of where shipping and submarines were located, from which patrol, convoying, and attack plans could be made. The various operating areas of the ocean are shown in Figure 1-5.

The lines of authority of these various commands were at first quite fuzzy. The absence of sufficient centralization led to considerable variation in tactics from one place to another, and there was also difficulty in transferring aircraft and vessels between frontiers as U-boat activities shifted.

### Rallying America's Scientists

As a consequence of America's conspicuous need to hone its military capabilities (antisubmarine and otherwise), efforts got under way to mobilize scientists in the national defense. Important in this drive was Dr. Vannevar Bush, former vice president of the Massachusetts Institute of Technology (MIT) and inventor. Bush was well known and respected among scientists around the country for his work in applied mathematics and electrical engineering. As head of the National Advisory Committee for Aeronautics, established in 1915 to direct the scientific study of flight, he naturally appreciated the idea that scientists could be organized for defense purposes. He also clearly understood the unique requirements of researchers:

> Research . . . is the exploration of the unknown. It is speculative, uncertain. It cannot be standardized. It succeeds, moreover, in virtually direct proportion to its freedom from performance controls, production pressures and traditional approaches . . . . To be effective, new devices must be the responsibility of a group of enthusiasts whose attentions are undiluted by other conflicting responsibilities.[5]

Bush discussed the need for and feasibility of an organization that would consolidate the efforts of researchers with several colleagues, among them: the president of MIT, Karl T. Compton; the president of Harvard, James B. Conant; and the president of the Bell Telephone Laboratories and of the National Academy of Sciences, Frank B. Jewett. After much deliberation, it was decided that such an organization should be formed and that it should be called the National Defense Research Committee (NDRC). A draft of the proposed committee's charter stated that NDRC would "coordinate, supervise, and conduct scientific research on the problems underlying the development, production, and use of mechanisms and devices of warfare . . . ." In June 1940, Bush met with President Franklin D. Roosevelt and convinced him to establish NDRC by executive order.

Bush was to serve as chairman. The rest of the committee was split into divisions: Division A, for armor and ordnance, headed by Richard C. Tolman; Division B, for bombs, fuels, gases, and chemicals, headed by

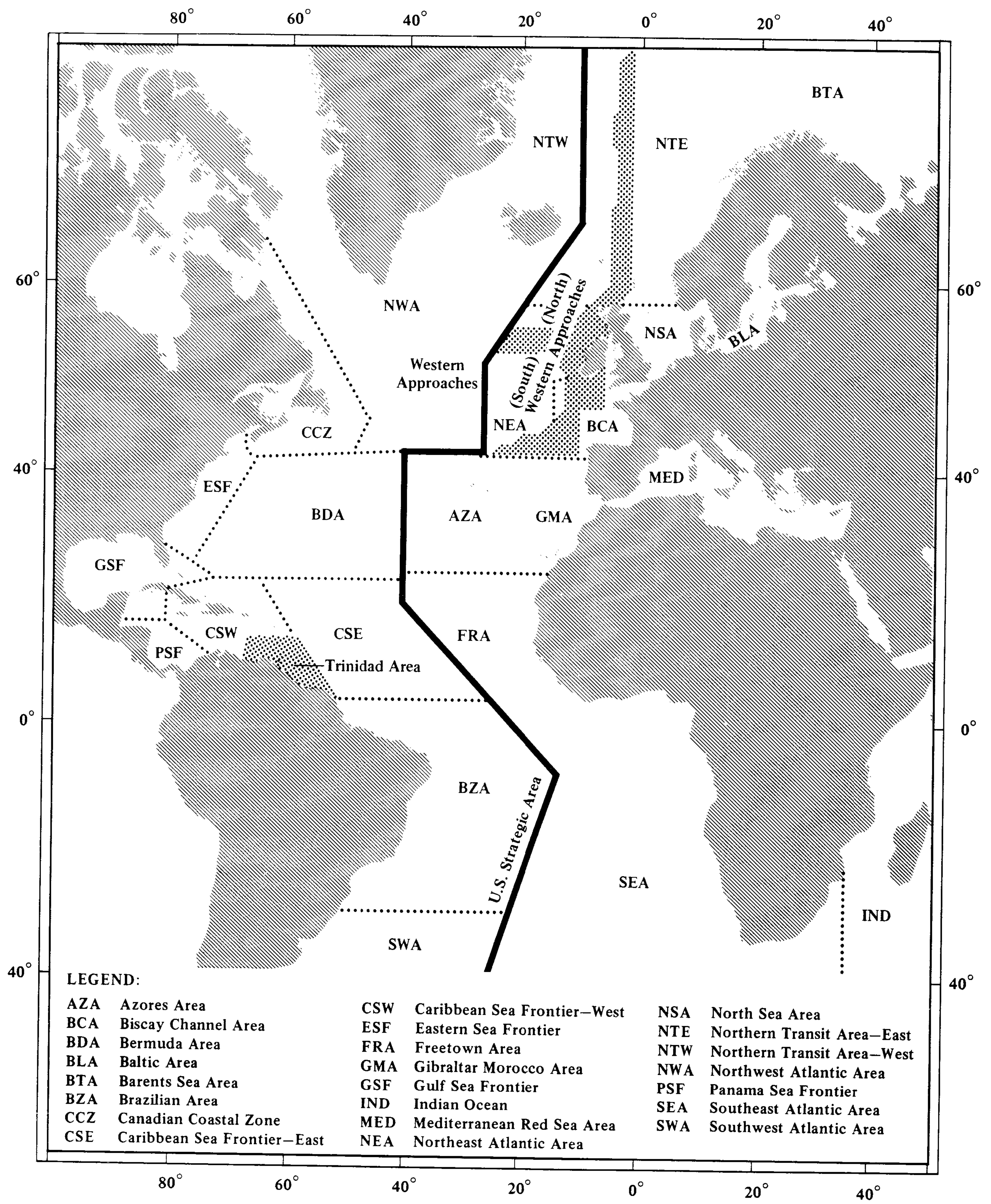



Figure 1-5. Atlantic Ocean Operating Areas

Conant; Division C, for communications and transportation, headed by Jewett; Division D, for detection, controls, and instruments, headed by Compton; and Division E, for patents and inventions, headed by Conway P. Coe.

Conant, who less than a year later was to rise from head of Division B to chairman of NDRC, is generally credited with playing a key role in arousing interest in operations research in the United States. This role resulted from an assignment to set up a London office of NDRC.[6] During his visit, Conant found that the British scientific community was unreserved in its willingness to share ideas and critical information with him. Among the ideas the British urged on him was that scientists could best verify the usefulness of their military research only by maintaining close ties with those who would actually use the resulting new and sophisticated equipment in combat. In short, the *operational* assessment of new systems was essential. Conant quickly perceived the value of the operational approach touted by the British, and on his return to the United States brought with him the seeds of formal military operations research.

Meanwhile, in December 1940, a section was established within Division C of NDRC for the express purpose of working on equipment designed to detect submarines. The Subsurface Warfare Section (or Section C-4) did not immediately become fully active, for two reasons. First, the navy was skeptical that enough qualified civilians could be assembled to make a serious dent in the problems that needed to be solved. After all, the navy—not universities or industry—had dominated development of underwater sound-detection gear for a good twenty years. Second, the person selected to head the section, Dr. John T. Tate, remained in England for awhile, to acquaint himself with the activities there. After he returned in May 1941, the pace picked up and offices were opened in New London and San Diego and at Harvard.

The navy's doubts about the usefulness of the Subsurface Warfare Section were soon allayed. Although virtually all the members of the section were novices in antisubmarine warfare, they learned quickly and the section made many improvements in underwater detection equipment.

Gradually, however, those involved realized that attempts to improve the detection equipment, though important, addressed only one facet of the entire antisubmarine problem. If the overall performance of our antisubmarine forces was to be significantly enhanced, corresponding attempts to improve other kinds of equipment were necessary. Depth charges, for example, had not been made more reliable or more lethal since World War I. (Analyses by Drs. L. B. Slichter and S. S. Wilks suggested that even with the best underwater detection system, standard depth charges would restrict success to one out of every twenty attacks.)

Furthermore, no one in the navy—not even the Bureau of Ships—was aware of the operational characteristics of much of the equipment available for antisubmarine warfare. Even after several months of American participation in the war, no quantitative analyses of operational results were being done. From the beginning, the few navy personnel with antisubmarine experience were channeled into positions required to prosecute the war, not to study it. In addition, few people in the navy at the time had the scientific or mathematical skills to conduct such studies.

In sum, then, two serious shortcomings stood out. In the navy's view, tactical doctrine was seriously deficient; in NDRC's view, the operational capabilities of equipment were poorly understood. The only way to surmount these shortcomings was to establish some formal and ongoing means of systematically gathering and analyzing all available operational data.

A 27 January 1942 letter from Captain Robert B. Carney, Admiral Arthur LeR. Bristol's operations chief, to Commander William B. Moses, gunnery officer of the Atlantic Fleet, set in motion a sequence of events that were to lead to today's Operations Evaluation Group. In the letter, Carney suggested that an antisubmarine warfare group be formed within the Atlantic Fleet, "located where the dope can best be collected on the spot while it is hot, free from any other duties, working from practical experience, and furthering the aims of CominCh [Commander in Chief, U.S. Fleet]."[7]

Within about a week, Moses brought Carney's recommendation before a conference of officers, which promptly endorsed the proposal. The result, on 2 March, was formation of the Antisubmarine Warfare Unit within the Atlantic Fleet. Captain (later Rear Admiral) Wilder D. Baker, a 1914 graduate of Annapolis, was chosen to head the group, with headquarters in Boston. The unit—dubbed "Baker's Dozen"—consisted of officers familiar with submarine operations, officers from destroyers, a navy air officer, and an army air officer. They brought with them a variety of specializations, including aircraft and submarine operations, communications, intelligence, and training.

The unit began immediately to collect, sort, and analyze whatever operational data became available. Their information comprised action reports that recounted the events of each combat situation, and intelligence. As Baker recalled,

> It was at this point in March 1942 that we were searching for any and every help we could find. There were many who had panaceas for the submarine menace. This invention or that type of weapon or ship would be the answer to our frustration. However, we knew that the answer lay not in one idea or gadget, but in the complete understanding of all the factors.[8]

It did not take Baker's people long to conclude that the paramount cause of the weakness of America's antisubmarine campaign was inadequate tactical doctrine. Baker decided, therefore, that this would be the first hole to plug. Intentions were soon translated into reality, for by the summer of 1942 the United States had its first manual on general antisubmarine tactics (issued on 9 July) and its first manual on specific search and attack procedures (issued on 22 August).

Only days after the Antisubmarine Warfare Unit had been commissioned, Baker, intrigued by P. M. S. Blackett's paper, "Scientists at the Operational Level," reasoned that civilian scientists would likely be of service to the U.S. Navy's analytical needs. Baker felt that because many of the antisubmarine devices were new, and hence unfamiliar to most naval officers, outside help in evaluating operational data at a quantitative level was needed. He also felt that the mathematical procedures used by physical scientists might be valuable in this endeavor.

On 16 March 1942, Baker wrote to the director of research and development, asking that an organization be formed consisting of a statistical and analytical section and stocked with "outstanding men of reputation with broad vision and receptive minds, able quickly to comprehend the needs and problems with which we are confronted, and experienced in utilizing . . . the tools of science in solving such problems." The request was forwarded to Dr. John Tate, then head of the Subsurface Warfare Section of NDRC.

Tate was enthusiastic about assigning scientific experts to the analysis of operational data on antisubmarine warfare. On 20 March, he asked Professor Philip M. Morse, a distinguished physicist at MIT, to head the group. Because of the importance of the appointment, Baker also approached Morse, who later recalled in his autobiography:

> Captain Baker impressed me as soon as I entered his office—steel-gray eyes, gray hair, a look of decisiveness . . . . At the end of [a] long introductory explanation—the longest I would ever hear him make—Baker asked me if I would organize a scientific task force to help his unit analyze the U.S. antisubmarine effort. It didn't take long for me to accept; this seemed to be the opening I had hoped for, and Baker and his staff were men I would be glad to work with.[9]

Whereas Professor P. M. S. Blackett is regarded by many as the father of modern operations research, Professor Morse may be considered the father of the Operations Evaluation Group and thus, by implication, of naval operations analysis in the United States. Even very early in life, Morse sought order in randomness: "Isolated facts didn't interest me much; patterns in facts were what excited me."[10] While attending the Case School of Applied Science (later part of Case Western Reserve University), Morse studied physics, in which he later earned a doctorate from Princeton. His enthusiasm for science in those early years comes across best in his own words:

> The devising of a new theory, or even the extension of a known one, is exploration, with all the excitement and trials and false starts and effort of any exploration. It is somewhat like putting together an intricate jigsaw puzzle. Here are two or more well-tried equations, from different parts of physics, that represent disparate sets of physical phenomena. Can they be combined to explain another set of measurements of still another part of physics? Can the investigator put together a mental picture of the phenomena, which will fit the equations into a logical, harmonious pattern of the process? And, finally, will the pieces of the puzzle actually join together to produce a recognizable picture; will the combined equations, when the proper numbers are inserted and the answers obtained, produce values that

Professor Philip M. Morse, founder and director of OEG's direct lineal progenitor, the Antisubmarine Warfare Operations Research Group (ASWORG). (OEG photo.)

> check with the ones obtained from experiment? . . . Concepts must be picked up and tentatively put next to one another. Some are discarded, some turned around and tried again, until all the pieces fit—or the mind gives up. The more pieces the investigator can keep in mind and the longer he can keep moving them around, the better theorist he is.[11]

After Princeton, Morse left for Europe on a Rockefeller-funded International Fellowship, choosing to visit Munich (where work on the quantum properties of metals was being pioneered) and Cambridge, England. Among those physicists at Cambridge with whom he became acquainted was P. M. S. Blackett.

On returning to the United States a year later, Morse began teaching at MIT, at the invitation of Karl Compton (soon to be president of the institute). The new head of the Physics Department, John Slater, was planning to transform the department from an adjunct of the then-all-important engineering departments into one of the best physics departments in the country. Acutely aware of the often inadequate physics curricula offered at that time at even the best American schools, Morse backed the plan wholeheartedly.

The international tensions were becoming hard to ignore by the late 1930s. Once war finally erupted, most scientists, including Morse, realized that their talents would be needed in one capacity or another. Many felt, however, that they could best serve the nation's defense by remaining primarily under civilian control, rather than by being swallowed up by the military bureaucracy. Their hopes were buoyed by the formation of the National Defense Research Committee (NDRC) in the summer of 1940.

The Radiation Laboratory at MIT was set up by NDRC in the same year. Headed by Lee A. DuBridge of the University of Rochester, its purpose was to contribute in any way possible to Britain's attempts to improve radar. Morse joined the lab early in 1941, but soon felt that its size had gotten unwieldy and that he could achieve more elsewhere. Consequently, he turned to acoustics, a field in which he had distinguished himself earlier. In one study for the Army Air Force, for example, he had examined the effects of noise on aircrews, and how the noise level could be reduced.

So, as early as a year or longer before the United States had entered the war, Morse had become thoroughly immersed in defense-related research. His involvement in naval matters began at this time, too. In January 1941, Morse was briefed by Commander E. C. Craig on efforts by the British to counter a new German mine that was sensitive to sound. The mine was designed to explode just as a ship, with its noisy engines and propellers, passed over it. The navy required some gadget that would replicate the sounds of a ship and that could be moved over the mine to set it off harmlessly.

The first step was to measure the underwater sounds given off by passing ships—not an easy task. No suitable microphone or recording equipment was available, so these had to be designed. The equipment had to be good enough to record every aspect of the sound, no matter how subtle, for frequent replay and analysis. After numerous setbacks, including flooded microphones and apprehensive ship captains, they succeeded by the end of the summer in recording the required ship sounds.

The next step was to come up with a device for generating underwater sounds that accurately duplicated those of a ship. The Naval Research Laboratory had several such devices and the British were already employing one of their own, though these were too heavy and awkward. Morse and his colleagues mulled over alternative design proposals until the fast-approaching competitive trials forced them to make a choice. Their decision was to rig together two parallel pipes, about four-feet long and a half-inch apart, to be towed crosswise. The aim was to simulate cavitation, that is, the noise made by a propeller moving rapidly in water. The device, much to everyone's dismay, made a loud buzzing noise that in no way resembled cavitation. None of the other test devices entered in the trials worked well either. The one consolation was that high-quality recordings of ship noise had been made. These were to prove quite useful in other ways, achieving particularly outstanding results in helping to counter acoustic torpedoes. (This will be described later.)

By this time, Morse had long since formed opinions concerning the important role civilian scientists could and should play in military operations analysis. He valued the special skills physical scientists and mathematicians could bring to the analysis of operational data, to the design and operational evaluation of new equipment, and to the development of tactical doctrine. It was in this mood, then, that Professor Morse accepted Captain Baker's invitation to head the group of civilian scientists Baker wished to assemble.

## The Emergence of ASWORG

It was in the later part of March 1942 when Captain Baker's plans began to solidify. With the aim of bringing together the best people available, various institutions, including NDRC itself, were approached. Morse—who became the first official member on 1 April—got personally involved in recruitment because he knew many of the top scientists at MIT, Columbia, Harvard, Cal Tech, Stanford, Princeton, and elsewhere. On loan from Bell Telephone Laboratories came Dr. William B. Shockley, who had designed the prototype of a submarine radar. (Shockley later received a Nobel prize for his work in solid state physics.) He was made both director of research and assistant supervisor, second only to Morse. The Harvard Underwater Sound Laboratory, which had done work for NDRC's Subsurface Warfare Section, offered a couple of high-caliber people. Other members were drawn from the Rockefeller and Carnegie Institutes; an array of insurance firms, such as Metropolitan and John Hancock; various manufacturing companies; the State Department, Bureau of Standards, and Federal Communications Commission; the army and navy; and from many other diverse quarters. Space for all the recruits was provided in the offices of Baker's Antisubmarine Warfare Unit, at the headquarters of the First Naval District in Boston.

Within days, the team had been formally titled the Antisubmarine Warfare Operations Research Group, or simply (but rather inelegantly) ASWORG. The name ASWORG was used by the navy and on classified reports; an alternative name, Research Group M ("M" for Morse), was used for administrative purposes and on unclassified reports. Columbia University was asked by NDRC to assume responsibility for the group, as a logical addition to a contract already in effect.[12]

On 1 May, a month after ASWORG's inception, there were still only seven scientists on the roster. The group grew slowly, taking on just a few newcomers a month, so that by the end of the year there were thirty members and by mid-1943, forty-four. Over the course of those initial days and weeks, the group's members began to meld—partly through the sharing of purpose—despite their assortment of professions: physicists, mathematicians, chemists, biologists, geologists, actuaries, and even a chess champion. As perhaps to be expected, however, the military personnel of Captain Baker's Antisubmarine Warfare Unit greeted the civilians with a great deal of skepticism. There were many among them who seriously doubted that scientists taken from outside the navy could provide any significant help. Indeed, it was deemed almost heretical.

The group was resolved, at the very least, not to be part of a "slit-in-the-wall" scheme, where projects of a highly limited scope would be fed to them and the results passed back, while they were kept isolated from the navy personnel. Morse and the others were nevertheless led almost immediately into a room where they were expected to pore studiously over a huge stack of action reports detailing encounters with German submarines. The consensus among the group's members, however, was that the reports would have to wait while the team took some time simply to think about the issues. Over the course of a week, they proceeded to formulate some theories concerning antisubmarine warfare.

They began with the deceptively simple notion that a major reason for the U-boat's menacing image was its relative ease at evading those who would locate it. Thus, the Allies' main task was to learn how to find the submarines. Two search methods were at their disposal. First, if the submarine were below the surface, sonar could be used; however, only specially fitted destroyers had this capability. Second, if the submarine were on the surface, planes could locate it. Because German submarines spent more time on the surface than below—to charge their batteries, take in air, and transmit messages—the group chose to direct their attention to searches by aircraft.

Several factors were evaluated, such as the distance at which a submarine on the surface could be spotted (visual sighting was used sometimes at day, but radar was generally employed both day and night). On the basis of quantitative data, a theory of search effectiveness took shape. Morse and his colleagues were able to figure out the area of ocean surface an aircraft could search in a given unit of time, and the number of aircraft required to search a particular area with a given probability of finding the U-boat. They subsequently worked out effective search patterns, both for planes and for sonar-carrying ships.

The next step was to verify certain assumptions and quantities associated with the theory. To accomplish this, the scientists needed actual operational data, not claims by equipment manufacturers or by test technicians. Now, it seemed, was the time to turn to the stack of waiting reports, from which such real-world data could supposedly be gleaned. To the group's chagrin, the reports left much to be desired. Few of the quantitative values needed had been recorded; moreover, those values that had been recorded were little more than guesses, and rather poor guesses at that.

The group therefore made what was to be a precedent-setting decision. Because of the inadequacy of the reports, ASWORG decided to try to obtain firsthand operational data at the source. When approached with the idea that members of the group be permitted to go to the antisubmarine bases, Baker—who already had his reputation at stake for bringing civilians into naval matters—balked. Surely, he countered, it would suffice to bring to the group some of the officers involved in antisubmarine operations, rather than vice versa. After further discussion, however, Baker conceded the point. This major concession marked the beginning of what came to be recognized as the key to ASWORG's—and later OEG's—effectiveness, namely, its field representative program.

Professor Morse carefully selected about half a dozen people to be assigned to various bases. Because of the delicacy of sending "civilian experts" to naval bases, the members' ability to get along with military personnel—in addition to their analytical competence—was a top consideration. Morse insisted that analysts not claim credit for anything, since they, in turn, took no responsibility for the ultimate decision made by a commander. Moreover, analysts were reminded of the importance of being polite and cooperative, given the tenuousness of their situation.

The care paid off, for the members quickly won the confidence of the aircrews and managed to ingrain in them the importance of recording accurate and complete data. They even flew on some of the missions. At last, ASWORG's theory of search effectiveness, expressed in mathematical form, could be fleshed out with the reliable values now being obtained. This enabled the group to provide Baker and the staff of the Antisubmarine Warfare Unit with precise search plans that increased the number of U-boat spottings.

## Sending Scientists to Naval Commands

At the end of May 1942, just a few weeks after everyone had settled into the Boston offices, Captain Baker was transferred to the Readiness Division of CominCh, to help install an antisubmarine warfare unit there.[13] It made sense, therefore, that Morse and the others go to Washington, too. During the following month, ASWORG was assigned to the headquarters of the staff of the Commander in Chief, U.S. Fleet (in the main Navy Building on Constitution Avenue), although a few members remained in Boston. Admiral Ernest J. King—who was both CominCh and the Chief of Naval Operations—and his staff were more than a little taken aback to see they were to deal with civilian scientists rather than naval officers or, at the very least, civil servants. But the impressive start the group had gotten off to in Boston helped to allay their discomfort.

From the outset of this new affiliation, more and more members of ASWORG were given the opportunity to observe combat operations first-hand. In June, the same month ASWORG moved to Washington, Shockley and Arthur F. Kip visited the headquarters of the Gulf Sea Frontier in Miami. Just the month before, four U-boats had sunk a startling forty-one ships of 220,000 gross tons, the most recorded for any area. The need for some kind of support was evident. Kip, assigned to work with the frontier's antisubmarine operations officer, was granted access to detailed operational records and took part in the planning of operations.

Less than a month later, on 1 July, ASWORG installed some of its people at the Eastern Sea Frontier in New York, reporting to the frontier's antisubmarine warfare unit. This assignment enabled the members to form a closer relationship with the First Bomber Command (later the Army Air Force Antisubmarine Command, or AAFAC). Among its other duties, the command employed its long-range bombers to patrol the East Coast for German submarines. ASWORG staff visited a number of army air fields, including Langley Field, Virginia, where Colonel W. C. Dolan was overseeing operational testing of tactics and equipment and the training of new squadrons in the specialized tasks of antisubmarine warfare.

Also in July, Shockley went to the Caribbean Sea Frontier, accompanied by Robert F. Rinehart, who was then assigned to the operations officer at the headquarters in San Juan, Puerto Rico. Later, Rinehart was transferred to the frontier's headquarters in Trinidad. This area, particularly the eastern approaches to Trinidad and the Windward Passage, accounted for over half the losses in the U.S. Strategic Area for August. A group of about five U-boats sank twenty-three ships east of Trinidad, and fourteen more between Key West and Trinidad and between Panama and Guantanamo. The following month, attacks on merchant vessels remained quite high, particularly in the inner area (Figure 1-6). From one to three ASWORG members were eventually assigned to the Caribbean Sea Frontier, collecting and publishing statistical records and working out the details of submarine hunts. The valuable information they garnered included data on the operational characteristics of airborne search radars and on radar antisubmarine countermeasure equipment.

Other members were assigned to sea frontiers outside the continental United States. In November, Maurice E. Bell and John R. Pellam went to the base at Argentia, Newfoundland, to help pave the way for a new assignment. They visited the headquarters of Commander Task Force 24, who was in charge of the escort vessels that protected transatlantic convoys transiting through the U.S. Strategic Area. Soon after this trip, ASWORG was asked for a scientist to work with the task force. Foster L. Brooks was sent to Argentia in mid-December, where he helped organize statistics on the U.S.-British convoy system. (The assignment ended in April 1943 when Britain and Canada took over complete responsibility for protecting the North Atlantic convoy routes.)

In January 1943, Vice Admiral Jonas K. Ingram, Commander Fourth Fleet, requested that a member of the group be assigned to the fleet's headquarters at Recife, Brazil. Ingram had command of the antisubmarine forces in the South Atlantic, where submarine activities had escalated dramatically. Jacinto Steinhardt—a member of ASWORG for just a couple of months—first went to Trinidad to acquire some experience with Rinehart and then proceeded to Recife on 1 March. John B. Lathrop joined him there the next year, and together they took an active part in laying out barrier patrols and antisubmarine searches. Their work contributed to the sinking of several U-boats and of a few surface vessels that tried to run the blockade with vital war materials from Japan.

Pellam, who earlier had helped set up the Argentia assignment, was himself sent to the Moroccan Sea Frontier at Casablanca, North Africa, in May 1943. His main contribution involved helping to lay a barrier of radar-equipped planes and destroyers to seal off the Strait of Gibraltar. Three U-boats were trapped in the Mediterranean by the barrier, and many others were kept out. The scientists also devoted much of their time studying data on U-boat operations between Spain and the Azores. Their analysis concluded that U-boats in the region seldom made use of radar, which turned out to be important in the selection of tactics and equipment for countering the submarines.

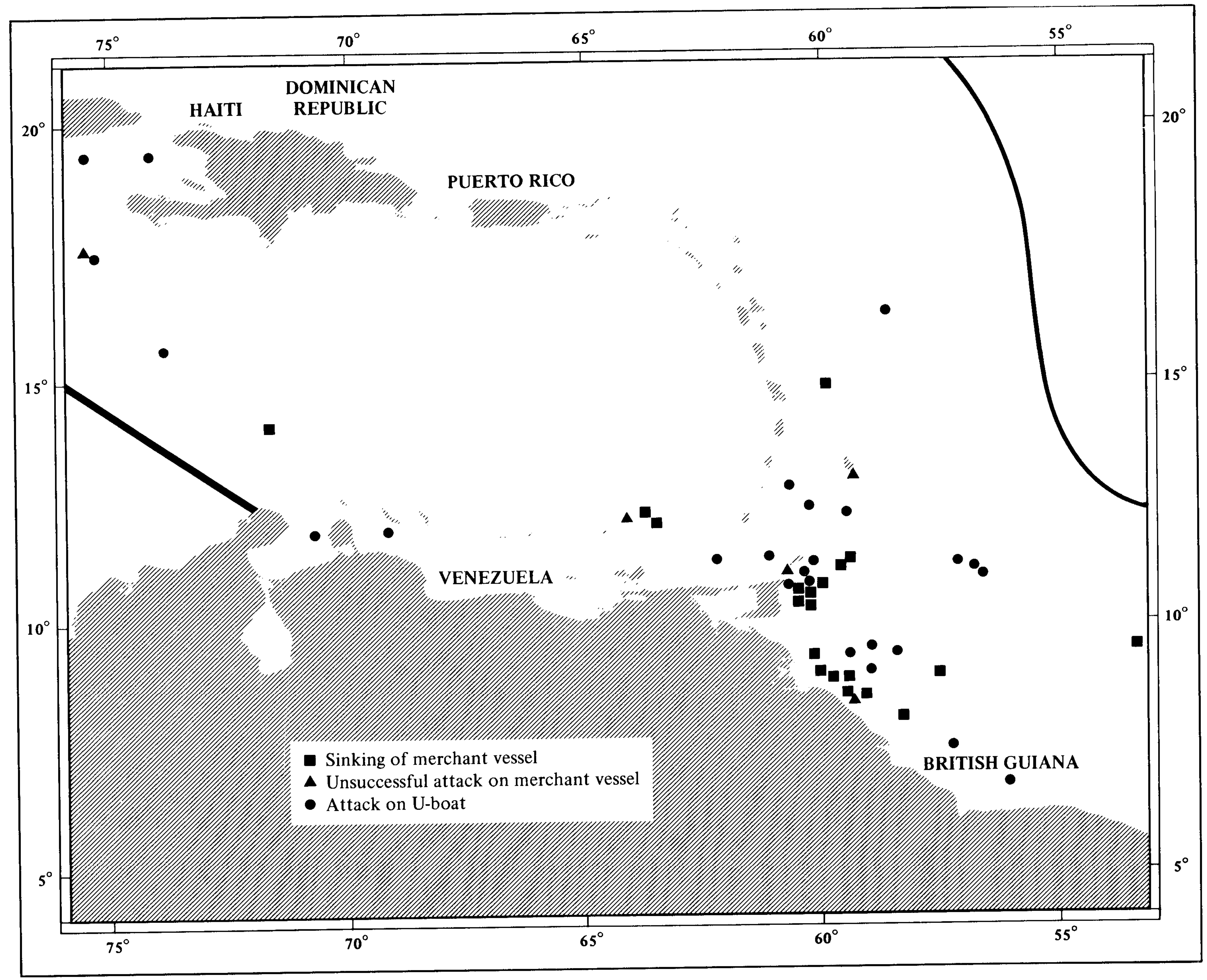



Figure 1-6. Attacks on Merchant Vessels and U-boats in Caribbean Sea Frontier (Inner Area) for September 1942

Quonset, Rhode Island, became the site of the Atlantic Fleet's Antisubmarine Development Detachment, established in June 1943. Here, new equipment could be tested, operational data gathered, tactics developed for employment of the equipment, and training programs worked out. It was decided that members of ASWORG would be of use at the detachment, to design tests and analyze results. At least two analysts remained attached to the air section, and at least two others to the surface ship section (which later moved to Fort Lauderdale, Florida).

The base assignments described above represent, of course, only a fraction of all of those actually made. Figure 1-7 lists all the bases—including those in the Pacific—that had ASWORG members attached to them and shows the manpower levels attained at each over the course of the war. Specific field assignments for all group members appear in Figure 1-8, with members listed in the order they joined ASWORG; both the location and duration of each assignment are given.

In addition to the regular assignments to the operational commands, a number of short-term assignments, usually to study specific problems, were necessary. One member, for example, went on a carrier cruise in the Atlantic to obtain hitherto unavailable information on carrier antisubmarine operations, while another deployed with a submarine to record the technical difficulties encountered in sinking Japanese shipping. Yet another member was stationed for several weeks aboard a variety of surface ships near Okinawa, during the time that the kamikaze attacks were peaking. His observations provided a basis for developing tactics to defend against these suicide missions and gave laboratories the feedback they otherwise would have lacked concerning the performance of new equipment under combat conditions. (Some of the work conducted in the field—as well as that done in Washington—will be described more fully later in this chapter.)

Without doubt, a sizable portion of ASWORG's noteworthy work during those early years was achieved in the field. Firsthand contact with the men and machines doing the fighting was relished by the field representatives and helped them build up a store of practical knowledge. Although the practical lessons took a while to filter back to Washington headquarters, they were clearly vital to the central group's ability to offer sound advice to the navy. Also, the close proximity of field analysts to actual operations permitted them to recognize problems and to see the need for new or modified tactics or equipment more readily than they could if detached from the scene. Being on the scene, they were able to get solutions into the hands of commanding officers more quickly. Finally, changes in enemy tactics were most often discovered by analysts at the outlying bases.

A policy of rotating Washington-based analysts and field representatives was instituted at the very launching of the field program. Thus, the Washington office benefited from the influx of new perspectives gained

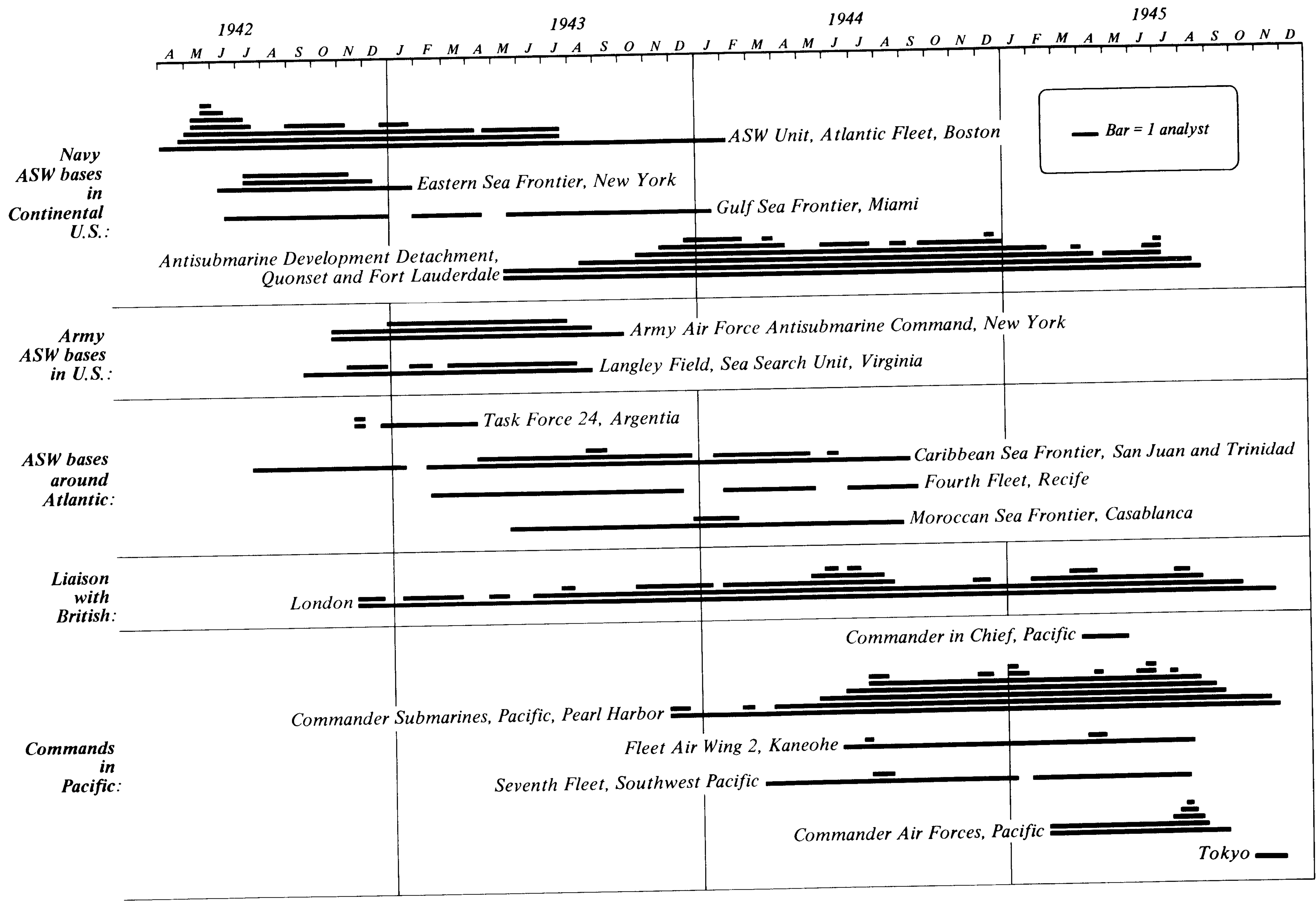



Figure 1-7. ASWORG Manpower Levels at Operational Commands

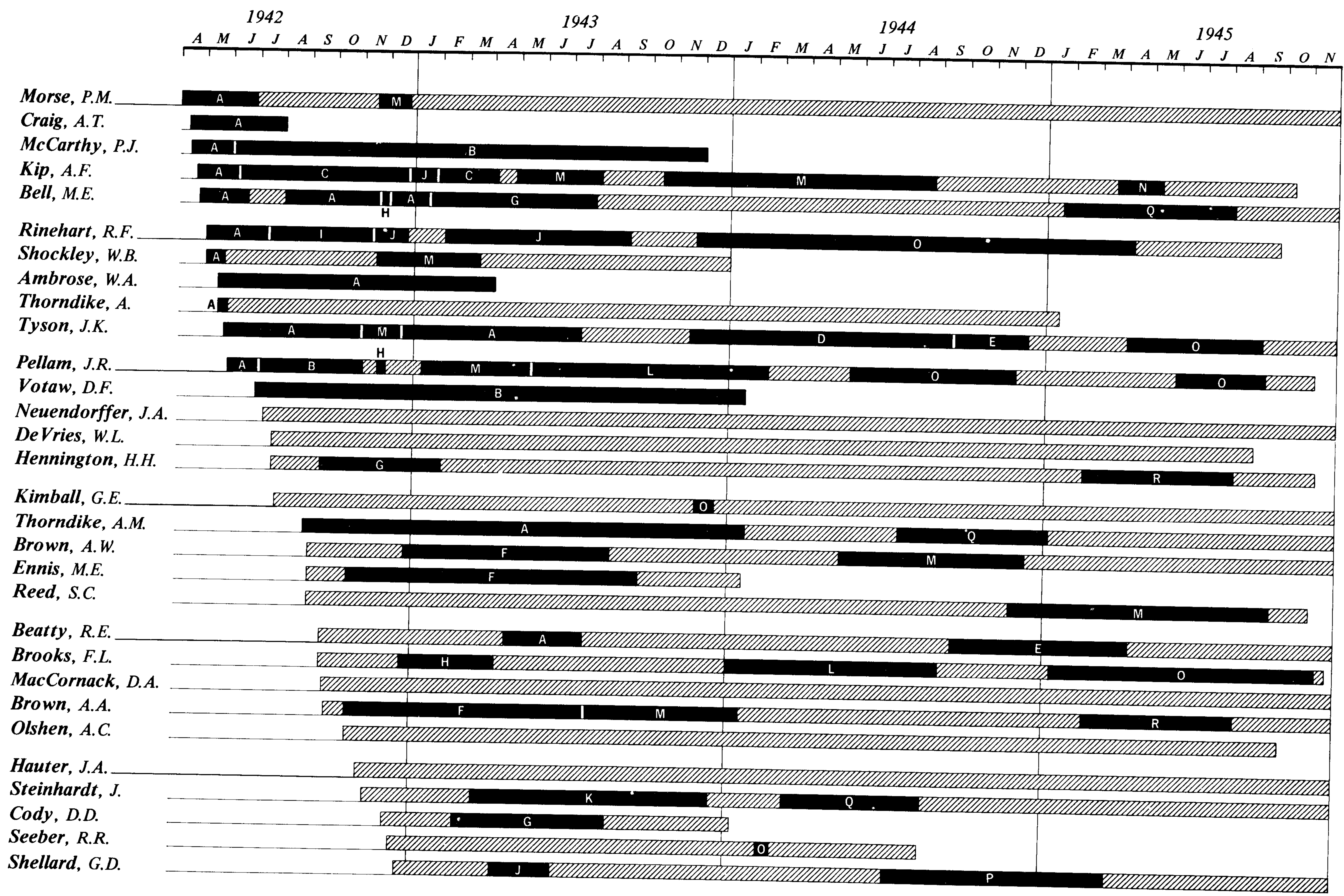
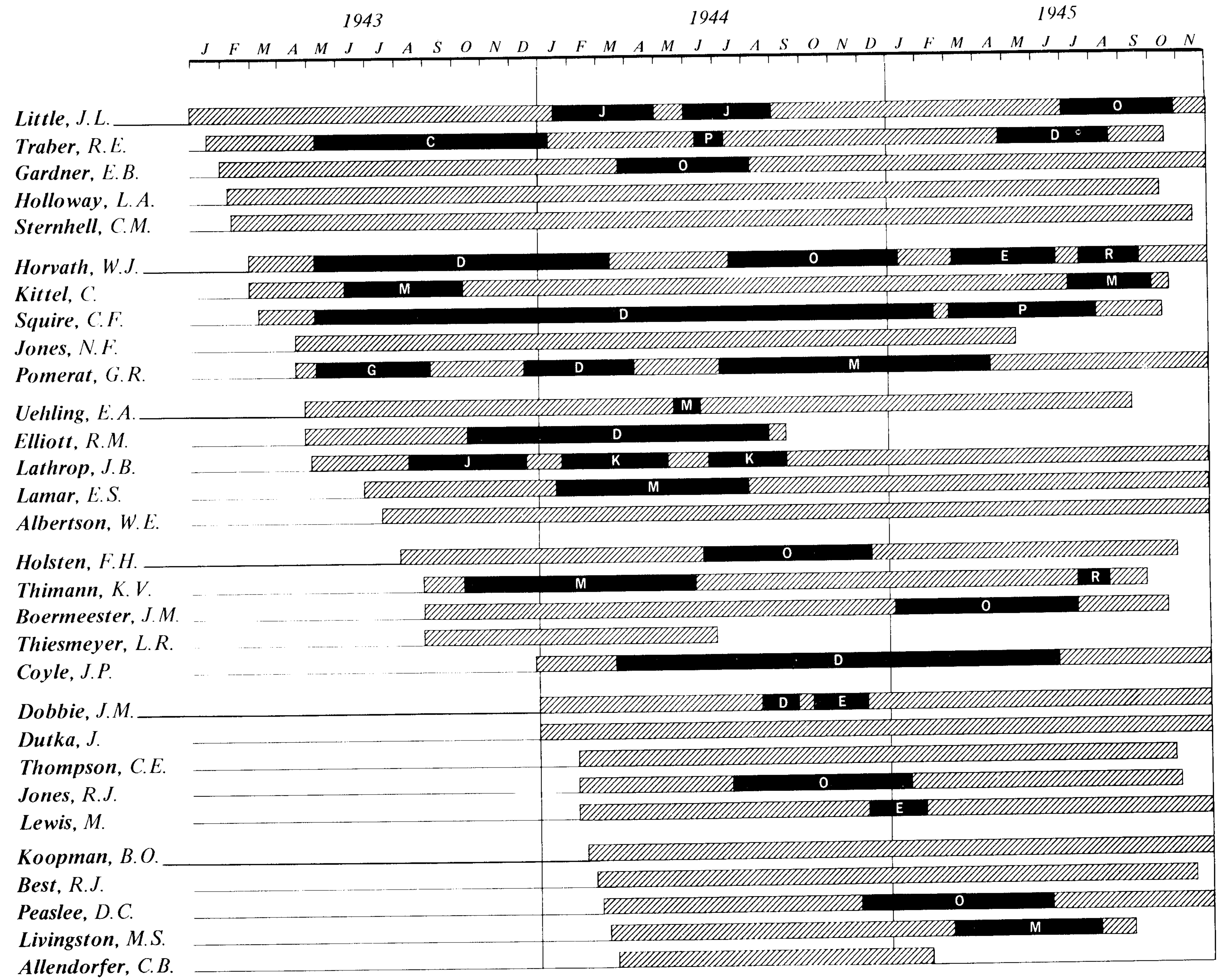
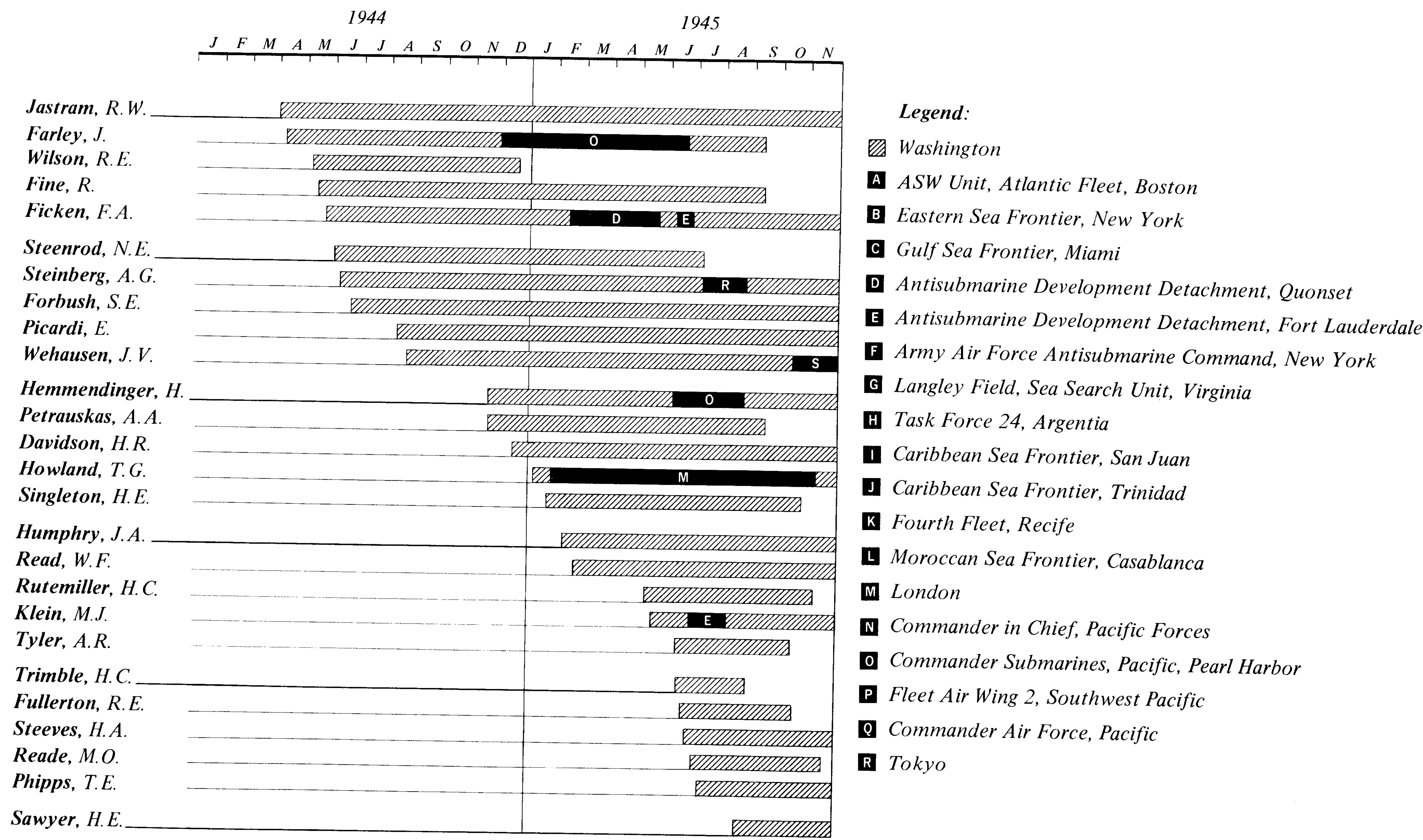



Figure 1-8. Field Assignments for ASWORG Members during World War II


1943
1944
1945
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N
Little, J.L.
Traber, R.E.
Gardner, E.B.
Holloway, L.A.
Sternhell, C.M.
Horvath, W.J.
Kittel, C.
Squire, C.F.
Jones, N.F.
Pomerat, G.R.
Uehling, E.A.
Elliott, R.M.
Lathrop, J.B.
Lamar, E.S.
Albertson, W.E.
Holsten, F.H.
Thimann, K.V.
Boermeester, J.M.
Thiesmeyer, L.R.
Coyle, J.P.
Dobbie, J.M.
Dutka, J.
Thompson, C.E.
Jones, R.J.
Lewis, M.
Koopman, B.O.
Best, R.J.
Peaslee, D.C.
Livingston, M.S.
Allendorfer, C.B.


1944
1945
J F M A M J J A S O N D J F M A M J J A S O N
Jastram, R.W.
Farley, J.
Wilson, R.E.
Fine, R.
Ficken, F.A.
Steenrod, N.E.
Steinberg, A.G.
Forbush, S.E.
Picardi, E.
Wehausen, J.V.
Hemmendinger, H.
Petrauskas, A.A.
Davidson, H.R.
Howland, T.G.
Singleton, H.E.
Humphry, J.A.
Read, W.F.
Rutemiller, H.C.
Klein, M.J.
Tyler, A.R.
Trimble, H.C.
Fullerton, R.E.
Steeves, H.A.
Reade, M.O.
Phipps, T.E.
Sawyer, H.E.
O
D
E
R
S
O
M
E
Legend:
Washington
A ASW Unit, Atlantic Fleet, Boston
B Eastern Sea Frontier, New York
C Gulf Sea Frontier, Miami
D Antisubmarine Development Detachment, Quonset
E Antisubmarine Development Detachment, Fort Lauderdale
F Army Air Force Antisubmarine Command, New York
G Langley Field, Sea Search Unit, Virginia
H Task Force 24, Argentia
I Caribbean Sea Frontier, San Juan
J Caribbean Sea Frontier, Trinidad
K Fourth Fleet, Recife
L Moroccan Sea Frontier, Casablanca
M London
N Commander in Chief, Pacific Forces
O Commander Submarines, Pacific, Pearl Harbor
P Fleet Air Wing 2, Southwest Pacific
Q Commander Air Force, Pacific
R Tokyo

from experience, and field members caught up with new developments (especially in terms of refined methods of analysis) at home. To formalize the policy, it was expressly stipulated to each field command upon a request for a group member that the member would be assigned for no more than six months. In setting the six-month rule for all tours of duty, ASWORG ensured that pressure from the commanding officer at the base would not cause the same member to be committed to the base for the duration of the war. Emphasis on this cycle between headquarters and the field distinguished ASWORG from other attempts at operations research in the United States at that time.

It was at the Washington office that the practical knowledge acquired in the field was consolidated and used to develop new doctrine or to support suggestions for new equipment. The information that arrived from the various base representatives provided the centrally located analysts with an overview of antisubmarine operations, which could then be passed on to higher echelons in the navy's command structure. The theoretical and statistical work done in Washington was essential to back up efforts in the field and to bring the results of the group's projects before the planning officers and the laboratory scientists. Some analysts, in fact, were so outstanding at the theoretical work that they were never (or rarely) sent to the field. Also, the Washington office was able to correlate these results and return them to the bases so that field analysts could see how things were going in other areas.

A study conducted in 1943 showed the Washington office's unique ability to address a particularly pressing concern. Intelligence reports had revealed that Germany was supposedly equipping its U-boats with a new weapon, an acoustic torpedo designed to head straight for a ship's propellers. (The United States was still in the throes of developing an acoustic torpedo of its own at the time the news broke.) Because escort destroyers emitted a great deal of noise, they were thought to be especially vulnerable, which caused the navy considerable worry. Hence, it was decided that ASWORG should learn what it could about the new weapon—with the hope that one could be captured intact—and develop countermeasures as quickly as possible. The Washington office had a head start in understanding some of the scientific principles involved, as a result of underwater sound measurements taken by Professor Morse and others in 1941 to help the navy deal with acoustic mines.

Morse recalled the fortuitous turn of events that followed the start of the project:

> At about that time, one of . . . the Navy's task forces was lucky enough to catch a submarine on the surface and disable it so that it couldn't submerge, and got aboard fast enough so that it couldn't be scuttled. They captured the submarine and its crew and brought it to

> Washington. The submarine didn't have acoustic torpedoes aboard, but one of the torpedo men had seen an acoustic torpedo displayed. This was probably for morale purposes. The submariners at the time were beginning to get a little bit depressed about their ability to keep up with some of the things we had been doing, and the idea of a new torpedo that would follow the ship's sound and infallibly sink the ship was one that was supposed to raise the morale of the submarine crews. He had seen an acoustic torpedo displayed—the outer casing of the nose was taken off, and you could see the size of the detection devices. Also, the man displaying it would tap one side, causing the rudder to turn sharply to that side, and similarly with the other side. Then, with the sound gone, the rudder would go back to neutral.[14]

ASWORG began meticulously to put the pieces of the puzzle together, under the direction of Edwin A. Uehling. Based on what it did know, the group estimated that the torpedo—designated the T-5—responded to sound between 20,000 and 30,000 cycles per second. The torpedo's trajectory and turning radius could also be estimated, given the fragmentary intelligence available. The fact that the torpedo ran off batteries enabled the group to determine its speed, estimated to be about 25 knots. Other assumptions had to be made concerning the torpedo's firing and homing range and its sensitivity to sound approaching from near the stern. (Some of the estimates were later verified, either by other prisoners of war or by captured torpedoes.)

Once these basic values were established, Uehling plotted the tracks the torpedo might follow under various conditions. He then adjusted these tracks to allow for a decoy, towed, say, a couple of hundred yards behind the targeted ship. After considering alternatives, Uehling concluded that the ideal instrument for drawing the torpedo away from the ship and toward itself would be the same parallel pipes Morse and the others had designed almost two years before to duplicate a ship's cavitation noise. Uehling correctly estimated that with shorter pipes, the frequency of the resulting noise was right for the gadget's new-found role as decoy. The navy agreed to have the noisemaker, called the FXR, placed on escorts, to be towed as soon as U-boats were thought to be near. A depressor would keep the noisemaker beneath the wake of the ship.

By this time, the Germans had indeed begun to use acoustic torpedoes; the decoy, therefore, was ready none too soon. The loud buzzing noise successfully diverted the torpedoes from their intended targets and saved many ships:

> We heard, after the war, that the U-boat crews were terrified by the loud buzzing of the pipes. They called them "singing saws" and were sure they were some powerful, dangerous weapon. Because of our quick reaction, the Germans never achieved the success they expected

> from their new torpedo. As usual with any innovation that does not succeed quickly, the submariners came to distrust it and used it less and less.[15]

Of the thirty-four escorts and nineteen merchant ships thought to have been sunk by acoustic torpedoes (Figure 1-9), very few were using the noisemaker. Moreover, the need to tow the device any time a ship was in

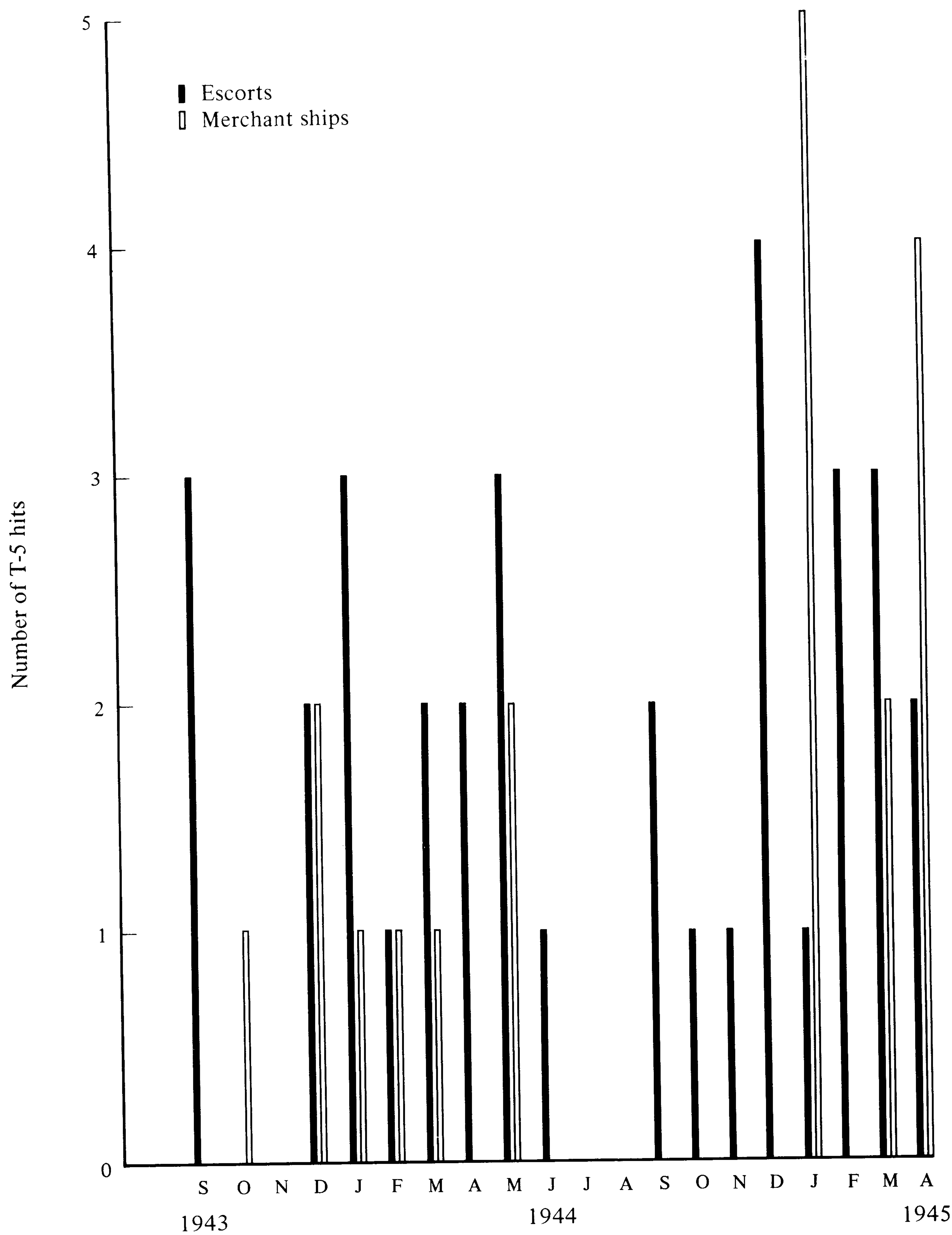



Figure 1-9. Number of Hits by German Acoustic Torpedoes (by Month)

dangerous waters was underscored by the frequency with which U-boats remained undetected until less than twenty-five hundred yards away, a range that would have precluded the successful use of any other countermeasure.

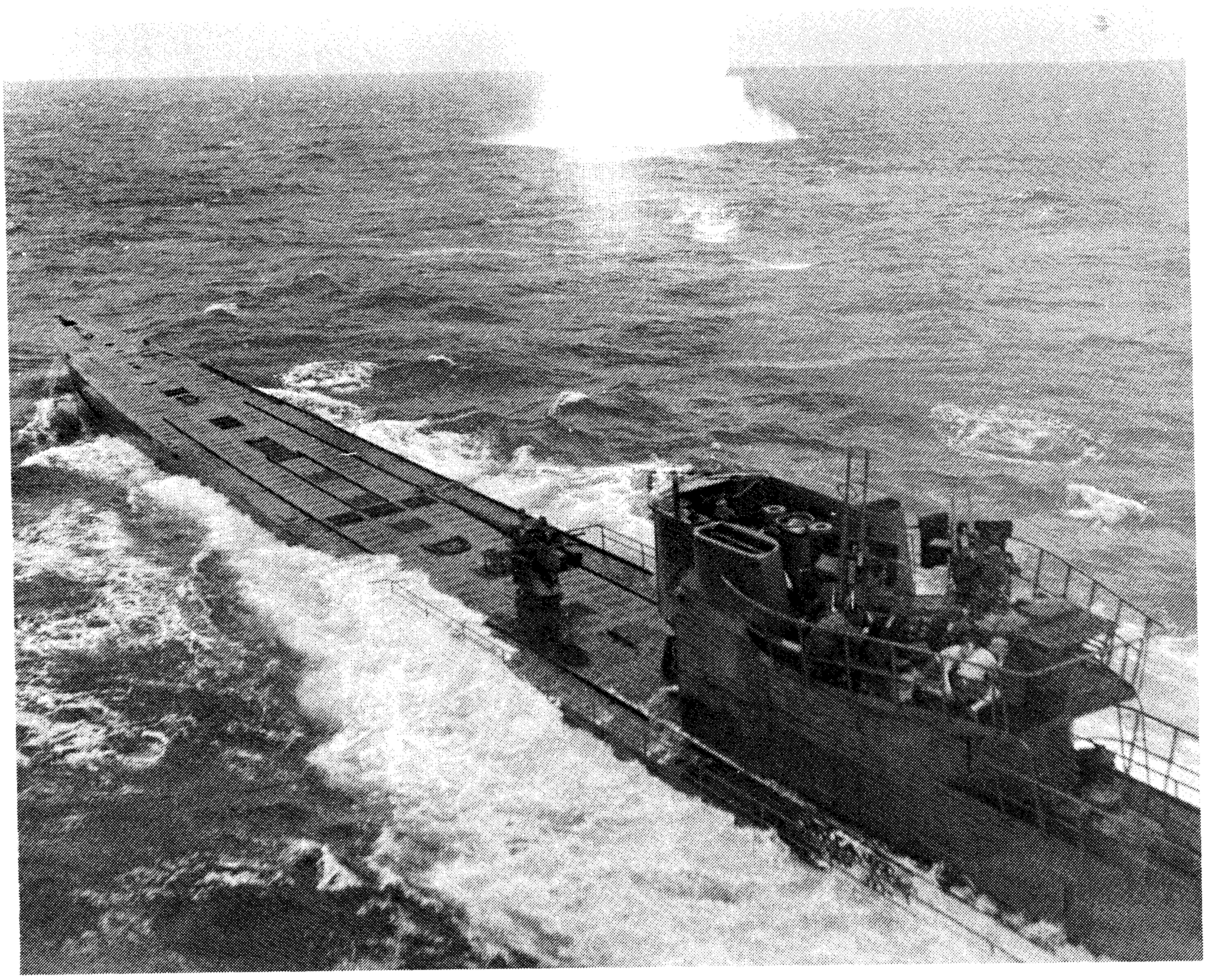
**Contact with the Army Air Forces**

ASWORG's relationship with the Army Air Forces began soon after group members were assigned to assist the Eastern Sea Frontier in New York. The sea frontier's headquarters happened to be housed in the same building as the staff of Brigadier General Westside T. Larson, commander of the First Bomber Command. More important, the command's long-range antisubmarine bombers had been placed under the frontier's operational control. Consequently, Shockley and other group members visited several of the command's airfields to acquaint themselves with the antisubmarine problems being encountered.

A short time later, the group made the acquaintance of Edward L. Bowles, scientific advisor to the Secretary of War. Bowles felt that ASWORG should learn more about the use of airborne radar in daytime as well as in nighttime searches for surfaced submarines, and he therefore introduced the group to Brigadier General H. M. McClelland, director of technical services of the Army Air Forces, whose staff knew very well the problems in this area. McClelland was made a liaison officer for ASWORG in December 1942, as was Larson in April 1943.

The army established a Sea-Search Attack and Development Unit (SADU) at Langley Field, Virginia, in June 1942 as one means of dealing with the tactical and equipmental problems associated with aircraft antisubmarine operations. Run by Colonel W. C. Dolan, the unit was placed under the control of McClelland's office rather than under that of the First Bomber Command, to free it from complicated command channels. At the beginning of September, ASWORG sent one of its scientists, Howard H. Hennington, to work with Dolan. Within a few weeks, two more members were assigned: Maurice Bell, who transferred from the Antisubmarine Warfare Unit in Boston, and Donald D. Cody.

These three ASWORG representatives worked on several projects at Langley. They helped develop tests of tactics and recorded the results, planned exercises to assess the performance of aircrews and equipment during the low-level bombing runs typical of antisubmarine attacks, and prepared tests to evaluate diverse antisubmarine gadgetry, such as sonobuoys, searchlights, forward-firing rocket flares, bomb sights, and odographs (an instrument for automatically plotting the course and distance traveled by the plane). Also, a full-dress tactical test, supervised by Cody, was conducted at Key West, Florida, to determine the operational use of the magnetic anomaly detector (MAD), a device for detecting distortions of the



Depth-charge attacks by U.S. Army B-25s and Navy Liberators produced a sure kill of this U-boat caught on the surface. (Official U.S. Navy photo.)

earth's magnetic field caused by the presence of a submarine. Finally, an army manual was prepared on the use of radar in sea searches.

In the fall of 1942, Brigadier General Larson asked that more ASWORG analysts be assigned to command headquarters. At about that time, the First Bomber Command changed its name to the Army Air Force Antisubmarine Command (AAFAC). Arthur A. Brown and Malcolm E. Ennis went to AAFAC headquarters in October, and Arthur W. Brown joined them in December. They worked on a variety of projects related to training procedures and equipment. One such project involved a study of alternative bomb sights for use in antisubmarine missions. Based on recommendations by the group, efforts to develop suitable sights got under way at Wright Field and other locations.

Additionally, a procedure was developed for obtaining aerial photographic coverage of antisubmarine attacks, and a set of grids were prepared for determining distances on the water's surface. In the case of aircraft attacks on U-boats, for example, it was possible to obtain from proper photographs the size of bombing errors and whether any bomb was within lethal radius, the spacing of depth charges and their underwater path, the rate of climb following the attack, certain dimensions of the U-boat, and other such vital information. Occasionally, the analysts accompanied AAFAC staff members on inspection trips, which gave them the opportunity to give specialized advice on the spot.

That winter, AAFAC formed an antisubmarine operational training unit, the 18th Squadron, at Langley Field. In response to a request by the squadron commander, Lieutenant Colonel R. W. Finn, ASWORG's Gerard R. Pomerat was sent there in May 1943 and assisted them throughout the summer. He helped set up training flight schedules and standards for bombing exercises. In addition, he began to put together an antisubmarine training film just before the unit was disbanded in the fall.

**Relations with British Operations Research Groups**

In the fall of 1942, ASWORG's director, Professor Morse, decided it was time for him and Shockley to visit England. They had gotten a good grip on American antisubmarine efforts and felt such a trip would be profitable. Furthermore, Morse wished to get together again with P. M. S. Blackett, whom he had met at Cambridge before the war.

A more critical reason for the visit arose after initial arrangements had been made in November. After France had been defeated in June 1940, German submarines began to make use of ports on the French coast—mainly Brest, Lorient, St. Nazaire, and Bayonne (Figure 1-10). The Germans would build the U-boats in the Baltic, then send them to bases in the Bay of Biscay from which their patrols would originate and to which they would return for repairs, supplies, and rest. Britain was therefore obliged to devote as many aircraft as it could to patrol the Bay. Subsequently, Coastal Command asked the United States to buttress British operations in the Bay by sending over as many bombers as could be spared.

The U.S. Navy could not meet the request right away, so the U.S. Air Force filled in, employing its long-range B-32 Liberators. By the fall of 1942, however, the navy's supply of aircraft had increased and the air force's stopgap role ended. Concurrently, it was decided that the U.S. Army Air Forces could spare a couple of squadrons from the newly established First Antisubmarine Army Air Command, an offshoot of the First Bomber Command. The first squadron, commanded by Lieutenant Colonel Jack Roberts, was delivered to St. Eval in Cornwall, England, on 1 November and placed under the operational control of the British. Shortly thereafter, two U.S. Navy squadrons were sent to operate from Iceland, under control of Coastal Command.

In November 1942, as Morse and Shockley were making final preparations to leave for England, Larson, commander of AAFAC, asked them to provide technical assistance to the squadron in Cornwall. So, with this additional assignment, Morse and Shockley took off for London. Their

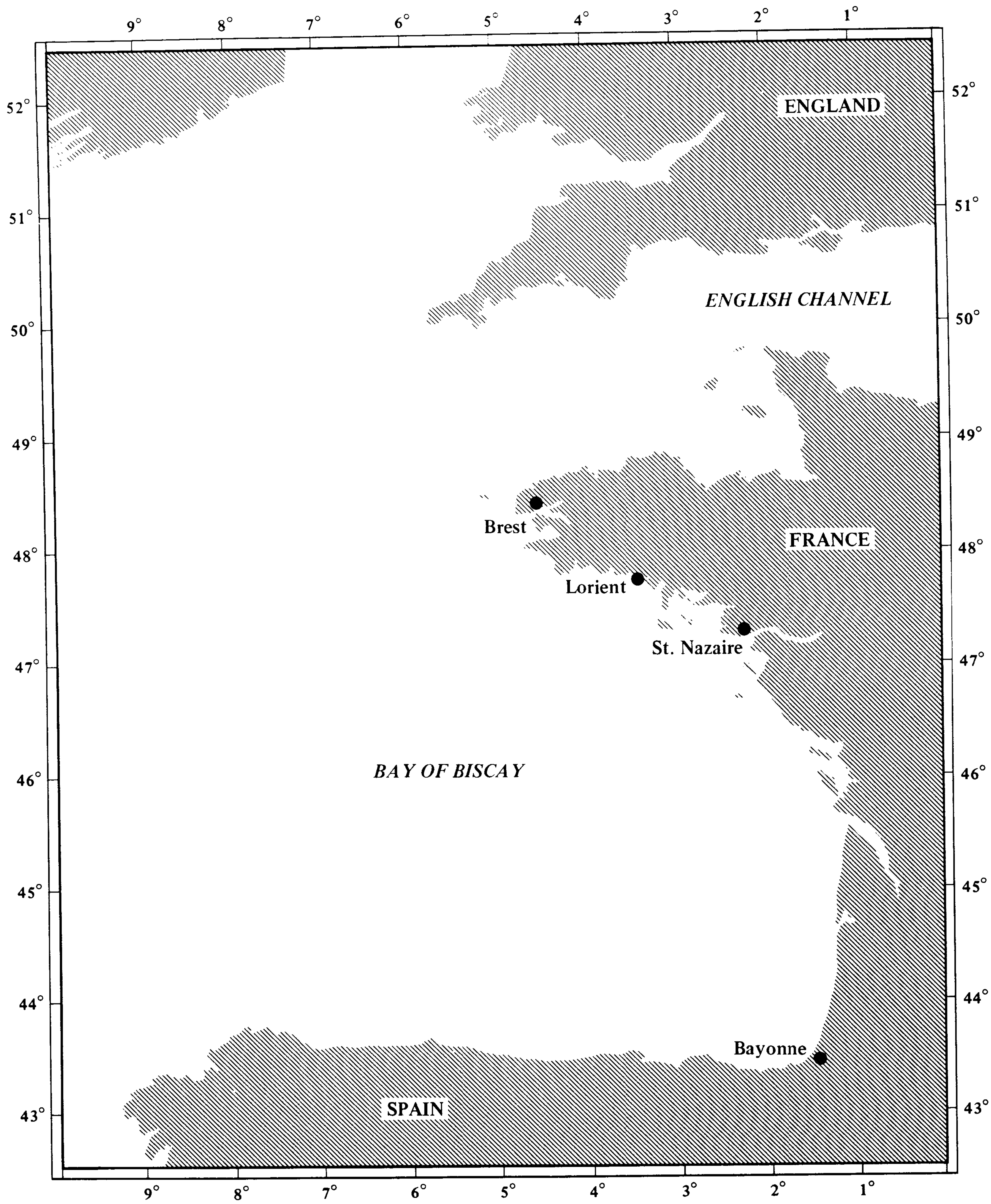



Figure 1-10. U-boat Bases in Bay of Biscay

route was circuitous, with stops in Bermuda and the Azores before arriving in Lisbon. After a day in Lisbon, they proceeded to London on a transport plane.

Their schedule, which Captain Baker had helped put together, called for them to report to the naval attache's office, where they were assigned to Captain T. A. Solberg, head of the Technical Section. There, they met other American civilian scientists who had come over in behalf of various organizations, such as the Naval Ordnance Laboratory and the Bureau of

Ships. Solberg was very helpful in arranging contacts with key people, as was the head of the NDRC London office, Bennett Archambault. To make it easier to acquire travel authorizations, Morse and Shockley were officially regarded as representatives of NDRC, which resulted in their reporting to Archambault as well as to Solberg.

Morse did get to spend some time with his former associate, Blackett, who at the time held the title of chief advisor on operational research to the first sea lord of the Admiralty. (Later, Blackett became director of naval operational research.) Blackett shared much information concerning his investigations into the behavior of U-boats and talked about his work in operations research in general. Morse and Shockley also made contact with Captain Philip Clark, director of antisubmarine warfare, and with others who worked on operational problems of antisubmarine warfare. These meetings with Admiralty people were especially important because the Admiralty had operational control of antisubmarine warfare. It routed the convoys, controlled destroyer escorts on the British side of the Atlantic, and managed employment of Coastal Command's antisubmarine aircraft.

Next, Morse and Shockley visited the headquarters of Coastal Command, where they were introduced to the director, Air Chief Marshal Philip Joubert, and to the head of the Operational Research Section, Professor Williams. At this meeting, they discussed the various problems of AAFAC's squadron of B-24s stationed at Cornwall. It turned out, for example, that this was the first squadron of antisubmarine planes in England to be equipped with the new S-band radar. This fact caused some complications because British plans (such as their arrangements for blind landings) were centered around the longer-wave ASV Mark II radar. Also, the squadron had been hastily assembled, and aircrews were not adequately trained in using radar. The capabilities of the S-band radar were therefore not being fully exploited.

It was agreed that Shockley would spend most of the rest of his time in England with the squadron, until it could establish itself more firmly. The squadron had been given the role of patrolling the Bay of Biscay by day, because Coastal Command had recently been so successful at night, using radar and searchlights, that a percentage of the U-boats were forced to return to daytime operations. A few days after Shockley arrived at the squadron, he witnessed a problem that was to reinforce ASWORG's conviction that its emphasis on the field program—by which the activities of operating forces could be observed closely—was warranted. One of the planes had sighted a surfaced U-boat and eagerly made its attack run. The crew was mortified to discover, however, that it could not release its depth charges. A second run was just as futile, and by the third attempt the U-boat had dived to safety. On returning to base, the crew found that moisture in the air had caused the releasing mechanism to rust and jam.

Two days later, the crew went out on another patrol, this time with the mechanism well lubricated. However, not only did the crew fail to find another submarine, but they crashed while trying to wend their way back to base in a dense fog.

Analysis, of this episode and others, revealed an interesting fact. That is, on the average, an aircrew had just one opportunity to kill a submarine before its own members were either killed or wounded or at least moved on to another assignment. An aircrew thus had little or no opportunity to learn on the job. Hence, efficient and effective methods of conducting antisubmarine warfare from the air could be developed only by operations research analysts—such as those who made up ASWORG—evaluating data taken from a large number of past missions.

In the meantime, still other meetings were being arranged for Morse during his stay in England. An important result of these meetings was the setting up of links between ASWORG and the Operational Research Section (ORS) of Coastal Command. Instrumental in making these links possible was J. P. T. Pearman, a prominent member of ORS who was already familiar with ASWORG's research program. Pearman had been sent to the United States early in 1942, to support the group's antisubmarine efforts in the Caribbean. During that trip, he devoted considerable time to familiarizing ASWORG members with the operations research work being done by Coastal Command. He returned to England in the fall, in time to lend a helping hand to Morse and Shockley.

Finally, Blackett arranged for Morse to visit Colonel (later Brigadier) B. F. J. Schonland, head of the Army Operational Research Group. This was followed up by a visit to a section of Schonland's analysts assigned to the Eighth Bomber Command, United States Army Air Forces, where Morse got to examine some of the operational problems being addressed.

Morse returned to the United States right after Christmas of 1942; Shockley stayed on another month. Their tour of British operations research facilities led them to conclude that at least two people from ASWORG should remain in England to maintain ties with their British counterparts. The two representatives were to be under the direction of Solberg, assigned to Commander Naval Forces in Europe. The British concurred that one of the two should work closely with the Operational Research Section of Coastal Command, and the other with operations analysts at the Admiralty.

### The Switch to Tenth Fleet

By the end of 1942, several significant weaknesses in the Allied antisubmarine campaign had become apparent, among them the division of responsibility between the United States and Britain for battling U-boats in the Atlantic. As Figure 2-5 shows, there was a line drawn down the middle of the Atlantic, where operational control transferred from one country to the other. Tactics, gunnery instructions, signals, and many other procedures differed between the two navies, lowering efficiency.

The desire for uniformity was felt on both sides of the Atlantic. In September 1942, Air Chief Marshal Philip Joubert, head of Coastal Command, proposed "a single supreme control for the whole anti-U-boat war, with a central planning staff to coordinate the separate and often conflicting policies of the British, Canadian, and American naval and air authorities."[16] Captain L. Hewlett Thebaud, U.S. naval control officer at Londonderry, made similar recommendations. Three conditions made such a far-reaching proposal impossible, however. First, because command of all forces and their operations would have to fall to a British admiral, such an arrangement would be politically intolerable to the United States. Second, the Americans and British disagreed about what were acceptable procedures, with each striking a different balance between innovation and tradition. Third, the United States had to rotate its antisubmarine units between the Atlantic and Pacific oceans. This meant that American forces would have to contend with a double system—the joint British/American system in the Atlantic and the strictly American system in the Pacific. Two inter-Allied boards were formed to consider these issues; one was to review the situation and offer suggestions, the other was to come up with specific uniform procedures. Both boards soon dissolved, however, with virtually nothing settled.

By the spring of 1943, Admiral Ernest J. King knew that a central planning and operational authority was essential, if only for American forces. Examples of divided authority abounded. Typical was the situation faced by the First Bomber Command, where all the squadrons were initially placed under the operational control of the Eastern Sea Frontier. A few of the squadrons were later based in England, attached to Coastal Command. Still other squadrons were sent to Africa, under yet another command. Finally, the First Antilles Air Task Force (later the Antilles Air Command) of the Army Air Forces transferred squadrons to the Caribbean Sea Frontier. Yet nothing was done to unify these dispersed forces. Some Army Air Force officers did advocate placing all of the army's antisubmarine forces under the control of the Antisubmarine Command, but they did not push the proposal. Training might have improved if the plan had been implemented, but operational control of the aircraft would have remained splintered. Furthermore, the relative autonomy of the sea frontiers would have remained an impediment.

Admiral King decided, therefore, to convene a conference in Washington, D.C., to survey possible solutions to the problem. Meeting on 1 March 1943, in the Federal Reserve Building, the conference was attended by Admiral Sir Percy Noble of the Royal Navy, chief of the British Admiralty delegation in Washington and highly influential in Britain's antisubmarine war. The American delegation was led by Admiral Richard S. Edwards. In an opening speech, King underscored his conviction that the convoy system was still the most effective way of dealing with the U-boat menace: "A ship saved," he said, "is worth two built!"

Meanwhile, the situation in the Atlantic worsened. The U-boats were trying every ploy: attacking from many directions, at night and at periscope depth, in an effort to confuse radar; using decoys to lure the escorts away from the convoys; transmitting fake messages to the convoys; and so on. During the first twenty days of March, over half a million tons of shipping was sunk. Doenitz made note of the tremendous indent his wolf packs were making: "After three and a half years of war, we had brought British maritime power to the brink of defeat in the Battle of the Atlantic–and that with only half the number of U-boats which we had always demanded."

At the conference table, valuable ideas were being put forth, and two important changes resulted. One was the increased use of carriers to protect merchant shipping; another was the formation of hunter-killer groups. But the conference failed to achieve its main aim, which was to submit a plan for unifying the diverse antisubmarine authorities. Each country was left to make its own arrangements, much as had always been the case.

Yet King remained determined to turn the tide in the battle in the Atlantic. To this end, he settled on the means of centralizing command of American antisubmarine operations. His first step, on 6 April 1943, was to have all the navy's antisubmarine activities brought under his control. Next, he asked Rear Admiral Francis S. Low, his assistant chief of staff, to make a report of the antisubmarine situation. Low separated the wheat from the chaff as he worked his way through the stacks of available documentation (both British and American). On 20 April, he submitted his recommendations to King, namely, that rigid training and adequate experience were essential and that fundamentals should be stressed. Moreover, his report supported the idea of an efficient central command that would take charge of all phases of the anti-U-boat campaign.

After more thought, King concluded that a "fleet organization" for antisubmarine warfare was a necessity, and he proceeded to outline its structure. First, the commander responsible for all antisubmarine decisions should wield sufficient power and influence to preclude challenges to his authority. Next, and rather curiously, the "fleet" would be strictly an administrative body, without ships of its own, but able to summon to its cause any antisubmarine asset the navy possessed. Third, the organization would have to be designated a fleet so that it could use the channels of fleet communications and enjoy the other administrative and operational benefits fleets normally exercised.

King decided, quite at random, to call the organization the "Tenth Fleet." Then, with Low's help, he prepared and sent to the Joint Chiefs a description of his proposed setup:

> The Commander Tenth Fleet is to exercise direct control over all Atlantic sea frontiers, using sea frontier commanders as task force commanders. He is to control allocation of antisubmarine forces to all commands in the Atlantic, including the Atlantic Fleet, and is to reallocate forces from time to time, as the situation requires. In order to ensure quick and effective action to meet the needs of the changing antisubmarine situation, the Commander Tenth Fleet is to be given control of all LR [long-range] and VLR [very long-range] aircraft, and certain groups of units of auxiliary carriers, escort ships, and submarines that he will allocate to reinforce task forces that need help, or to employment as "killer groups" under his operational direction in appropriate circumstances.[17]

The Tenth Fleet was made official on 20 May 1943, with Admiral King as commander and Rear Admiral Low, chief of staff. It was an ambitious undertaking.

The division of antisubmarine authority that had so bothered King and others in the navy had also complicated ASWORG's operations. Members assigned to the Army's Antisubmarine Command, for instance, discovered that training, tactics, and plans for developing equipment often differed from those of the navy. This difference in the way things got done—made worse by a fairly persistent rivalry among the many antisubmarine units—meant a certain amount of duplication. Moreover, each sea frontier had its own interpretation of doctrine. Hence, it was frequently the case that ASWORG's field representatives were the only ones trying to convey a uniform doctrine or operational plan.

ASWORG's Washington-based scientists were even more affected than the analysts in the field by the way in which the separate antisubmarine units conducted business. The very purpose of operations research is neutralized if the results of studies cannot be handed to a central authority endowed with the power to change procedures. The effect of all this confusion on the Washington office, then, was to stymie some projects. Consequently, the more the Tenth Fleet succeeded in unifying the diverse antisubmarine efforts, the more effective ASWORG could be.

One of the first jobs the Tenth Fleet undertook was to settle on the antisubmarine role army forces would play in the future. It was thought, initially, that the army's antisubmarine planes should be placed under the control of the Antisubmarine Command. But this would still have left a division of antisubmarine forces: those that belonged to the army, and those that belonged to the navy. The army had originally become involved in antisubmarine missions solely because navy planes were spread too thinly at the start of the war and army planes happened to be available along the East Coast. By the time the Tenth Fleet was formed, though, the situation had changed. Although navy planes were by no means abundant, they were sufficient to begin taking over all antisubmarine flying in the Atlantic. The next step was to phase out the army's antisubmarine role entirely, rather than find some way to integrate its forces with the navy's. Army squadrons in England and Africa were therefore replaced by navy squadrons by the middle of 1943.

This shift in antisubmarine responsibility meant changes in ASWORG's field assignments. Members connected with the army's antisubmarine efforts—for example, at Langley Field and at the Army Air Force Antisubmarine headquarters in New York—were moved to new locations. For instance, Pellam, who had been assigned to Lieutenant Colonel Jack Roberts's squadron in England and later in Africa, moved to the Moroccan Sea Frontier, under naval authority. Meanwhile, ASWORG's involvement with the navy's antisubmarine efforts burgeoned.

Just one and a half months after the Tenth Fleet was established, ASWORG was made an official part of it. The move resulted from an agreement between Admiral Low and John Tate, head of the Subsurface Warfare Division of NDRC. Tate subsequently wrote a directive, dated 7 July 1943, calling for the reassignment of ASWORG to the Tenth Fleet and explaining the reasons for the switch. Admiral King endorsed the directive two days later.

The Tenth Fleet was organized along lines similar to CominCh headquarters, which comprised four major divisions: Plans (F-1), Combat Intelligence (F-2), Operations (F-3), and Readiness (F-4). The first of these did not have division status in the Tenth Fleet because Low, in conjunction with King, took care of planning; however, Low did make use of CominCh's Plans Division for assistance in strategic issues. In addition, the Tenth Fleet relied on the Combat Intelligence Division of CominCh to supply the copious quantities of intelligence that were required (although the Atlantic section of F-2 was later assimilated by the Tenth Fleet).

The main function of the Tenth Fleet's Operations Division (FX-30) was to help direct the operation of antisubmarine ships and planes within the Atlantic Fleet, without infringing on the prerogatives of the Commander in Chief, Atlantic Fleet, Admiral Royal E. Ingersoll. It monitored the capabilities of ships assigned to antisubmarine missions and constantly reviewed the allocation of antisubmarine forces.

The Tenth Fleet's counterpart of the Readiness Division was the Antisubmarine Measures Division (FX-40). This division had responsibility for development of equipment, training, and analysis to support new tactical doctrine. ASWORG was placed under this division, with Morse designated FX-45. ASWORG reported to Low by way of Captain John M. Haines, head of the Antisubmarine Measures Division. (Captain Harold C. Fitz replaced Haines in September 1943, after Haines returned to sea.)

Low and the Tenth Fleet were extremely generous in granting ASWORG access to vital information, no matter how sensitive. However, there was one rather curious episode in which, understandably, they at first held back. It began with a project Jacinto Steinhardt was given, requiring an analysis of the accuracy of radio direction-finding (RDF) in searches for German submarines. Stations had been set up along the East Coast to intercept the coded messages U-boats transmitted each day to headquarters. The stations could then determine the approximate location of the submarines, based on triangulation, and antisubmarine aircraft would then fly to these locations. In those instances where the planes did indeed find the submarines, the actual locations of the U-boats could be correlated with the positions provided by the RDF stations. Oddly, however, Steinhardt found that the RDF-based estimates of U-boat locations were ten times more accurate than analysis showed they should be.

So Morse went to Low to report what Steinhardt had uncovered, and to let him know that the anomaly would be investigated. At this meeting, Low acknowledged that it was an interesting finding, but left it at that. Morse was suspicious, however: "We had known for some time that there was something going on because although we . . . made the list of all submarine contacts each day for the session that Adm. King had every morning, there was a certain amount of data that we were not permitted to find out about. One was this RDF location—we were simply given it and told it came from RDF"[18] The answer came the very next day, when Low revealed that the locations ASWORG was being given actually came from decoded messages the U-boat captains were sending back to Germany, not from the RDF net.

The breaking of the German code is now well known, ever since the intriguing story was disclosed in 1974. This intelligence coup stemmed from the concerted efforts of a group of highly talented cryptoanalysts holed up at Bletchley Park in Buckinghamshire. Operation Ultra, as it was called, "involved intercepting enemy signals that had been mechanically enciphered, rendering them intelligible, and then distributing their translated texts by secure means to appropriate headquarters . . . . Exact and utterly reliable information could thus be conveyed, regularly and often instantly . . . to the Allied commanders."[19]

The cryptoanalysts had learned how to unscramble signals the Germans had encoded with their ingenious ciphering machine, Enigma. The Germans relied on Enigma throughout the war, to transmit messages on land and at sea. Confidence in the inviolability of the machine's encoding ability led the Germans to entrust most of their secret communications to radio. In addition, because the Germans chose to centralize operations, particularly as the war progressed, they were compelled to use radio to link headquarters with the distant battlefields. Germany's continued faith that the ciphers had not been broken was made evident time and again:

> That U-boat dispositions were indeed being identified was accepted and brushed off as early as September 1941, when a staff report on the 19th stated with normal confidence: "The decoded signal from the British Admiralty of 6 September, a survey of the probable positions of German U-boats, is completely true and can only have been gained by reported sightings and radio reports. An insight into our own cipher does not come into consideration."[20]

It was assumed by Admiral Doenitz—as it was, for a while, by Morse and Steinhardt—that the shore-based RDF stations and airborne radar deserved all the credit. For the rest of the war, ASWORG's people had access to other Ultra data, sometimes knowingly, other times not.

Once the Tenth Fleet had been formed, only one major antisubmarine organization remained outside its purview, the Antisubmarine Development Detachment.[21] The detachment grew out of the navy's need for experimental tactical work in antisubmarine operations and for training for antisubmarine aircrews. The army had its Sea-Search Attack and Development Unit (SADU) at Langley, along with a separate training unit. The navy's first venture in this area came in February 1943, with formation of what at first was called the Aircraft Antisubmarine Development Detachment, Atlantic Fleet, at Quonset Point, Rhode Island. The organization was run by Captain Aurelius B. Vosseler, a former member of Baker's Antisubmarine Warfare Unit in Boston and an early associate of ASWORG. Its role was to improve the air aspects of antisubmarine warfare by testing new equipment, devising ways to derive the most out of the equipment on hand, and developing tactics.

During their regular training at the detachment, all antisubmarine squadrons were required to take part in a joint aircraft-submarine exercise called 6A-S. This training mission allowed data to be collected concerning the range at which sightings were made for each aircraft type, the effect of altitude on sighting ranges, the percentage of sightings made on a submarine's wake as the plane's altitude increased, and the relative effectiveness of various radar types. In response to a request, ASWORG assigned Charles F. Squire and William T. Horvath to the detachment in May and Maurice E. Bell in July. They helped set up tactical and operational tests of new equipment—bomb sights, rockets, sonobuoys, and so forth—and wrote manuals on the equipment's operation.

In July, the detachment's work broadened to include surface ships, in large measure at Admiral Low's urging. The organization's name was then shortened to the Antisubmarine Development Detachment, consisting of two divisions: one for aircraft issues and one for surface issues. By this time, the detachment and the Tenth Fleet were cooperating closely, to the extent that the Tenth Fleet made sure that both divisions were adequately supported by ASWORG field representatives. ASWORG sent Robert M. Elliott to aid the Surface Division, then headed by Commander H. R. Hummer. Elliott ran tests of various detection gear and countermeasure equipment, and analyzed test results. Another ASWORG member, James K. Tyson,[22] also provided assistance by analyzing tests of tactics used by ships in antisubmarine attacks. A total of six ASWORG scientists were assigned to the detachment by the end of 1943.

### Operations Research Conducted by ASWORG

We have already made several references to some of the operations research work done by ASWORG members during the first couple of years of America's participation in the war. At this point, we will examine this work more closely, but we cannot, by any means, present a comprehensive account. Rather, we present a few samples of work that typified ASWORG's efforts in various locations at the same time. The work chosen is more or less representative and illustrates methods of solution and degrees of success. Excessive technical detail is avoided.

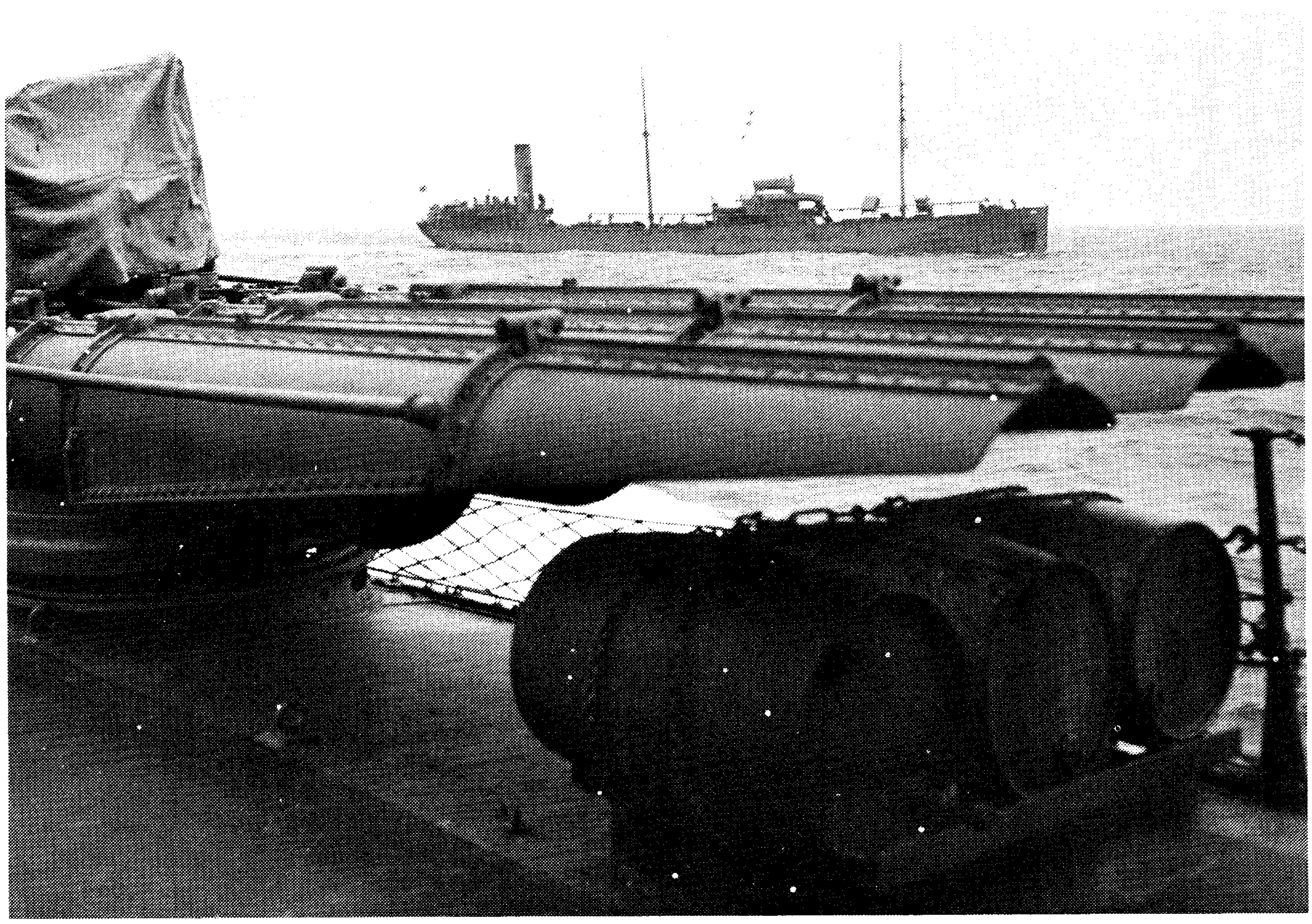
For convenience, we observe a division of three parts. In practice, of course, the demarcation between the three areas, far from being rigid, blended in most studies. The first part concerns analysis of past operations, which helped develop tactical doctrine making available forces more effective. The second part deals with the detailed statistical analysis of operational data, the object being not just to piece together a historical record, but to support other operations analysis being performed by the group. The third part consists of studies of the operational capabilities of new equipment, so that its most effective employment could be ascertained and design modifications suggested.

ASWORG spent a great deal of time analyzing the tactics used in searching for submarines. Indeed, search accounted for more than half of the antisubmarine tactics employed by the navy. Given the impracticality of trying to monitor every bit of the enormous expanse of the ocean, searches had to be conducted on tried and documented methods of locating submarines, and those methods had to become increasingly efficient. In addition, plans were needed by which the navy could concentrate on a specific region of the ocean, such as a strait, when the situation called for apprehending *all* enemy craft venturing into that region. Quite simply, the goal was to determine the most effective course for patrol aircraft and ships and to compute their chances of locating the enemy. Emphasis on the role of probability in the theory of search was quite new at the time, and gained its most firm hold on search theory through the theoretical studies of ASWORG during the war years.

There were several situations in which the principles of search came into play. One involved determining the best course for a destroyer to follow in trying to locate a submarine that had been forced by planes to dive. Another concerned the correct procedure for turning off a radar when looking for submarines suspected of being fitted with search receivers that would alert the submarines to the radar's presence. The disposition of escort ships about a convoy was also a search-related issue, as was the design of barrier patrols intended to prevent U-boats from passing through a fairly narrow passageway, such as a strait or harbor entrance.

ASWORG first defined the basic mathematical techniques essential to understanding the principles of search and identified those factors that should be studied. Of primary importance was the range at which the human eye, radar, or sonar could detect a submarine. At the beginning, rather crude assumptions were made regarding the limits of detection range. The most basic assumption was that once the detection range of a particular piece of gear had been determined, then any enemy unit that came within that range would be sighted and any that stayed outside would not.

It was quickly realized, however, that in the real world, detections did not abide by such a simple prescription. Some sightings occurred outside these sharply defined ranges, whereas others, under similar circumstances,



A U.S. destroyer, escorting a convoy in the Atlantic, moves ahead of one of the tankers in order to clear the way of German submarines. (Official U.S. Navy photo.)

occurred only at close range. A more meaningful approach to this aspect of the search problem required determination of the probability that a submarine would be detected at a given range. The probability could then be used to compute the average detection range for certain conditions.

Of greater significance than range was the rate at which a patrolling plane or ship could search for a submarine. The rate was taken as the area of ocean surface (in square miles, say) that could be searched in an hour. Obviously, the search rate would differ according to the type of search equipment employed. For instance, a plane employing either visual means or radar to spot a surfaced submarine was capable of searching about a thousand square miles in an hour; a ship employing radar, on the other hand, was capable of searching as little as a tenth of that in the same amount of time. In looking for submerged submarines, however, the search rate for a plane was virtually zero, but a ship equipped with echo-ranging gear could cover about fifteen square miles in an hour. Analysts were then able to figure out the average number of submarines that could be detected in an hour-long search.

The next stage was to examine operational data. Reports of aircraft attacks on submarines usually included the range at which initial contact was made, and the means of sighting–visual or radar, for example. As expected, analysis of the data showed considerable variations of ranges reported. The plan, then, was to use these operational data as the basis for computing the likelihood of visual sightings. The data, however, were flawed. Aircrews too often failed to record their altitude and visibility at the time of a visual sighting, and, also, only those sightings that led to an attack were reported. Quite likely, a large proportion of these unreported sightings involved long ranges, where the U-boats might have seen the aircraft in the distance and quickly dived to safety. Other, more reliable data were therefore needed.

The effective search rate, for example, could sometimes be worked out from other operational data. In some parts of the ocean, it was possible to estimate with reasonable accuracy the number of submarines present at a given time. If the enemy's submergence tactics were known, it was also possible to estimate the average number of submarines that could be sighted by planes in the area. Then, given the search rate of the planes and the number of hours of flying in that area, analysts could figure out the number of sightings to be expected. Conversely, knowing the sightings and hours flown allowed computation of the effective search rate.

Considerable data were gotten from the Eastern Sea Frontier and from the Bay of Biscay, providing the total number of hours flown by the planes and the total number of sightings made (regardless of whether the sightings resulted in attacks). From this, the effective search rate was obtained for each of the two regions. Surprisingly, these rates turned out to be much smaller (between one-third and one-twentieth) than those computed by using the average range of visual sightings and the speed of the plane. The discrepancy could not be attributed entirely to faulty estimates of the number of submarines present or of U-boat submergence tactics. For some reason, many submarines simply were not being sighted that supposedly should have been. Until the problem could be resolved, the navy would remain plagued by uncertainty concerning the effectiveness of its patrols. But first, still more data were needed if a reliable quantitative solution was to be had.

Because American antisubmarine forces continued to report incomplete and statistically biased data, ASWORG turned to Coastal Command for information. Fortunately, sightings in the Bay of Biscay were numerous, largely because U-boats left and returned to their bases along the French coast at a fairly heavy rate. Coastal Command allowed Arthur F. Kip, an ASWORG analyst assigned to London, to visit several British air antisubmarine bases to study the records of more than five hundred sightings. All pertinent data–altitude of plane, visibility, range and bearing of first sighting, and so forth–were sent back to the Washington office. George E. Kimball, who had done much of the theoretical work on the search problem, analyzed Kip's data and found that the average range of first sightings was related to visibility and the plane's altitude in the same manner he and others had predicted. (Confirmation of theory by operational data was as gratifying then as it is today.) It was then a fairly simple procedure to compute the likelihood of a sighting as a function of range, referred to as the "sighting likelihood curve." This curve served as the basis for all air search plans incorporated into the navy's official publication on antisubmarine doctrine.

More research was needed to link the sighting likelihood curve (with its reliance on empirical data) to basic theory, so that it could be applied to other areas. The first step, for visual search, was to better understand the connection between the operational data and the physiological properties of the human eye. ASWORG's Edward S. Lamar, who had been working with Kimball, went to London where he conferred with members of Coastal Command's Operational Research Section. With their help, Lamar was able to obtain physiological data from the British Medical Research Council.

The council's measurements on visibility showed that there was a maximum range at which any given object would be visible, and that this range depended on the apparent size of the object and on the brightness contrast between the object and its background. The brightness contrast depends directly on the visibility, because distance reduces the contrast, particularly on a hazy day. The apparent size of the object depends on the altitude of the plane if the object is flat on the surface of the water, as was the wake of a U-boat. The final result was a complicated relationship between maximum range and visibility and altitude. For objects of intermediate size and for reasonable visibilities, this relationship was reduced to a simple product (visibility times square root of altitude) that the operational data had shown.

On the basis of this work, the sighting likelihood curve could be extended to much smaller objects, such as periscopes. It could also be applied to studies of the effectiveness of lookouts on our own submarines in spotting enemy aircraft, and in determining the usefulness of various types of camouflage. Hence, the fundamental problem of visual searches for U-boats (or other objects) on the ocean surface from planes had been essentially solved. Similar analyses were done for radar, sonar, and other means of detection, which, in conjunction with the work on visual sightings, provided the basis for devising search procedures for specific situations.

One of the practical search problems ASWORG faced was that of the barrier patrol, designed to detect all enemy vessels trying to enter or leave a certain area, such as a harbor or strait. For the barrier to succeed, the strip of ocean searched out had to be wide enough and the patrol craft had to trace a course back and forth often enough to prevent enemy vessels from crossing the strip. Many geometrical considerations were carefully reviewed in deciding on effective patterns for patrol courses. (A simple barrier is shown in Figure 1-11.)

A successful barrier was set up, with the assistance of John R. Pellam at the Moroccan Sea Frontier, across the Strait of Gibraltar to keep U-boats out of the Mediterranean Sea. Its careful placement took into account the deep channel that passes through the strait and the whereabouts of other antisubmarine planes and ships that operated in the strait. The barrier caught three U-boats during the first four months of its use and continued to prove its relative impenetrability for much of the rest of the war.

A second successful barrier was arranged, with the help of Jacinto Steinhardt, to intercept German ships attempting to run a blockade with strategic supplies (mostly tin and rubber) picked up in Japan and Malaya. The Allies knew that just five such ships could supply Germany's needs for a year and a half. Planes patrolled a strip between Brazil and Ascension Island, a distance of about fourteen hundred miles, following carefully laid-out courses and exact rates of return. Three of the five blockade runners—the *Burgenland, Wesserland,* and *Rio Grande*—were sunk within three days. A fourth was sighted but avoided positive identification because of its elaborate disguise. The fifth got through before the patrols were under way but ran aground in the Bay of Biscay when attacked by British destroyers operating on information supplied by American forces.

Early in the war, plans for aircraft to escort convoys were devised, with the aim of their spotting surfaced submarines before they could get within attack range. ASWORG took up this urgent issue as early as May 1942,

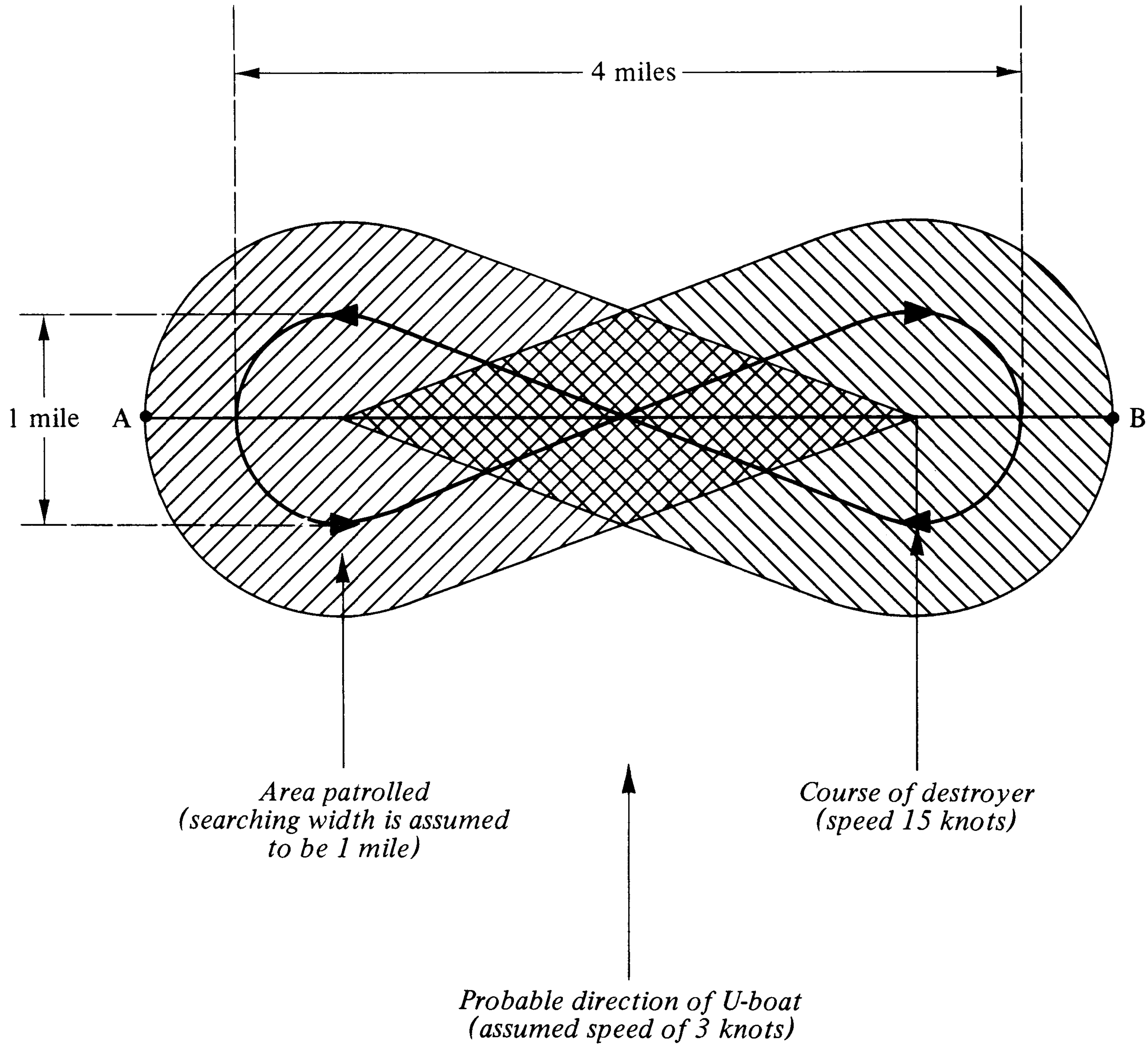



Figure 1-11. Sample Barrier Patrol for Destroyer Attempting To Keep U-boat from Crossing Line A-B

soon after the group's inception, but because of the general lack of understanding of the subject at the time and the group's inexperience, there was considerable uncertainty about the viability of the plans. After all, they rested almost entirely on theory and had not been realistically tested. Shortly after Rinehart had been assigned to the Caribbean Sea Frontier, he proceeded to test some of the escort plans he had done so much to develop. (The sighting likelihood curve was useful here.) The tests pointed to defects, subsequently fixed, and a final set of plans was drawn up and made a part of official navy doctrine.

The next type of search plan studied involved the hunt for a submarine that was known to be in the area because of a sighting or an attack by the submarine on a ship. The least sophisticated technique—more brawn than brain—called for planes to provide saturation coverage of the entire area in which the submarine was thought to be located for as long as it took to force the submarine to the surface. To execute the tactic successfully,

The German blockade runner *Rio Grande* is sunk by the guns of the light cruiser USS *Omaha* and the destroyer USS *Jouett.* The *Rio Grande* was one of five such ships trying to transit the South Atlantic with valuable war materials. (Official U.S. Navy photo.)

planes had to be available to patrol continuously over the constantly increasing area in which the submarine was believed to be located. Of the many such hunts conducted during 1942 and 1943, few succeeded.

ASWORG decided to find out the reasons for the failures and to propose alternative hunt plans. To this end, several group members visited those air bases where the so-called hunt-to-exhaustion technique was popular. In studying the records, the analysts found that the planes failed to cover a large enough area and did not continue the hunt long enough. Sometimes breakdowns curtailed the search, other times bad weather or reassignment was the culprit. Typically, the hunters were exhausted before the hunted; failure of the U-boat's battery power, for example, might not occur for up to forty-eight hours. The problem, therefore, was to work out a way for aircraft to regain contact with the submarine that would have a reasonable chance of success without using an unreasonable amount of flight time.

Because almost every ASWORG member assigned to an operating base was asked by the operations officer to suggest hunt plans, an impressive body of operational data was collected. This knowledge helped reveal which plans had promise. To support this endeavor, the Washington office developed a war game to simulate the hunt. The Special Devices Section of the Bureau of Aeronautics built equipment that enabled the participants in the game to simulate the search range of the plane and the range of visibility of the submarine at periscope depth and at the surface. The war game showed that many hunts had failed because the submarine had a chance to observe the patrol plane through its periscope. In doing so, it could establish the patrol plane's course and frequency of return, and coordinate its escape accordingly.

One way of avoiding this difficulty was a plan that came to be called the "gambit," in analogy to the term applied in chess. It consisted of flying the aircraft in a course that would take it out of the visual range of the submarine for a suitable period. This would lead the submarine to believe that the plane had been withdrawn, thus offering a "gambit" and inducing it to surface. Once surfaced, the U-boat would likely try to escape at high speed, causing it to cross the path of the patrolling plane, thereby presenting the plane with another opportunity to attack. Even if the U-boat dived again, the search area was reduced in size, by which time surface vessels could probably join the hunt with a good chance of success. Gambit tactics were found to be least useful at midday with good visibility and most effective at night.

Gambit plans were used with success in hunts in a number of sea frontiers. Such plans usually had to be made up on the spot, to fit the particular situation. ASWORG members at the Gulf, Caribbean, and Moroccan sea frontiers all contributed from time to time in planning hunts after a submarine had been spotted. Data on sixteen hunts conducted between 15 March and 20 October 1943 in the U.S. Strategic Area—although representing only a few cases—helped to confirm that gambit plans were indeed more profitable than hunt-to-exhaustion searches. Not only were more recontacts achieved, but much less flying was required.

Combinations of hunts and barrier patrols were flown from carriers employed to escort convoys, and much analytical work was done in devising plans for their use. Because carriers used planes that differed from their land-based counterparts, convoy escort plans had to be modified. Carriers of this type turned out to be most useful as offensive weapons, that is, in aggressively searching out and sinking U-boats rather than waiting for the submarines to come to the convoy. ASWORG developed a large number of carrier search plans for different situations and evaluated others submitted by commanding officers.

Searches conducted by a surface ship were more problematical than those by aircraft, largely because a ship did not have the advantage of speed that a plane did. To some extent, this disadvantage was offset by the ability of the ship to stay on the spot for a long time and to coordinate operations with other ships more closely (and thus more effectively) than could aircraft. It was found, for instance, that three destroyers hunting abreast in a line were more than three times as effective as *one* destroyer. A U-boat had a good chance of evading a single ship—but not three abreast—by steering to one side at high speed as soon as the approaching ship was detected. A ship also had the advantage of being able to detect submerged submarines through its use of echo-ranging gear. Based on detailed studies at the time, it was possible to determine the probability of a ship being able to locate a submerged submarine under various conditions.

It often happened that destroyers were called in by an aircraft that had made an initial sighting and had forced the submarine to submerge. The destroyers would arrive on the scene one or more hours later. A search plan had to be devised for the destroyers to locate the submarine as soon as possible. Another similar situation involved contact with a U-boat being

Water heaves up astern a surface ship patrolling the North Atlantic as its crew practices depth-charge attacks in preparation for its mission of keeping the Allies' shipping lanes free of German submarines. (Official Coast Guard photo.)

made and subsequently lost by a surface vessel. Because of the relative slowness of the destroyers, some form of search course that spiraled out from the contact point—known as the retiring search curve—was usually the most effective (Figure 1-12). The rate of retirement and the spacing of ships in line (if there were more than one ship in the hunt) were analyzed, various plans laid out, the probability of the submarine escaping computed for each plan, and the best plan chosen. The plans ASWORG settled on became part of the navy's official doctrine.

Further complications were added when aircraft were available, as with a carrier task force. Aircraft might be used on a gambit hunt, for instance, outside the expanding spiral of the destroyers. If the submarine managed to escape the destroyers and tried to depart at high speed on the surface, the aircraft had a chance of intercepting it.

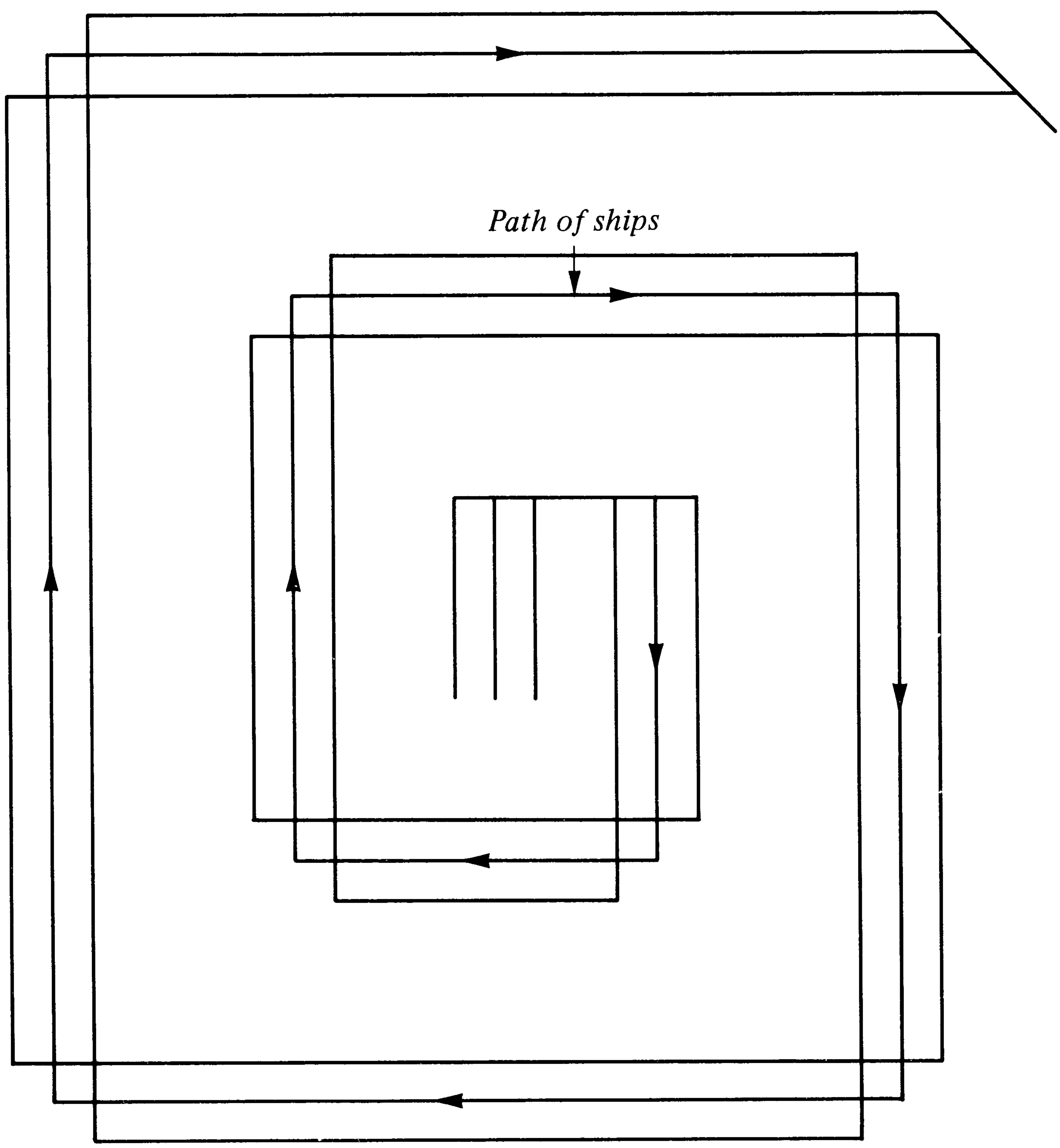
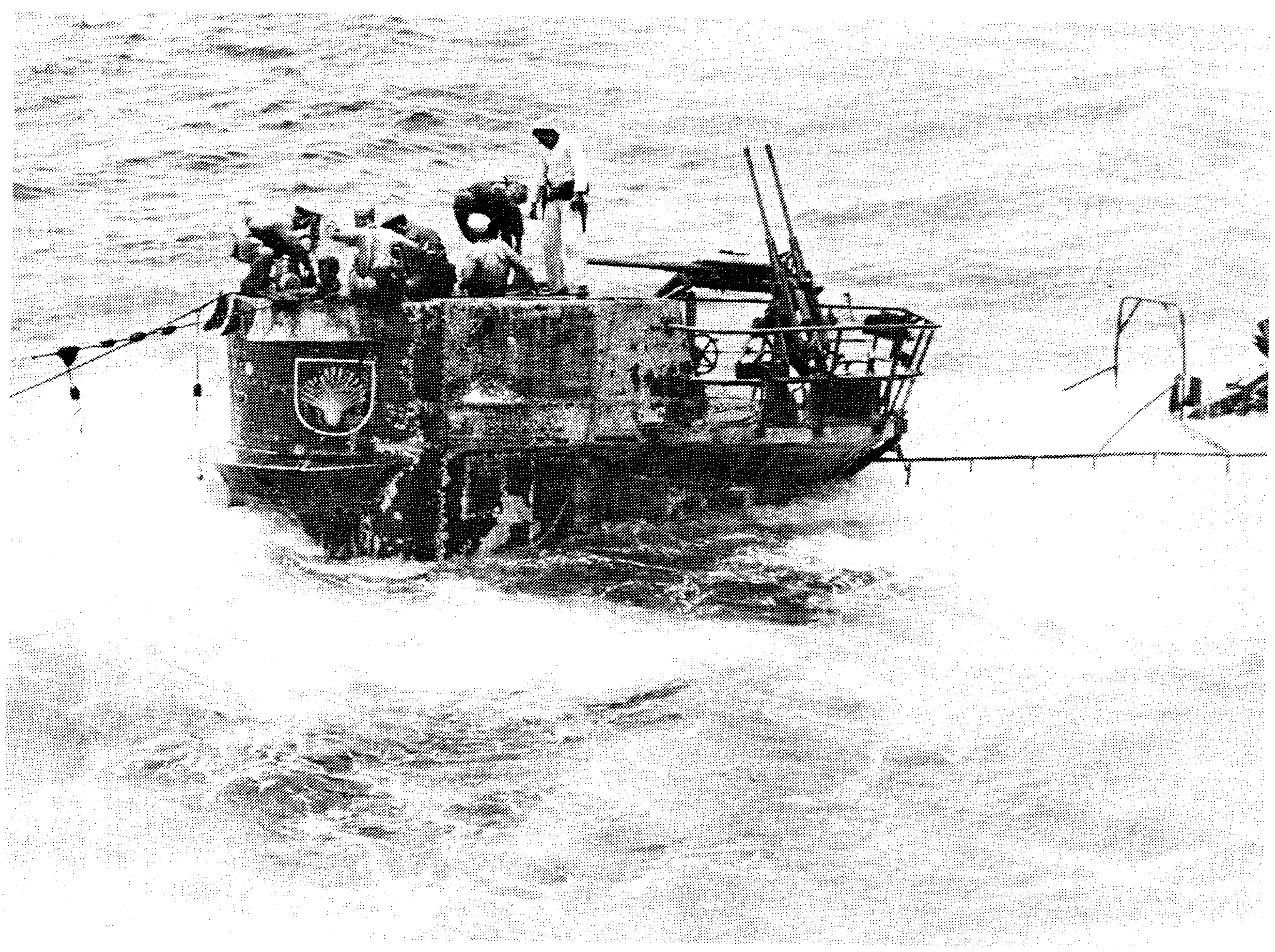



Figure 1-12. Typical Expanding Search Path of Three-Abreast Surface Ships Equipped with Sonar

Each new means of detection or modification of detection gear required altering the various search plans in some way or other. For example, the introduction of the use of sonobuoys by aircraft enabled the planes to keep track of submerged submarines. This made it possible for the aircraft to maintain contact with the submarine after it was forced below, and to call destroyers to it from farther away than was previously considered worthwhile. Even if the destroyers arrived on the scene several hours later, it was possible for the aircraft still to be in at least tenuous contact with the submarine. In such cases, ASWORG worked out extensions of the fundamental theory and investigated each of the standard search plans to see whether it should be modified.

Most of the statistical work carried out by ASWORG involved abstracting the details of operations from standard naval report forms, then using these data for statistical studies.[23] The abstracted data could be used to prepare an up-to-date summary of a particular operation for higher command. Alternatively, and of greater interest to ASWORG, the data could help formulate a measure of effectiveness for an operation. ASWORG would then apply the measure over the course of weeks of observation to



Capture of the German submarine U-505 by a navy escort carrier task group headed by the USS *Guadalcanal* (CVE-60). Members of a boarding party prepare to go below, as a motor-driven pump is used to pump out the water below decks. (Official U.S. Navy photo.)

determine the best tactics for an operation or to learn whether changes in German tactics had adversely affected our own operations.

It was important to measure the effectiveness of aircraft in searching for submarines. To obtain this from operational data, it was necessary to know the number of contacts made with surface submarines by aircraft in a given area and to maintain records of the search hours flown in that area. To compare different regions or types of operation, the time spent in those regions or on those types of patrol (convoy escort, hunt, and so forth) had to be segregated. If, in addition, the range of first sighting and other related data were reported, a good start could be made toward understanding the operational side of search.

ASWORG therefore arranged to get some of these data from the Eastern Sea Frontier. Each aircrew, on returning from an antisubmarine mission, would fill out a form giving the details of the mission: sightings, visibility, and so forth. Duplicates of all forms were sent to the Antisubmarine Warfare Unit of the Eastern Sea Frontier, where ASWORG members tabulated the data and sent their material on to Washington. The data were first recorded in great detail to see what was significant, and several interesting conclusions came from this study. One was that the regions with the greatest amount of patrol flying often produced the fewest sightings per hour flown by the planes. From this, analysts could determine the advantages and disadvantages of excessive amounts of patrol flying and could estimate the amount of flying in a given region that would adequately protect the region and still produce sightings that could be converted into attacks. It was also found that flying some distance from the shore (one hundred miles or more) produced more sightings and attacks than flying within fifty miles of the shore. The study showed, too, that the use of radar planes at night was a particularly effective method of obtaining sightings and, eventually, attacks, once proper searchlight equipment had made night attacks possible. These results subsequently affected the distribution of flying. A similar study of flying time and operational search rate was made with data from the Caribbean Sea Frontier, confirming these findings.

Proper measures of effectiveness and proposals of effective tactics relied on the analysts carefully evaluating the action reports in which the circumstances of operations were described in detail. In many cases, the results of operations were clearly apparent, and action reports sufficed to give a fairly accurate picture of what happened and to measure the effectiveness of the operation.

In other cases, however, the results of operations were not at all apparent, even to the forces involved. Action reports therefore had to be scrutinized before a considered judgment could be reached. The job was made somewhat easier by the Naval Assessment Committee for Antisubmarine Action, which graded antisubmarine attacks: A for submarine known sunk; B for submarine probably sunk; C for submarine probably damaged, possibly sunk; and so forth to G for attack probably on a submarine, no damage; and H for attack probably not on a submarine. These assessments held up remarkably well as later information became available.

The assessments enabled ASWORG to devise a measure of effectiveness for various types of attack, and thereby to compare the effectiveness of various attack tactics. Several different numerical weights were tried in place of the committee's letter grades. These values represented the relative probability that the U-boat was sunk: 1.0 for A, .8 for B, .5 for C, and so on. It was finally decided that the percentage of A and B assessments resulting from a given type of attack was an adequate measure of effectiveness.

With this measure as a tool, it was possible to study the attack data in order to judge the efficacy of various antisubmarine tactics. In studying the statistics of aircraft attacks, for instance, it was discovered that attacks made on a submarine that had submerged more than thirty seconds before the plane dropped its depth charges were unlikely to produce a kill. The longer the length of time the plane was blind to the whereabouts of the submerged U-boat, the larger the area in which the U-boat could have moved around (Figure 1-13). The results were striking enough to warrant including a phrase in the air attack doctrine, forbidding the dropping of depth charges on submarines that had been submerged more than thirty seconds.

Another subject of early study was the question of the depth setting of depth charges carried by aircraft, which E. J. Williams at Coastal Command had also addressed under different circumstances (see Introduction). The depth charges being dropped by planes were consistently ineffective, chiefly, it turned out, because the charges were set to explode at the same depths—fifty feet—as those dropped by destroyers. For a "slow" destroyer, the setting was perfectly adequate. By the time a destroyer could attack, the U-boat had time to dive, often placing it at the same depth as the exploding charge. But when a plane attacked, the U-boat was usually still on or near the surface, and the fifty-foot setting took the charge too deep for its detonation to have much effect (Figure 1-14). In fact, a statistical analysis of aircraft attacks on U-boats showed that about 40 percent of the submarines were on the surface at the time of the attack and another 10 percent were still visible even though they were diving. Consequently, doctrine was modified to require a twenty-five-foot setting. A later comparison on assessments of attacks with the two settings showed that the

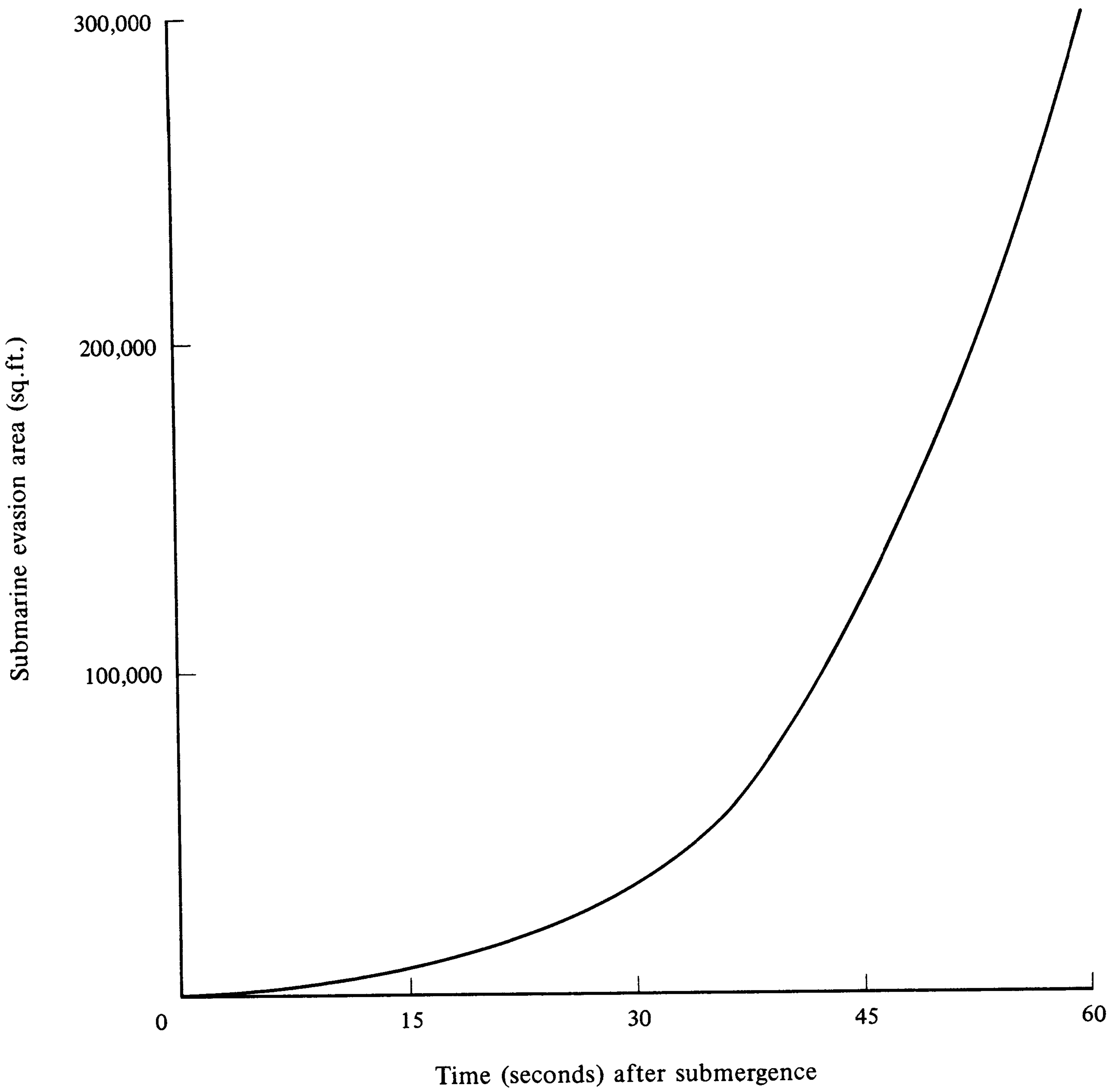



Figure 1-13. Submarine Evasion Area as a Function of Time

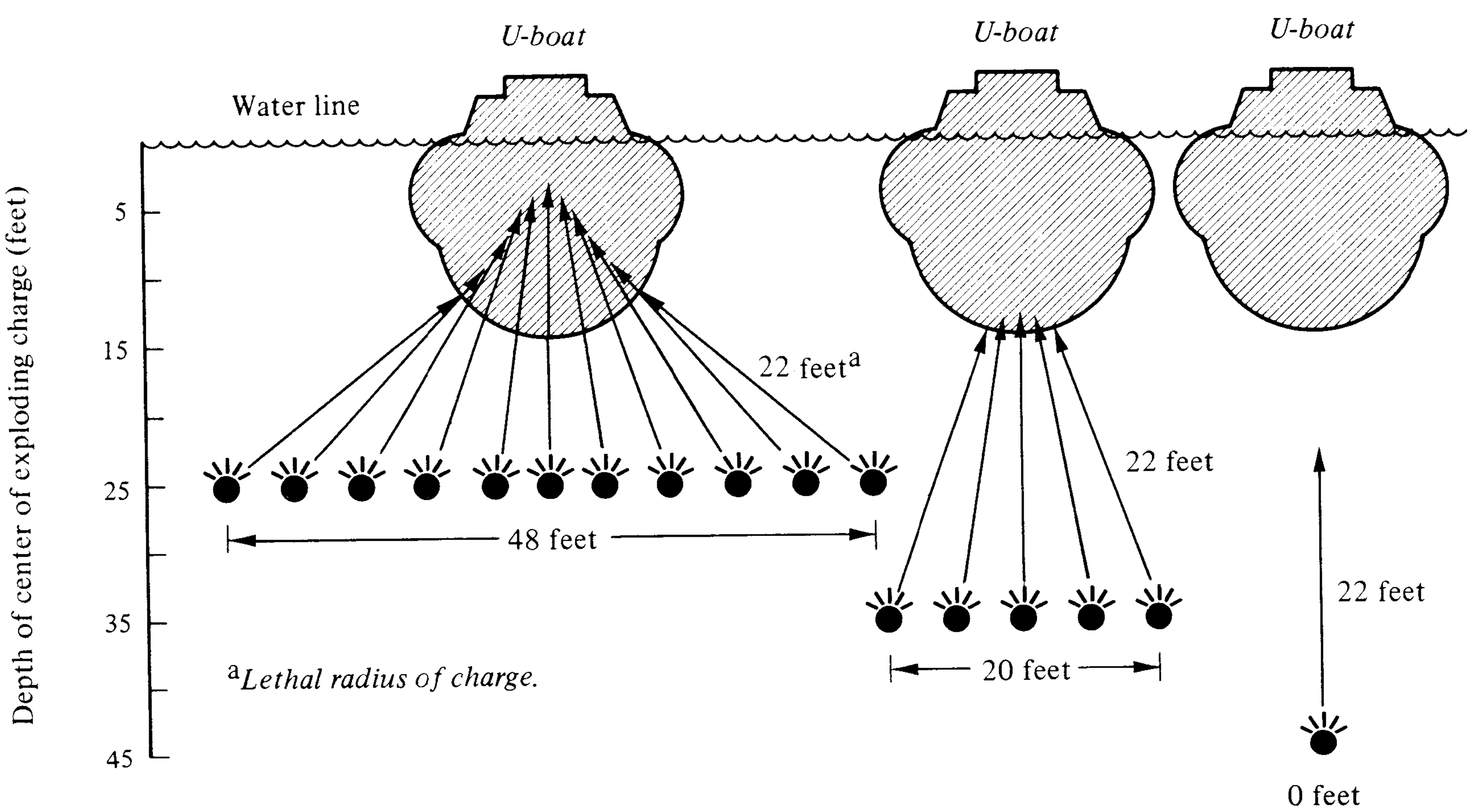
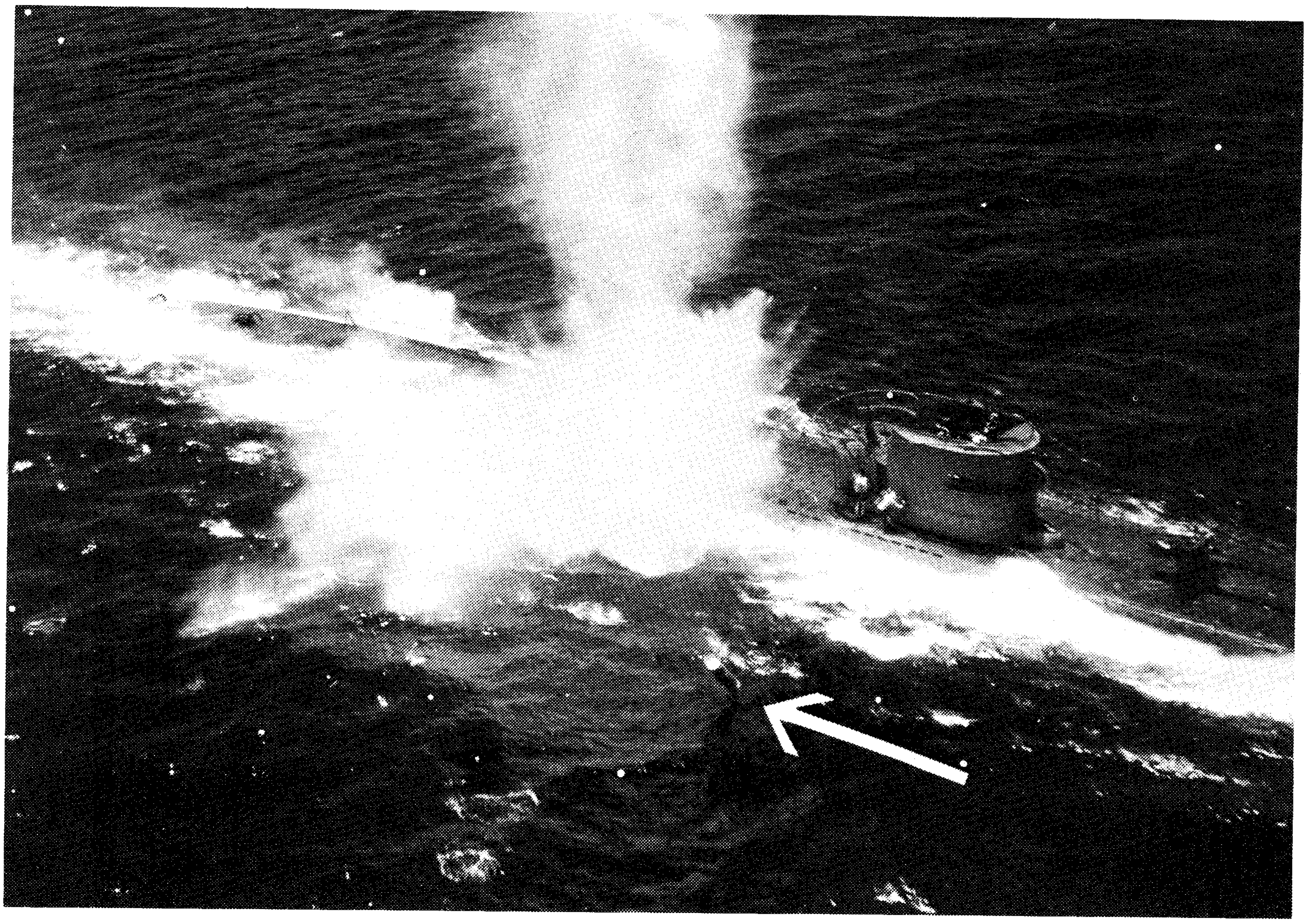



Figure 1-14. Effectiveness of Depth Charge Exploding at Different Depths



A column of spray marks the accuracy of a depth-charge attack against a U-boat. A depth charge can be seen (arrow) about to hit the water. (Official U.S. Navy photo.)

change in depth setting was equivalent to a doubling of the effective lethality of the depth charge.

The third and last area of ASWORG's operations research work that we will discuss concerns the operational capabilities of equipment. A portion of this work related to the problem of countermeasures in antisubmarine operations, primarily in two areas: radar and sonar. The scenario usually went like this. Germany would develop and begin perfecting for operational use a new piece of equipment or tactic. In response, the United States had to devise equipment or tactics (or both) to counter the enemy's innovation and to propose when these countermeasures should be introduced by American forces. (Indeed, timing the introduction of countermeasures proved as important as the development phase.) There was also the issue of foreseeing possible enemy countermeasures to our own equipment and tactics.

The radar countermeasure problem in antisubmarine warfare had a longer history at that time than the acoustic problem, so it provides more examples of ASWORG's work. To help understand the interplay of events–the alternation of measures and countermeasures–it might be useful to outline the history of the air offensive carried out by Coastal Command against U-boats in the Bay of Biscay (the results of which appear in Figure

1-15). Early on, most of the sightings were made by visual means, the flying was nearly all done in the daytime, and the number of sightings and attacks on U-boats remained fairly constant. In June 1942, however, Coastal Command outfitted a number of squadrons of planes with both the long-wave Mark II ASV radar and Leighlight searchlights, so they could find and attack surfaced submarines at night. Night flying was arduous, but quite effective. The psychological effect on the Germans was, moreover, substantial. Previously, submarines had been relatively immune in the Bay of Biscay at night, and it was customary practice to travel all night on the surface. The first reaction of the enemy to searchlight- and radar-equipped planes was to reverse their procedures, that is, to stay submerged at night and to come to the surface by day. By September 1942, the searchlight planes were making very few attacks, but the number of attacks made by planes flying at day rose considerably. In sum, the night flying of two squadrons had increased the effectiveness of antisubmarine operations in the Bay by more than seven squadrons of day flying.

After just a few months of night flying by the British, the Germans installed GSR search receivers on most of their submarines. These receivers were designed to pick up signals from the radars on the planes, warning the submarines in time for them to submerge and escape. Evidence for the installation of these receivers was given by an increase in the number of lost contacts. In fact, by October 1942, the searchlight radar planes had been effectively countered by these receivers. The submarines had gone back to surfacing at night, diving only when their receivers warned of a plane's approach. The number of attacks at day decreased to its previous level.

The introduction of S-band radar on the British night-flying planes altered the situation all over again. The German search receivers were not designed to pick up the shorter wave length of this type of radar. The number of sightings and attacks by night-flying planes therefore rose rapidly. The cycle went through its previous course, with the Germans submerging by night and surfacing by day, with a resulting increase in day sightings and attacks. Next, the Germans rushed development of a search receiver, Naxos, intended for use against the shorter-wave radar. This system proved more difficult to install, however, and worked somewhat inefficiently, although it did have an effect by the fall of 1943.

This sequence of events involving measures and countermeasures was duplicated in one form or another in locations other than just the Bay of Biscay, including in waters close to the shores of the United States. It was the responsibility of ASWORG to study the ways in which events in American waters compared with the problem in the Bay and to suggest modifications to both equipment and tactics.

Because it took considerable time to develop and produce equipment, development laboratories had to work out countermeasure equipment for

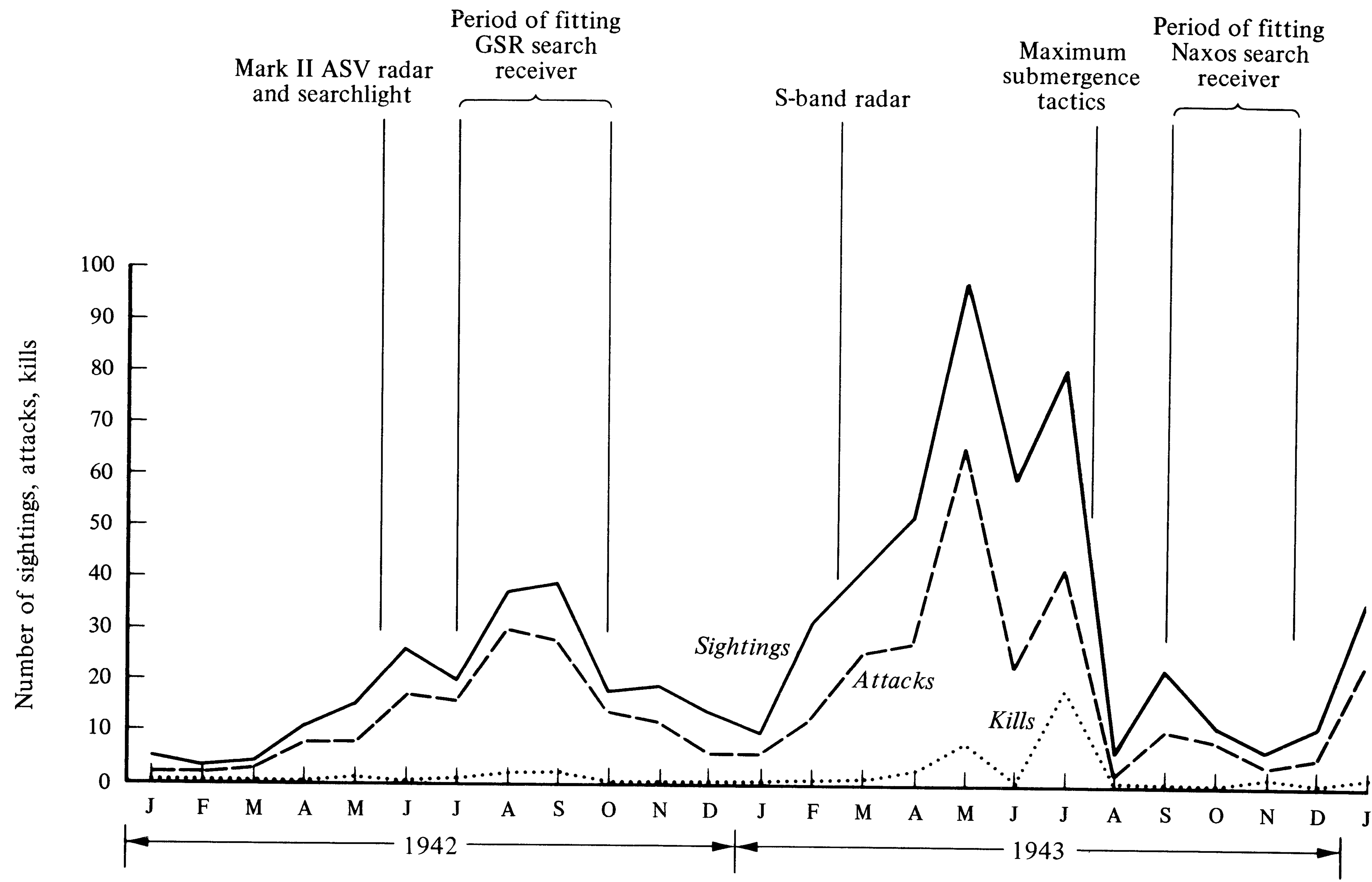



Figure 1-15. Results of Bay of Biscay Offensive

every type of imagined enemy gear in the hope that the right piece of equipment would be ready when the enemy came out with his next device. In the field of antisubmarine warfare, for instance, these laboratories had to anticipate that the Germans would outfit their submarines with either aircraft warning radar or search receivers. Equipment therefore had to be developed for both possibilities. The proper countermeasure for an early-warning radar on a U-boat was a search receiver on our own aircraft; receivers of this sort were developed by the Naval Research Laboratory and the Radio Coordination Division of the National Defense Research Committee (NDRC).

Equipment to counter the German search receiver was not so easily come by. Nonetheless, the Radar Division of NDRC succeeded in devising such equipment. The device was an attenuator built into the aircraft's radar and designed to weaken the radar's signal once a possible target had been detected. The U-boat would then receive a signal, the strength of which either remained the same or weakened despite the fact that the plane was approaching for an attack. This constant or reduced signal was intended to trick the submariners into thinking that the plane was not heading toward them.

It was important, however, not to introduce countermeasures prematurely—that is, before the Germans had installed their equipment in a large enough number of submarines—because changes in gear or tactics tended to disrupt other phases of our own operations. ASWORG's role, then, was to determine which type of gear the Germans were going to opt for and when countermeasures should be implemented. To help accomplish its task, ASWORG recommended that a plane be equipped with a search receiver and sent to North Africa so that it could operate in an area frequented by submarines. Use of the plane over a three-month period, by day and by night, produced no recognizable radar signals from U-boats. The test confirmed that radar was *not* being employed to warn submarines of the presence of aircraft.

The extent to which U-boats were using search receivers was harder to find out but important because it would affect the tactics of our own forces. If, for example, the German search receiver was capable of very long ranges, operated reliably, and was fitted to many submarines, then American planes might benefit by switching off their radars and conducting visual searches. If, on the other hand, the receiver had a short range, was often out of adjustment, and was absent on most submarines, then switching off the radars would needlessly reduce the number of attacks against the U-boats. A decision could be reached only by analyzing data acquired from several sources.

One source of operational data was reports on disappearing contacts. Until it could be determined, however, that the U-boats really were using search receivers or, alternatively, that aircrews were simply overreacting to lost contacts because they expected the receivers to be employed, the data had to be viewed with skepticism. The first opportunity to check up on this problem came in the latter part of 1943, when planes newly equipped with S-band radar (specifically, the SCR-517) reported many disappearing contacts in the Caribbean Sea Frontier. The squadron's reaction was to turn off their radar sets. This would indeed have prevented the U-boats from relying on their search receivers, but it would also have reduced the aircraft's average search rate by a factor of two or three.

Not believing that U-boats yet had S-band search receivers, ASWORG sought out other possible explanations for the disappearing contacts. Arthur F. Kip, then at the Gulf Sea Frontier, learned that the SCR-517 radar was more likely than other models to produce what were called "second-time-around echoes." This effect consisted of echoes of the previous pulse from large, distant objects appearing on the screen as small, near objects. Further investigation by Kip and Robert F. Rinehart confirmed that this phenomenon was the likely cause of most, if not all, reports of disappearing contacts. To witness the problem firsthand, Rinehart accompanied a pilot who claimed to be able to reproduce a disappearing contact at will. It was soon revealed that the apparent contact actually resulted from the "echo" effect of a mountain on an island about sixty miles away. Discovery of the cause of disappearing contacts led to an adjustment in the radar to eliminate the problem. Sure enough, reports of such contacts plummeted. More important, aircrews no longer felt obliged to turn off their radar sets and thus maintained their effectiveness in searches for submarines.

In the meantime, tactical countermeasures also had to be investigated. To do this, it was necessary to keep abreast of the current operational capabilities of our own radars and search receivers. ASWORG's M. Stanley Livingston remained in close touch with the Naval Research Laboratory and NDRC for just that reason. In addition, the capabilities of German search receivers could be estimated by statements made by prisoners of war.

One function of ASWORG was to analyze the effectiveness of procedures and equipment in order to make radar less vulnerable to search receivers. For example, was turning off radar completely the only way to deal with search receivers? Several alternative tactics were reviewed. One involved turning the radar on and off intermittently, so that the plane would retain its long-range search advantage while denying the submarine a clear opportunity to detect or understand the significance of the signal. To do this, the pulses could be sent in regular bursts of only a fraction of a second, or, alternatively, at irregular intervals to make them appear as static rather than as a recognizable signal. Captured documents describing official

German doctrine for the use of radar search receivers indicated that a U-boat was ordered to dive not on first detecting a radar signal, but only when it believed that the patrol craft had located the U-boat and had begun to home. Hence, intermittent use of radar might delay realization by the U-boat that the craft was in fact homing until it was too late. In the course of this work, ASWORG played an additional important role as a link between the development laboratories and the operational units.

The results of these and other studies by ASWORG were made available in various forms, other than by just personal communication. If the results were considered of use to a fairly broad audience, the Commander in Chief, U.S. Fleet (CominCh), would approve of their publication as an ASWORG Memorandum, to be distributed to appropriate operating forces. After the Tenth Fleet came into the picture, synopses of these reports appeared in the monthly U.S. Fleet Antisubmarine Bulletin. Results not of broad interest to the operating forces, such as basic theory or mathematical procedures, were put out as Interoffice Bulletins. All ASWORG field representatives would receive a copy of the bulletin, because the theories or procedures described in it were applicable to other operations research projects; service personnel generally did not receive a copy. Finally, whenever analysis was in response to a specific request, or the work addressed a narrow subject, the results were published as Research Reports. These had a very limited distribution and, on occasion, went only to the individual in Tenth Fleet who had requested the work.

**Expanding ASWORG's Horizons**

Until the fall of 1943, all of ASWORG's energy had been concentrated on antisubmarine warfare in the Atlantic, because of the urgency and complexity of the problem. By this time, however, it had become apparent that the battle in the Atlantic was now more manageable. Realization of these changed circumstances dawned, in fact, as early as July, when a staggering forty-six U-boats were sunk, the heaviest monthly total of the war, and the first month in which more U-boats than merchant ships were sunk. Thirty-seven of the forty-six losses occurred in the Atlantic, which must have made U-boat captains only too aware that they could no longer operate in that ocean with impunity. Heavy U-boat losses were also inflicted in the Bay of Biscay that month, with fourteen submarines sunk, and in the Gibraltar-Morocco Area, with six. The U-boats had only meager successes in September, and even those were offset by the surrender of the Italian Fleet and the turning over to the Allies of twenty-nine Italian U-boats.

In October, the U-boats again suffered serious defeats. They had difficulty finding the convoys—because of the latter's evasive maneuvering—and thus sank only three merchant ships and one escort in the all-important North Atlantic routes. The price to the Germans for these paltry gains was twenty-two U-boats. As a result of these continued heavy losses, the U-boats began to adopt a defensive rather than aggressive posture, further reducing their mobility and effectiveness. By November, U-boat tactics called for the virtual abandonment of wolf packs for attacks, leaving it to submarines to attack alone as an opportunity arose. (The following months, particularly the first half of 1944, were marked by Atlantic-based U-boats playing a reserved role, generally confined to reconnaissance, weather reporting, and awaiting the anticipated Allied invasion.)

Because of the decreased U-boat threat in the Atlantic, ASWORG began now to think of turning a portion of its resources from the Atlantic theater to the Pacific. In addition, the lessons learned over the preceding year and a half would be helpful in areas other than antisubmarine warfare. This argument was given more weight by reports submitted by Shirley Quimby, a U.S. naval attache in London, describing the more broadly based British practice of operations research. Moreover, many of ASWORG's analysts had already become involved in other subjects, such as antiair warfare, out of necessity. The result was that ASWORG began to spawn subgroups that focused on a variety of fields other than just antisubmarine warfare.

The first subgroup grew out of a request by the Commander Submarines, Pacific Fleet, to the Tenth Fleet for an ASWORG member to be temporarily assigned to his Pearl Harbor staff. The analyst's investigation satisfied everyone concerned that the same sort of operations research that had favorably affected the war in the Atlantic could be of service to the U.S. submarine force in the Pacific. Hence, a division of ASWORG was founded in November 1943, known as the Submarine Operations Research Group (SORG). Two of the group's members, Kimball and Rinehart, were immediately sent out to Pearl Harbor, although Kimball returned after a month.

The number of scientists assigned to SORG grew slowly, until by mid-1944 there were five at Pearl Harbor and six in Washington. Those at Pearl Harbor were responsible to the strategic planning officer, and those in Washington to the submarine desk of CominCh. For the most part, the former group worked on problems of a more immediate nature, whereas the latter devoted its time to longer-range subjects. ASWORG's policy of rotating field-based and Washington-based analysts on a six-month schedule applied to SORG, too.

SORG did many studies that helped the Pacific submarine force improve its operations. One of the most important evaluated the causes of U.S. submarine losses and considered ways to provide better protection. There was little information available on the probable causes of losses or on the circumstances in which they occurred. An effectively attacked and heavily damaged submarine had little chance of limping home with the information because of the great distances at which it operated. Moreover, in no case was a fatally damaged submarine able to transmit a radio report on the type of craft, weapon, or tactic that was responsible. Since direct evidence from sunk or damaged American submarines was unobtainable, indirect evidence had to be substituted. The next best information concerned those attacked but missed. Presumably, the number of American submarines claiming to have been fired at and missed by enemy submarines bore a direct ratio to the number fired at and hit.

So the group had to start from the ground up. In mid-1944, a study of contact rates on enemy submarines was made on the basis that there should be some correlation between the experience of American submarines and that of Japanese submarines, even though the submarines were not identical in design or tactics. The most direct approach was simply to assume that Japanese submarines suffered about the same percentage of misses against our submarines as ours did against theirs, and apply this figure to the number of times American submarines had been attacked and missed. Contrary to common wisdom up to that point, the analysis suggested that the Japanese submarine—rather than the surface ship or plane—was the single most critical cause of American submarine losses in the Pacific.

The group's findings led to an effort by the Underwater Sound Laboratories in New London, Connecticut, to enhance the capabilities of existing sound equipment designed to detect torpedoes. The equipment was placed on nearly all our submarines within just a few months. Also, SORG worked out tactics so that a submarine had a better chance of evading a torpedo detected by sonar or visual means. In essence, the tactics required the submarine to turn as sharply as possible toward or away from the torpedo, to present as small a target as possible. The probability of being hit was calculated, taking into account such factors as the promptness with which the evasive maneuver was applied, the speed of the torpedo, the firing range, and the number of torpedoes in the salvo. The navy issued the tactics as part of their official submarine doctrine. By the close of the war, several commanders had credited the modified torpedo detection equipment and new tactics with saving their submarines from destruction.

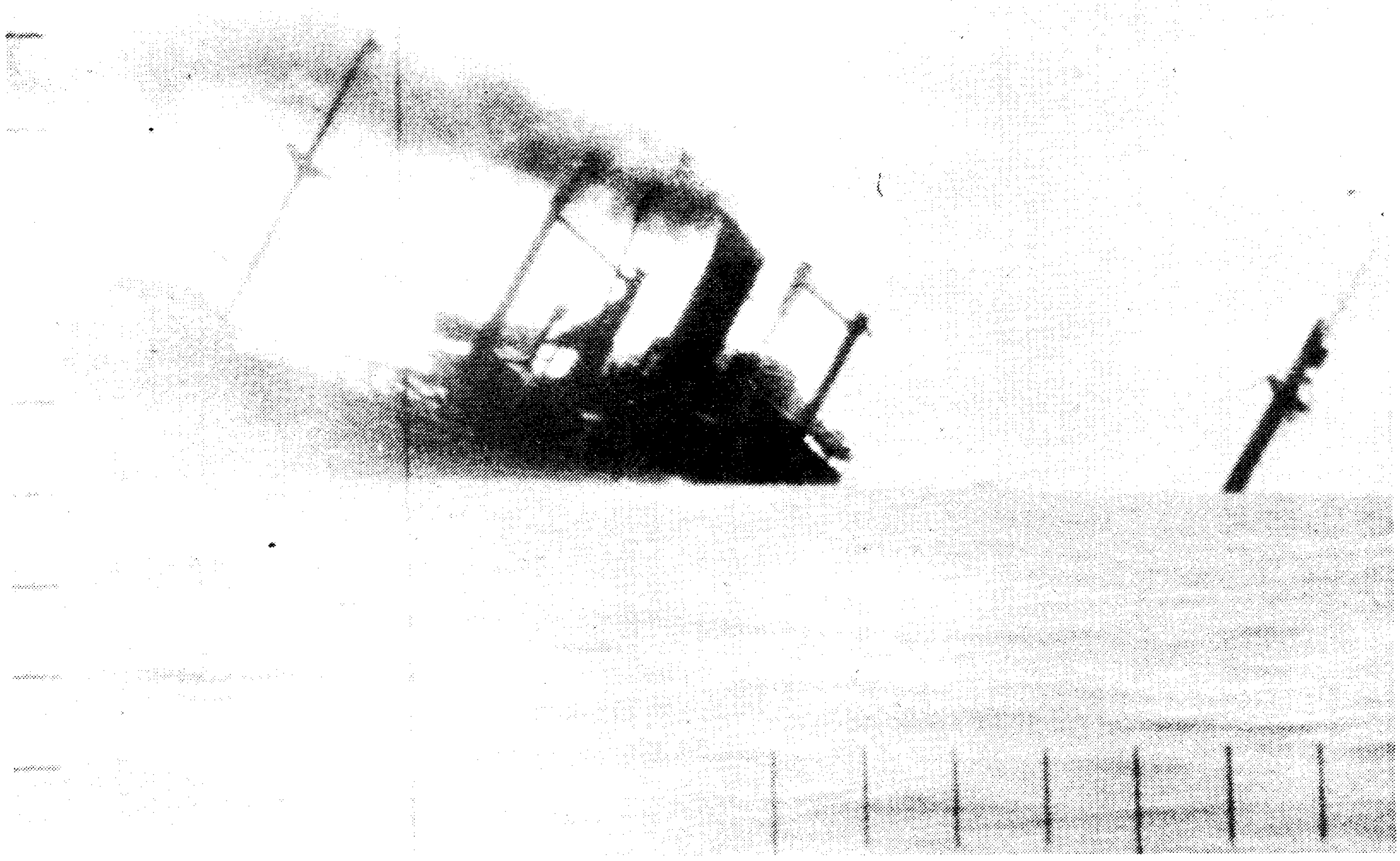
Similar work estimated the probable losses of submarines to enemy planes. The Japanese antisubmarine flying effort reached its peak during the summer and fall of 1944. Because the Japanese planes seemed to enjoy considerable success in finding our submarines, it was widely believed—as it had been earlier for the Germans in the Atlantic—that they were equipped with radar search receivers. This suspicion caused increasing numbers of submarines to turn off their radars rather than expose themselves to the supposed threat. SORG analysts, by showing that the number of contacts by Japanese planes per day in a given area remained the same whether the radar was left on or turned off, prevented an unnecessary loss of radar. (They adjusted, of course, for the reduced range of visual detections once the radar was off.)

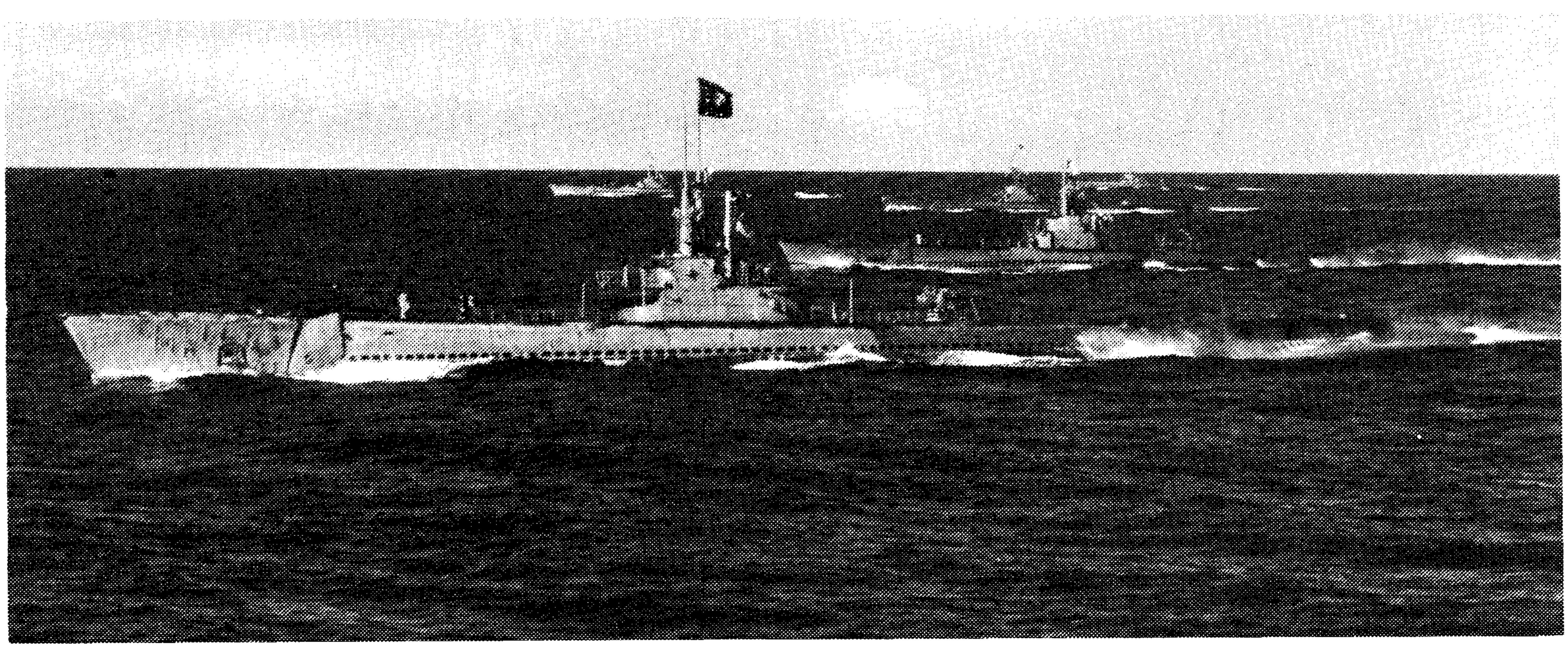
SORG also served a valuable role in helping to improve the submarine force's offensive capabilities. For example, several studies were conducted with the object of evaluating the effectiveness of various models of torpedo and of learning, in particular, the reasons for errors in torpedo firings. It was found that one type of torpedo performed poorly because of its relatively slow speed, and that two types were prone to passing under targets with shallow drafts. Firing plans were devised to help solve some of the problems.

Two tactics-related efforts by the group are also of interest. The first involved development of a comprehensive theory of coordinated attacks by multiple submarines (the wolf pack) in place of attacks by individual submarines. The group was able to predict the optimum number of submarines to assemble for certain operations and to suggest the spacing between adjacent submarines. The second such project addressed the problem of having to operate in mined waters. The tactics worked out enabled submarines to run mine fields unharmed. In fact, of twelve submarines assigned to operate in the Sea of Japan, none was lost to the mines that heavily dotted the straits leading into and out of the area.

In January 1944, ASWORG (and thus SORG, too) came under the direct administration of the Office of Scientific Research and Development (OSRD) rather than the National Defense Research Committee. A new subdivision of OSRD had been set up in October 1943, called the Office of Field Service (OFS), headed by Karl T. Compton, president of MIT. The impetus for forming the office had been recognition of the need to get more scientists out of the development laboratories and closer to where the fighting was, so they could work on improving operations with equipment the military services had at hand. The job of OFS was to facilitate this shift of personnel, while centralizing control of related activities. It seemed appropriate, then, that OFS administer ASWORG. Throughout 1944 and 1945, members of ASWORG were contract employees of OSRD, assigned as a group to the navy.

In 1943, Secretary of the Navy W. Frank Knox had prophesized that "each time they [the U-boats] go out, there will be a sharply increasing likelihood that they will not come back." By 1944, this bold prophesy had been confirmed. Hence, more and more of ASWORG's people were taking on assignments in subjects other than antisubmarine warfare. Given that the Tenth Fleet, to which ASWORG reported, existed solely to deal with the antisubmarine problem, it made sense to move the group elsewhere. Consequently, it was decided that ASWORG should be reassigned to the





Top: A sinking Japanese cargo vessel, as seen through the periscope of an American submarine. Bottom: Five U.S. Navy submarines—the USS *Flying Fish, Spadefish, Tenosa, Bowfin,* and *Skate*—head home through the Tsushima Strait following a raid into the Sea of Japan. (Both are official U.S. Navy photos.)

Readiness Division of CominCh and, in the process (on 7 October 1944), renamed the Operations Research Group (ORG), to reflect its broader interests. Professor Morse remained as director. At the same time, additional subgroups were formed to conduct operations research in special areas of warfare. Those scientists who continued doing antisubmarine work remained together as ASWORG, but became just another subgroup among the several that constituted ORG over the ensuing months.

One of those subgroups was the Air Operations Research Group, or simply AirORG. It was made up mostly of experienced members of ORG (that is, members of the old ASWORG), plus some people from OFS who had been assigned to the Air Intelligence Group of the Office of Naval Intelligence. A few new recruits were hired, too. Later, a liaison analyst from the British Air Ministry became a working member, and a naval officer was on loan from the Office of the Chief of Naval Operations as a technical aide. Early in 1945, two members of the subgroup, Howard H. Hennington and Arthur A. Brown, were sent to Commander Air Force, Pacific Fleet, at the command's request. This led to the establishment of a formal staff section at the command, made up of four AirORG members.

An early AirORG project involved a search for ways to lessen the risk to naval aircraft from flak. At the time, losses to antiaircraft guns were rising steeply, and prospects for improvement in the situation seemed grim. To accomplish their goal, the group began by learning how antiaircraft damage was generally inflicted. They examined the relative frequency with which the various calibers of gun damaged American planes, the severity of the damage, the parts of the plane hit, the phase of the attack in which damage occurred, and other such factors. In addition, they calculated the probability of enemy guns hitting the planes, taking into account various courses, speeds, and angles of dive. The work gave rise to a system of figuring the safest heading for planes engaged in an attack against gun-defended targets. Naval officers were then trained in the use of the system—and in flak evasion generally—and assigned to carrier task forces, where they helped plan missions. Vice Admirals Marc A. Mitscher and John S. McCain credited the work with saving the lives of many pilots and reducing aircraft losses.

AirORG also examined the effectiveness of naval air attacks against surface ships. They reported on the accuracy of attacks for all weapons employed and on the effect enemy antiaircraft fire had on accuracy. Choices of weapon types and fuses were recommended for the various ship targets encountered. Studies were made of the force requirements necessary to achieve a particular probability of sinking each type of ship. In response to a request from the Bureau of Aeronautics, an extensive study was made of the navy's program for electronics-assisted, low-altitude bombing. This included a review of available devices, of the training offered, and of operational data. The group, in conjunction with the Panel for Range of Naval Aircraft, established by the secretary of the navy, worked on ways to enable aircraft to fly farther. To gather information for this study, a member of the group toured bases in the Pacific and visited carrier forces at sea.

To help the Pacific Fleet improve its own antiaircraft capabilities, another subgroup was set up, called the Antiaircraft Operations Research

Group (AAORG). For some time, its main task was to pull together in some useful fashion all that there was to be learned about the use of antiaircraft fire by American naval forces. Action reports were pored over and tactics—our own and Japanese—described. This information was then distributed throughout the fleet. AAORG was later enlarged, to coincide with the setting up of the Special Defense Section in the headquarters of the Commander in Chief, Pacific Fleet. The section was tasked with accelerating the development of tactics and equipment to counter kamikazes. AAORG's role thus expanded to encompass all phases of the defense of ships against air attacks, including the use of radar and patrol aircraft.

One of the group's research projects had to do with the disposition of combat aircraft about a task force, to protect the force from enemy bombers. The task force would use its search radars to detect incoming bombers, then vector patrol planes to intercept and shoot them down. Several factors had to be considered in the study, such as the detection range of the radars, the possibility that the enemy could approach from any direction, the speed of the bombers and patrol planes, the number of planes available, and the average effectiveness of each plane. The results pointed to improved tactics for distributing the patrol aircraft.

Heavy flak fills the Pacific sky as antiaircraft batteries aboard ships of a U.S. Navy task force fire at Japanese planes. (Official U.S. Navy photo.)

The first systematic and large-scale use of kamikazes by the Japanese against American ships began in mid-October 1944, during action in the Philippines. The shift to suicide tactics was caused by the poor results obtained by the Japanese in the Marianas campaign in June and July, where they threw their entire weight into dive-bombing and torpedo attacks. In that campaign, about eight hundred enemy planes attacked our ships. Of those, over five hundred were shot down by fighter aircraft before even reaching the ships; another sixty were brought down by antiaircraft fire. The results of their efforts totaled only one ship sunk and ten damaged.

In the Philippines campaign, from mid-October to the end of the year, the Japanese began seriously to implement their kamikaze tactics. Of those planes that reached the task groups and tried suicide attacks, 5 percent hit ships and sank them and more than another 30 percent hit ships and damaged them. The rest missed. Compared with the Marianas campaign, suicide attacks were several times more effective than dive-bombing and torpedo attacks in causing damage or actual sinkings.

Over the following months, the threat from suicide attacks grew. Hence, in July 1945, AAORG was reorganized to apply greater effort to the kamikaze menace. It was subsequently renamed the Special Defense Operations Research Group (SpecORG), and assigned to the navy's Special Defense Section. (The group, however, continued to study many of its previous subjects also.)

Despite heavy antiaircraft fire, about a third of the suicide planes managed to get through, and about one of every seven hits resulted in a sunk ship. SpecORG addressed the question of whether radical ship maneuvers would foil the kamikaze or merely spoil the aim of the antiaircraft gunners. Results indicated that the larger craft—battleships, cruisers, and carriers—benefited from radical maneuvers. However, radical turns by smaller craft, such as destroyers and auxiliary naval vessels, reduced antiaircraft effectiveness because of the attendant rolling and pitching. A related question SpecORG examined was whether a ship under attack by a kamikaze should present a particular aspect (ahead, bow, beam, quarter, stern) rather than another. The relative safety of each aspect was worked out, depending on the dive angle—high or low—of the suicide plane. Two facts were apparent, given the relative weight placed on the amount of antiaircraft fire that could be brought to bear at each aspect and the target dimension presented to a plane approaching from the same angle. Specifically, it turned out that a ship was safer if it presented its beam to a high diver, but turned its beam away from a low diver.

The last of ORG's subgroups to be mentioned is the Amphibious Operations Research Group (PhibORG). Creation of this subgroup stemmed from a request by the research and development section of CominCh that ORG

A Japanese suicide plane comes in for a kamikaze attack against the USS *Missouri* during the invasion of Okinawa. The plane, which can be seen coming in over the port antiaircraft batteries, caused only minor damage. (Official U.S. Navy photo.)

consider ways to improve naval gunfire support of amphibious landings. Information regarding the effectiveness of the various support weapons and procedures was first sought in reports prepared by the operational forces engaged in this activity. As had been the case with earlier reliance on such reports, the quality and completeness of the information left much to be desired. Therefore, recommendations were made to upgrade the data.

PhibORG closely examined force requirements for each phase of gunfire support, in terms of weapon selection and tactics. The accuracy of naval gunfire was determined from the results of target practice and used in analyses of the influence of range, target type, ammunition expenditures, and lethal radius of projectiles on the support of amphibious landings. To obtain more precise measures of accuracy, the group suggested improved recording procedures for those persons tasked with reporting data during shore bombardment exercises. Benefits derived from this work included a better understanding of the destructive value of long-range shelling and the calculation of safe distances at which naval gunfire could be employed in close support of troops.

Also, PhibORG studied the use of ship radar to find concealed enemy mortars that were causing a high casualty rate among beachhead troops. On the beaches of Normandy, for example, it was estimated that each enemy mortar caused thirty-five casualties to Allied troops during the landing phase—three times as many as those caused by each machine gun. Fewer than one out of every ten mortars was knocked out by preparatory naval fire. At Leyte and Iwo Jima, more casualties were caused by enemy mortar fire than by all other weapons combined. The problem was worsened by the difficulty of fixing a mortar's position, because of the negligible smoke, flash, or noise given off by the weapon, as well as its mobility. PhibORG therefore investigated the possible use of shipborne radar to detect and track a shell, from which the shell's trajectory could be plotted and the mortar's position estimated.

The remaining members of ORG made up the Operations Research Center (ORC), which provided both administrative and general scientific support to the other subgroups. Central to this part of the operation was the Intelligence Section, which arranged for the filing and distribution of a variety of material—technical reports, naval intelligence reports, action reports, and other sources of vital information—to both field-based and Washington-based members. Contact was maintained with those officers who supplied the information, to ensure that they were kept abreast of the entire group's needs. The movement of reports was enormous. In an average month, for example, the group received about sixteen hundred reports. Five hundred of these had limited distribution and were sent back to the providing office within a day. The other eleven hundred were distributed more widely within ORG, with about six hundred placed permanently in the files for ready reference by ORG and navy personnel. The various administrative functions of the Intelligence Section—including the clearing-away of petty bureaucratic nuisances—helped keep the rest of the group operating smoothly.

ORC also consisted of a General Analysis Section, established with the purpose of working on theoretical (and largely mathematical) problems in any area of naval warfare. In addition to aiding the subgroups of ORG with theoretical analysis, the section also took up issues that did not fit neatly into the scope of these other subgroups. Some of the major areas of concern were: detection, by radar or other means; search, screening, and task force deployment; countermeasures to radar and sonar; tactical considerations related to guided missiles (worked on in conjunction with the Guided Missile Committee of the Joint Chiefs of Staff Committee on New Weapons and Equipment); and strategic problems of the atomic bomb.

Other areas of concern were studied, which did not readily come under the charter of the other subgroups. These included the bombardment of inshore cities for the purpose of harassment rather than demolition; the vulnerability of Japanese tanks to aircraft rockets; the capabilities and tactical employment of airborne early-warning radar; and the relative capabilities of light and heavy bombers.

When ORC was formed, ASWORG was in the midst of an extensive study effort on the employment of radar for submarine and antisubmarine operations. It was decided, however, that this work should be picked up by ORC, because of the project's specialized nature, and that a new section of ORC be set up to accommodate it. The new section, initially called the Radar Section, engaged in basic research on radar tactics and measures of effectiveness. Later, its interests extended to all detection equipment and the means of correlating such information aboard ship via the Combat Information Center. Hence, the name was changed to the Detection and Combat Information Section.

At this time, in the fall of 1944, the section's main subject of study was the detection of U-boats equipped with a snorkel (referred to in those days by its German name, *Schnorchel*). This then-revolutionary device, introduced earlier in the year, enabled U-boats to take in air, let out exhaust, and charge their batteries while staying at periscope depth, thus making the submarine harder to spot. The snorkel was particularly useful to the Germans during the latter months of 1944, following final evacuation of the Bay of Biscay ports in September. The device, in effect, made it possible for the submarines to compensate for their lost Biscay bases by enabling them to operate in dangerous inshore waters, and to proceed to and from their bases in Norway and the Baltic via more direct routes than they otherwise would have dared. Although use of the snorkel meant that U-boats lost much of their mobility compared with surface operations, the increased safety (particularly against aircraft) was a welcome reprieve.

Measurements, made by the Coastal Command Development Unit, of radar ranges against a mock snorkel showed that the greatest distance at which a snorkel could be detected in calm seas by an airborne S-band radar averaged three and one-half miles at an altitude of five hundred feet, and five miles at one thousand feet. X-band radar gave up to about twice these ranges. The tests also showed that such a small target produced only intermittent blips on the radar's screen. It was therefore necessary to determine the fraction of radar scans that produced blips, taking into account the range, that is, the blip-to-scan ratio. Then, using estimates of the number of blips necessary for an operator to recognize the target, the analysts were able to recommend sweep widths for use against snorkel-equipped U-boats and to construct search plans for ships or planes operating alone, or for a joint air-surface effort.

Other work by this section of ORC included an assessment of radar countermeasures employed by German submarines. For example, projects on radar camouflage were arranged with MIT's Radiation Laboratory and Harvard's Radio Research Laboratory. Toward the end of the war, camouflage coatings, which had been under intensive study in Germany since June 1943, were applied to snorkels to enable them to absorb rather than reflect radar waves. They were effective enough to reduce the radar detection range to about 15 percent of what was otherwise possible. Use of these absorptive materials came so late in the war, however, that their impact was not fully felt. Visual detection of targets was also a subject of study. In particular, work on lookout scanning rates and the effect of target shape on visibility was coordinated with the Joint Army/Navy/OSRD Visual Committee. The main goal was to come up with measures of effectiveness for visual searches and weapon aiming.

Finally, ORC included a Machine Section, stocked with IBM equipment used to build records of operational data. The statistics-handling capabilities of this section were a considerable improvement over the original capabilities of ASWORG back in December 1942. Part of the section's responsibilities involved record-keeping directly for the navy. When their resources were placed at Tenth Fleet's disposal, most of their support centered on antisubmarine activities. Losses to Allied merchant shipping and attacks on U-boats were recorded daily, and situation reports were issued to keep navy personnel up-to-date on the antisubmarine campaign. Later, the Air Intelligence Group maintained a record of aircraft action reports of use in analyses of naval air warfare. After V-E day, as antisubmarine concerns diminished, resources could be switched over to helping CominCh record ship movements and losses, which up to that point had been done by hand. A file was begun, showing damage sustained by ships of the U.S. Fleet and the location, assignment, fleet status, and other information on each of the navy's ships. This information provided the basis for redeployment of naval units following V-J day.

Another part of the Machine Section's responsibility involved record keeping for the subgroups of ORG. SORG was a particularly large user of their services, accounting for about twice the operator time required by the other subgroups combined. SORG requested that data be compiled on each sighting and attack by American submarines and on each counterattack. The information was helpful in evaluations of weapons and tactics and in the preparation of monthly summaries of events for distribution to fleet commanders and operations officers. AirORG and AAORG similarly put the Machine Section to good use in the course of their studies of operations.

### Lessons Derived from the Wartime Experience

By the end of the war, ORG comprised almost eighty scientists, whose analytical interests had ranged from broad studies of methodology to studies of narrow operational concern. Indeed, virtually all aspects of naval warfare had come under the group's analytical scrutiny. Although well over a third of its members were in the field at any one time—assigned to theater, fleet, and sea frontier commanders—the group managed to function cohesively and effectively. Furthermore, none of the many members sent to the field was killed or seriously hurt, despite some close calls and the proximity of some members to combat. Arthur F. Kip, for example, found himself off Okinawa on a ship rammed by a kamikaze. Maurice E. Bell was in an antisubmarine plane that was forced to land in a field, though neither Bell nor the others onboard suffered more than minor injuries. Robert F. Rinehart spent a month in a submarine on patrol in the highly dangerous Sea of Japan.

Several lessons were learned during the war years concerning the makeup and operation of a group like ORG. Perhaps the most important of these lessons was that civilian scientists could best serve the military while remaining in the civilian sector rather than by donning a uniform. Although this relationship between civilian scientist and officer is now commonplace, it was entirely new at that time:

> Many of the necessary procedures of an operations research group run directly contrary to long-established precedents of military organization. Ordinarily, breadth of knowledge of a military situation, command responsibility, and power go hand-in-hand in the military organization. The soldier in the lower echelon is supposed to know just enough to get his own job done, and his power and responsibility are commensurate with his knowledge. The high command, on the other hand, has access to all of the information concerning the military situation, and concurrently has broad powers and responsibilities. It is a fundamental property of operations research that operations research groups *must* have broad knowledge, but should have *very little* power and responsibility. Operations research workers must be able to think about the military situation impersonally and impartially, and this can be done best if they are relieved as much as possible of the responsibility of issuing orders. Their conclusions must take the form of advice to some high-ranking officer, for him to make the orders (if he sees fit).[24]

The wisdom of this special relationship was soon apparent. In particular, the fact that civilian scientists were not subject to rank meant they could interact with navy personnel at all echelons—from the equipment operator to the admiral—without feeling restrained. Another benefit was the avoidance of time-consuming staff work that would have sidetracked the scientists from their principal objective of improving operations. Furthermore, many scientists, accustomed to intellectual freedom, would have demurred at the prospect of relinquishing some of this autonomy once a uniform had been put on. Finally, the effectiveness of the relationship was borne out by the contributions ORG made to naval operations throughout the war.

The second lesson from those war years concerned the suitability of scientists and mathematicians to military operations research. The scientists brought with them a thorough understanding of the physical laws that govern electromagnetic radiations, underwater sound, and the myriad of other properties and phenomena that bear on naval operations. At the same time, the mathematicians brought with them a wealth of procedures for manipulating the available data, so that an understanding of past operations might be fully exploited in developing plans for future operations. Additionally, both the scientists and mathematicians could add to the stock of methodologies as experience was acquired and requirements better defined.

The third lesson involved the necessity of establishing open channels between the group and the very top of the navy's hierarchy. In this way, results and recommendations stemming from the group's efforts could be made immediately available to high-ranking decision makers. Hence, there was minimal filtering of the group's work by intermediate levels of reviewing officers and few delays in getting recommendations translated into real-world improvements. The navy benefited, too, by having the opportunity to convey to the group exactly which facets of its operations were the weakest and needed the greatest shoring up. The advantages of this situation were an improved chance that the group would tackle the right issues at the right time and a feeling on the part of naval officers that ORG members were part of the team.

Another lesson, the fourth, was the paramount importance of maintaining a field program in addition to the core group in Washington. Sir Isaac Newton once wrote that "if, instead of sending the observations of able seamen to able mathematicians on land, the land would send able mathematicians to sea, it would signify much more to the improvement of navigation and to the safety of men's lives and estates on that element."[25] It took nearly two hundred fifty years, however, for Newton's exhortation to be heeded.

The placing of a significant fraction of the group's scientists at the operating bases perhaps more than anything else distinguished ORG from other attempts at military operations research at the time. The benefits realized from this setup have already been described in some detail. In short, analysts in the field could more readily learn of operational problems and pass along proposed solutions directly to those in command. In addition, practical knowledge was always readily available—usually from participants returning from operations—and fed to group members back in Washington, who needed to know whether their suggestions concerning tactics or equipment squared with real-world requirements. The Washington office, meanwhile, provided broader and longer-range studies, derived new analytical methods, coordinated the disparate efforts of the various group members in the field, and maintained liaison with the top rungs of the navy administration.

One final lesson from those war years was that mutual trust had to exist between the navy and ORG. Despite the lack of historical precedent, the navy chose to divulge to the group whatever information was necessary to get the job done, irrespective of whether the information was politically or militarily classified. ORG reciprocated by protecting the information and ensuring that safeguards were not breached, and the group was able to accomplish much more than it could have otherwise.

ORG emerged from the war having demonstrated that civilian operations research scientists could contribute in a signficant way to the nation's defense needs.[26] It established for future use an impressive body of methodology that had been thoroughly tested by the rigors of the war years. The group's formative years, though brief, were intense. It was now time to begin thinking about the group's peacetime mission.

# 2

# A Period of Consolidation and Growth

### Transition to Peacetime

In the summer of 1945, the navy began restructuring itself to meet a wholly different set of circumstances engendered by peacetime needs and expectations. Naturally, the question of ORG's structure—and, indeed, its very existence—was an integral part of this debate. Admiral Ernest J. King's interest in the "uninterrupted continuation of [ORG] into peacetime" was evident in a 19 August 1945 letter to Secretary of the Navy James V. Forrestal, urging retention of the group, albeit at lower manpower levels. King was unequivocal in his desire to see the navy continue to harness this analytical resource, and just two days later, Forrestal attached his signature to the letter, approving the recommendation.

That fall, Admiral King had an opportunity to elaborate on his rationale for championing ORG's continuation. An official report to Secretary Forrestal on the operations of the U.S. Navy in World War II provided details on combat operations, logistical and base preparations for the invasion of the main Japanese islands, the Pacific submarine operations, the gamut of operations in the Atlantic, and the capabilities of the various ships and planes in the navy's arsenal.[1] Then, in a large section toward the end, King lauded the entire scientific community, not only for contributing to the development of new devices, but also for aiding the "development of new and more deadly means of waging war" (that is, operations research).

To further underscore the importance of science to military operations, Admiral King added:

> The complexity of modern warfare in both methods and means demands exacting analysis of the measures and countermeasures introduced at every stage by ourselves and the enemy. Scientific research can not only speed the invention and production of weapons, but also assist in insuring their correct use. The application, by qualified scientists, of the scientific method to the improvement of naval operating techniques and material, has come to be called operations

> research. Scientists engaged in operations research are experts who advise that part of the Navy which is using the weapons and craft—the fleets themselves. To function effectively they must . . . have close personal contact with the officers who plan and carry on the operations of war.[2]

King's report to Forrestal continued by describing the original impetus for creating ASWORG and ORG and the fairly rapid evolution of the group over the preceding three and a half years. Because operations research at that time was new and still regarded as somewhat esoteric, King proceeded to explain what it entailed. He noted that operations research, as used during the war, consisted of two major phases. The first phase involved the theoretical analysis of each type of naval operation in order to prescribe ways of conducting these operations for maximum effectiveness. The second phase involved the statistical analysis of actual operations in order to check theory. He then cited some of the group's more salient—and exciting—successes, such as development of a countermeasure to the German acoustic torpedo. Admiral King concluded by confirming what had been agreed to in his 19 August letter, namely, that ORG was to continue serving the navy during peacetime.

In deciding how ORG's peacetime extension should be formalized, it was felt that the group's special character should be kept unimpaired. Specifically, Admiral King and others believed that the group's value to the navy stemmed from its ability to provide original scientific insight, free from bias and with an academic orientation. The group, therefore, should be attached to an academic institution to preserve the integrity of its work and the independence of its members. (The Office of Scientific Research and Development was to fold, now that the war was over, so a new parent organization had to be found if ORG was to survive.) Consequently, the navy approached the Massachusetts Institute of Technology with a proposal that it enter into a contract for responsibility for the group. The choice of MIT was largely the result of efforts by Professor Morse, who had returned to the Physics Department of the institute shortly after the war.

MIT administrators took some persuading, however. Although the institute had ably run the Radiation Laboratory during the war, it had qualms about picking up the responsibility for another group, particularly one five hundred miles away. The lab's projects had, at least, fairly closely resembled the philosophy and background of the school, with emphasis on education. ORG's interests, on the other hand, centered on this rather abstruse, not entirely legitimized field called operations research. The group clearly did not spend its time conducting research projects in the pure physics, chemistry, or engineering with which MIT felt most comfortable.

Still, from the point of view of ORG and the navy, the prospect of ties with MIT stirred considerable enthusiasm. Both the group and the navy recognized the advantages of an affiliation with MIT. It would mean, for example, that ORG members could enjoy ready access to the academic environment; this link to academia was expected to prove especially beneficial in recruiting new people. Additionally, the institute's enormous scientific and technological resources could be called on from time to time, particularly for the occasional project that might spill over from the normal working group. The affiliation with MIT would also help ensure the group's independence if the navy should ever attempt to impose its will over study projects. One fear was that the navy might wish to influence study results unduly, to support a point of view to which it was already predisposed. Last, the navy would gain political points if it could show that many of its operational decisions were grounded in objective analyses emanating from a group of highly competent scientists whose intellectual freedom and professional integrity were implied by the link to MIT.

Despite MIT's lingering misgivings, a contract (NOD-6964) was signed on 1 November 1945 between the navy and the institute's Division of Industrial Cooperation. The group was to be pared back to about twenty-five scientists, a third of its wartime peak. MIT made it perfectly clear that its role was to be mostly that of paymaster. The contract called for a change in the group's name from ORG to the Operations Evaluation Group (OEG), as it has remained ever since. The reason for the name change is best understood by first examining the curious manner in which the group was to be controlled administratively. That is, although the group was to report to the Office of the Chief of Naval Operations (OpNav), its formal contractual link was with the Office of Naval Research (ONR). The reason for this circuitous line of attachment was twofold. First, OpNav had no funds at its disposal for the purpose of contracting. But, just as significant in its own way, ONR's charter gave it direct responsibility for the navy's research program; hence, it was a proprietary issue, too. The latter point provided the rationale, then, for replacing the word *research* in ORG's name with the word *evaluation.* By no means was the change popular with everyone, though, since some members believed that the original name more accurately described the group's function. It was a small enough concession, however, in the effort to preserve the group, and there was every reason at that delicate time to avoid controversy over such a relatively minor point.

ONR was understandably not entirely pleased to serve, in effect, as the guardian of the contract, largely because its role excluded control over OEG's work. That prerogative was OpNav's. In all other contracts held by ONR, the functions of Technical and Scientific Officer were retained by them, and not relinquished to OpNav or to some other office. In the case of OEG's contract, ONR's oversight powers extended only to decisions concerning the group's funding levels. Although this role caused some initial resentment within ONR—indeed, a few people in ONR erroneously thought that OEG's funds came from their budget—time tempered any minor irritations.

Another feature of the contract was a provision for "forward funding." On one side of the issue, MIT's apprehensions on being approached about the contract stemmed to some degree from uncertainty concerning the durability of the arrangement. The school was reluctant to involve itself in a situation where it might be vulnerable to the vicissitudes of politics or simply to an abrupt change of mind by the navy. Such an eventuality, possibly resulting in a terminated contract, would saddle the school with a large pool of unemployed scientists. On the other side of the issue, the prospect of OEG having to dissolve abruptly because the contract was terminated would have hung menacingly over the heads of the group's members. Most likely, many of the best scientists would not want to enter such an uncertain environment.

To resolve the problem, the navy agreed to a three-year (instead of one-year) contract, which seemed to mollify both those at MIT who had concerns and those who were weighing employment with OEG. Because of this feature, the contract had to pass through several levels of review, with final approval coming from the secretary of the navy. The funding arrangement called for about $300,000 to be set aside for each of the three years (in contrast to an annual budget of about $800,000 at the end of the war). This amount had to be increased, of course, as costs increased over the years (Figure 2-1).[3]

The task order attached to the contract spelled out the role of OEG. Much of its wording came verbatim from Admiral King's 19 August letter to Secretary Forrestal. The group's mission, it stated, 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). The studies were to address the following broadly defined subjects:

(1) Analysis of past operations
(2) Evaluation of the operational capabilities of new equipment, in light of the navy's requirements
(3) Development of tactical doctrine, based on the above two subjects
(4) Formulation of new requirements
(5) Analysis of strategic alternatives.

The analyses were to be conducted from the perspective of the operational commander versus that of the laboratory scientist. Of course, the navy anticipated having to employ the group in ways that would not fit neatly into one of the preceding categories. From time to time, for example, OEG was expected to serve as a data-collection body, especially during crises. Indeed, this role was often expanded during actual crises to

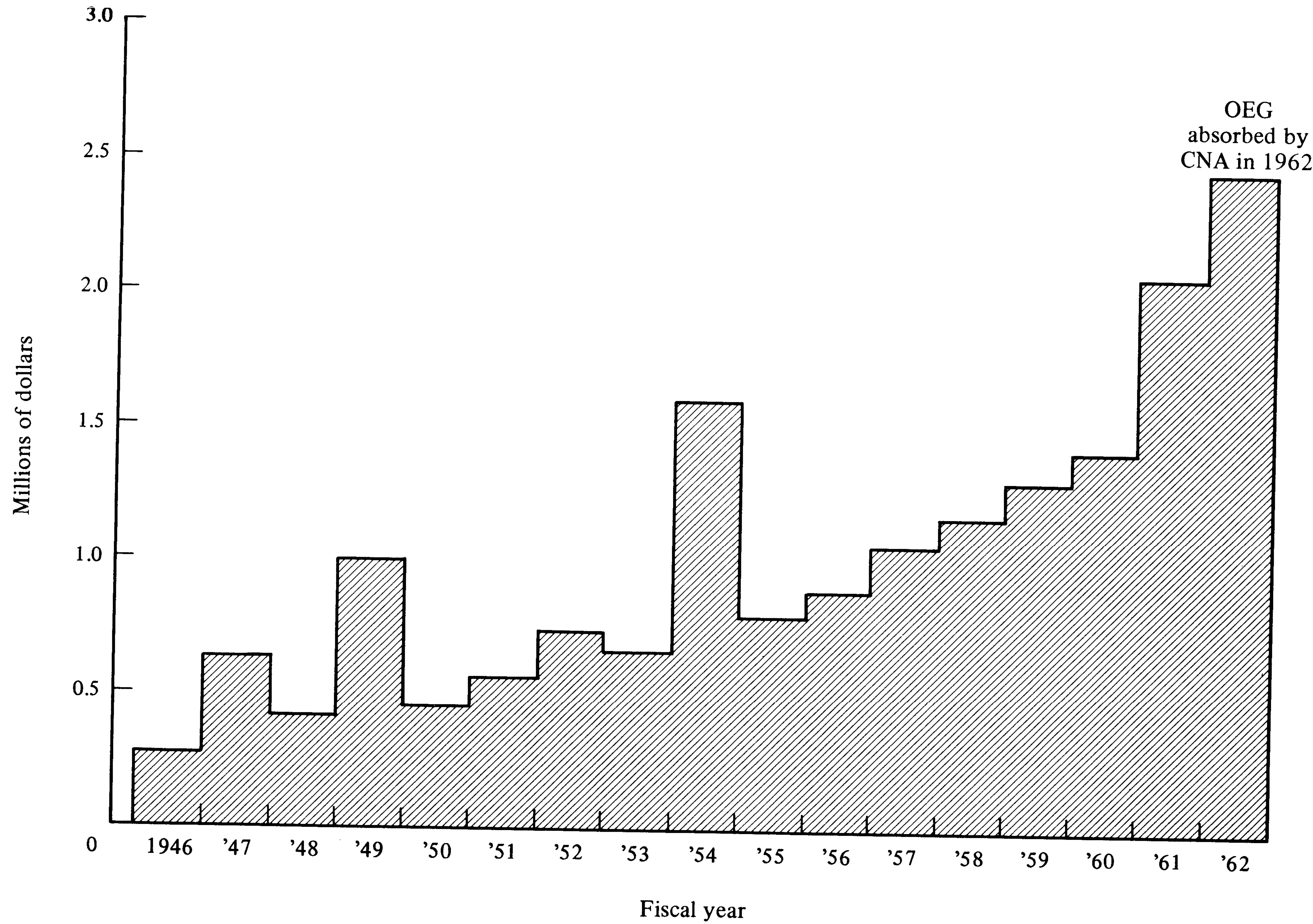



Figure 2-1. Fiscal History of OEG (to 1962)

encompass the storage and dissemination of collected data if the navy could not readily do so through its own means and to encompass immediate analysis if the data were considered of use to pending operations. Finally, the task order specified that OEG was to report to OpNav's Technical and Scientific Officer every two months to inform him of the results and recommendations arising from studies.

In the meantime, the group's stewardship changed hands. Professor Morse, the wartime director, elected to return to MIT, to teach and engage in research of a different nature from what he had known in Washington with ORG. At Morse's recommendation, Jacinto Steinhardt was made the new director of the group, largely because of his performance during the war. Steinhardt had made an impression on everyone, particularly as field representative assigned to the Fourth Fleet in Brazil and later to the Seventh Fleet in the Pacific. He had also organized and ably directed AirORG. After earning his doctorate in chemistry at Columbia University in 1934, he became a National Research Fellow at the Physical-Chemical Institute in Copenhagen; at the Physiological Laboratory in Cambridge, England; at the Physical-Chemical Institute in Upsala, Sweden; and at Harvard University. He was then Rockefeller Fellow at Harvard, until he worked as a physical chemist for the Laboratories of the Textile Foundation at the National Bureau of Standards. The latter position was interrupted on 10 November 1942 when he joined ASWORG.

Morse, meanwhile, retained an oversight role over OEG as chairman of a small advisory committee at MIT. His first major project after the war, though, was as director of the new nuclear research laboratory at Brookhaven. Established in 1946 by a contract between a consortium of nine universities and the federal government, the laboratory housed a nuclear reactor for use by academic research scientists to advance knowledge about the atom. A couple of years later, Morse was asked by Frank Collbohm, director of the newly formed Rand Corporation (the air force's civilian scientific advisory group), to become a member of the board of trustees. Morse accepted, in part to promote the general philosophy of a strong civilian influence on military decision making and in part to help Rand solidify its influence on specific air force policy.

Shortly afterwards, he left Brookhaven—"I am much more interested in starting things than in running them after they are under way"[4]—and returned to MIT. Morse's World War II experience, however, gave rise to yet another opportunity. The Department of Defense had just been organized, with James V. Forrestal as the first secretary of defense. An operations research group, called the Weapons Systems Evaluation Group (WSEG) and headed by Lieutenant General J. E. Hull, was assembled to do analyses for the secretary of defense and the recently formed Joint Chiefs of Staff. Convinced by Hull and Forrestal that the civilian half of WSEG would not become subservient to the military half, Morse agreed to become deputy director and director of research. Several decisions in which the group played a role—for example, that the H-bomb was feasible and warranted application of resources and political support—were made during Morse's tenure. Once again, in September 1950, Morse chose to go back to MIT, feeling that he had done what he could to set WSEG on the right track.

At this point, Morse concluded that he would like to direct his knowledge of operations research techniques to nonmilitary problems, such as those posed by industry and government. He also wished to stay closer to MIT, to concentrate on teaching and research. His commitment to the spread of operations research earned him the presidency of the Operations Research Society of America (ORSA) at its founding meeting in May 1952.[5] Three years later, he set up at MIT the Operations Research Center, for the purpose of supporting graduate students interested in specializing in the subject. (Reflecting the skepticism with which operations research was still viewed—and the rarefied atmosphere its practitioners were believed to function in—the center had no faculty of its own. Rather, it had to use faculty members assigned by the other departments of the institute.)

Beginning in the late 1950s, Morse began to turn his attention to the potential uses of operations research outside the United States and Great Britain. Europe was the first object of his efforts because its political and social systems resembled ours more closely than did those of the Third World and because it was believed that European scientists converted to the cause could be a great asset as fellow proselytizers. With the help of Bernard O. Koopman, a former ORG member who had returned to Columbia University after the war, Morse worked out a program whereby a two-week course on the subject would be given in Europe to persons from NATO countries, supplemented by visits to several other countries arranged through the Military Assistance Advisory Groups (MAAGs) of U.S. embassies. Among the experts recruited to take part was another former member of ORG, George E. Kimball. The program was a success and had a bearing on a request from Fred Seitz, science advisor to NATO, to form the Advisory Panel on Operations Research (APOR), which was to report to Seitz on ways to expand operations research within NATO.

Although Morse began his international activities by helping to solve NATO problems, his later efforts turned more and more toward nonmilitary social issues, such as transportation, city planning, and communications. Later honors bestowed on Morse, such as the presidency of the American Physical Society (APS), have paid tribute to his contributions. Meanwhile, OEG was embarking on a new path, too.

## A Year of Recapitulation

OEG's first post-World War II year was devoted to consolidating the learning acquired during the tumultuous war years and to establishing a permanent record of the large body of methodology that had been developed and documented piecemeal. The group felt strongly that this task should be completed before too many of its members departed for their peacetime vocations. The result was three documents, initially put out in 1946 as OEG Reports 51, 54, and 56. Their titles, respectively, were *Antisubmarine Warfare in World War II, Methods of Operations Research,* and *Search and Screening.*

A more formal, hardbound version of the three reports was prepared by the Summary Reports Group of the Columbia University Division of War Research under a contract with the Office of Scientific Research and Development (OSRD). In addition, they were issued, respectively, as volumes 3, 2A, and 2B of Division 6 in the series of Summary Technical Reports of the National Defense Research Committee (NDRC). Distribution was controlled by the Office of the Chief of Naval Operations. Initially classified Confidential, all three documents have long since been declassified and approved for public release. In fact, *Methods of Operations Research* and *Search and Screening* have been reprinted by commercial publishers (see Bibliography). As an interesting aside, none of the three books could contain references to other scientific literature on the subjects covered, because no such body of literature yet existed—it was all very new.

The approach of Sternhell and Thorndike's *Antisubmarine Warfare in World War II* is essentially historical, rather than predictive of future antisubmarine warfare. The report consists of two parts. The first summarizes the evolution of U-boat operations and Allied attempts to defeat them. The description is chronological, but not all-inclusive; rather, just the major shifts in events and in the dramatic interplay of measures and countermeasures are described. Accordingly, the war is divided into phases, representing sigificant changes in U-boat strategy, tactics, and equipment. Because the U-boat war was forever in a state of flux and not all U-boats switched from one mode of operation to another simultaneously, the demarcations between the phases are, of course, somewhat indefinite. Besides giving an account of the U-boat offensive for each phase, the report details the uses of Allied countermeasures, that is, the convoy system, antisubmarine aircraft, and scientific and technical innovations. The narrative is kept succinct, with a highly quantitative flavor.

The second part of the report highlights examples of analysis conducted during the war by ASWORG, and later ORG, to thwart the machinations of U-boat Command. Despite forays in other oceans and seas, it is the Battle of the Atlantic that assumes a preeminent position in the report. Emphasis is placed on the way in which operations research was used to solve specific problems in the Allied antisubmarine effort. Theoretical analyses as well as studies based on operational data are laid out. The examples were picked for their importance to antisubmarine strategy and tactics and for their demonstration of the techniques of operations research. The latter of these two factors—the science—continues to have more than just historical significance, despite obvious changes in the principles, craft, and weapons associated with antisubmarine warfare since World War II.

Of equally lasting value is Morse and Kimball's *Methods of Operations Research.* The report outlines many of the operations research procedures developed and employed during the war, but which the group had hitherto been unable to consolidate because of the rush to keep abreast of the navy's wartime needs. It contains the fundamental concepts worked out by the group to deal with the special set of problems posed at the time. Examples of studies are presented, in part to preserve a record of some of the early triumphs of this relatively new branch of science, but also to illustrate the real-world applicability of the theory. The report stresses the importance of this latter requirement: "To be valuable [operations research] must be toughened by the repeated impact of hard operational facts and pressing day-by-day demands, and its scale of values must be repeatedly tested in the acid of use. Otherwise it may be philosophy, but it is hardly science."[6]

The impetus for compiling the report was the desire not to lose the analytical methods to sheer neglect. Although the descriptions are based on studies that address World War II situations, the methods remain valid today, as much for nonmilitary applications as for defense research. Hence, the need to make the methods available to *all* scientists engaged in operations-related work was apparent. The durability of these early methods is evidenced by the continued use of the report as a textbook.

Also of lasting value is Koopman's *Search and Screening.* The book was the product of contributions by several of Koopman's colleagues, most notable of whom was the pioneer of the theory of search, George E. Kimball. Individual chapters were published as OEG studies as they were compiled, to make the information available as quickly as possible. The book serves as an extension of *Methods of Operations Research* in that it develops scientific and mathematical methods by which the rather special area of search is analyzed:

> It is intended to be scientific and critical in spirit and mathematical in method, and while the data upon which its theory rests are practical and experimental and the ultimate application of its conclusions is to naval warfare, the book itself is not a manual of practical information for naval officers. Rather, it is intended to serve as a theoretical framework and foundation for immediately practical studies and recommendations.[7]

Many aspects of the search problem are discussed by Koopman, largely in the context of antisubmarine warfare: the detection, localization, and tracking of a target; the distribution of the search effort; force requirements; screens and barriers; and so forth. The "ubiquitous presence" of the laws of probability, to borrow Koopman's phrase, should be noted, even though application of these laws to the search problem has long since become commonplace. Even though systems available to both the searcher and target have advanced enormously over the last four decades—as, to a lesser degree, has the associated mathematical theory—the book's basic principles hold true even today.

The three books just described were not, however, the sole product of OEG's effort to establish a historical record of the analytical techniques developed during World War II. Many studies (fifty-five in all) and other reports were issued in 1946, picking up on select issues from the war work. These served a vital function, as they amounted to the only systematic attempt by the navy to finish or expand on scientific analyses begun during the war. A sampling of the subjects includes: the kinds of contacts made on U-boats; attacks against enemy ships by U.S. Navy planes; the accuracy of antiaircraft fire and the mathematical basis for evaluating antiaircraft firing tests; the design of shipborne radar search receivers; the performance of various radar types; evasive maneuvering against submarines; and weapon capabilities. Also, statistical summaries were compiled of various aspects of the war. For example, for torpedo firings by German submarines, a summary might include the number of each type of torpedo fired, the number of torpedoes per salvo, the number of hits (on escorts or merchant vessels), the number of sinkings or the extent of damage to unsunk ships, and so forth.

One of the studies addressed the advisability of zigzag plans by ships as an antisubmarine measure. The object was to complicate the submarine's approach by making fairly radical course changes about every ten to thirty minutes. The ship's captain could then choose to maintain a straight course during each leg of the zigzag, or, if he suspected that a torpedo had already been fired, could perform continuous rudder adjustments throughout each leg (Figure 2-2). Some plans were suitable only for large ships (cruisers or larger), others only for small ships (destroyers or smaller). Some plans were suitable for ships in formation, others for independents. Calculations indicated that zigzagging would make it much harder for a submarine to gain contact on the ship, but only when the ship was moving about twice as fast as the submarine. The benefit derived from zigzag plans was thought to be as much for maintaining the morale of one's own forces and avoiding predictability as for actually thwarting submarine attacks.

The incentive for continuing to devote resources to the study of World War II operations was also derived from the realization that some ways in

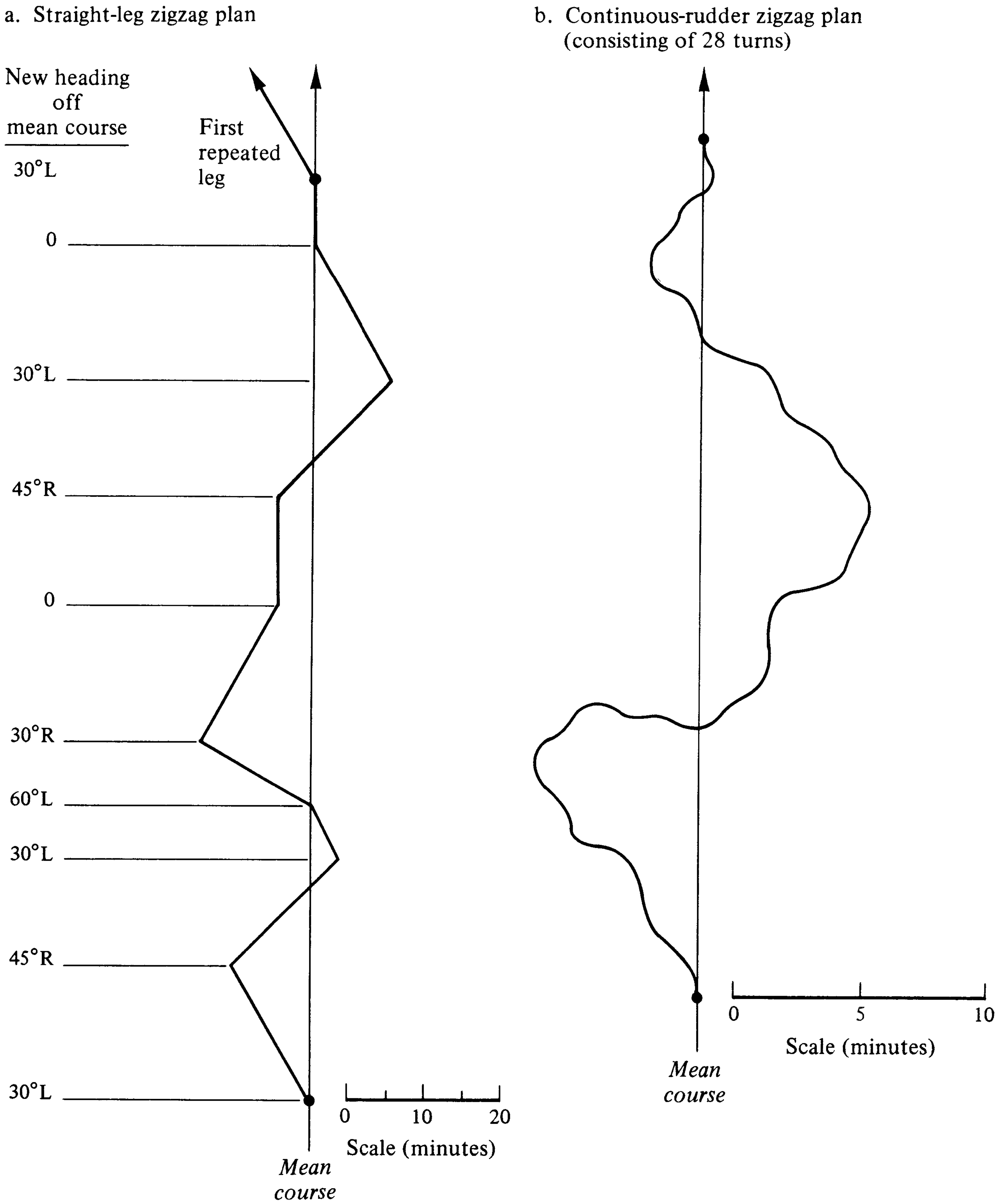



Figure 2-2. Sample Zigzag Plans

which the war was fought heralded a major new form of combat. One study that fit into this category—worked on by R. T. Best and Arthur G. Steinberg—examined the performance of fighter planes in defense of a carrier task group, from mid-October 1944 to May of the following year. The fighter defense of such a task group was designed to meet and destroy raids by enemy bombers through coordination of the fighters and the Combat Information Center (CIC). The CIC was responsible for spotting incoming bombers through the use of radar, tracking them, and then directing the fighters to intercept them. Because classical Japanese bombing doctrine was built around massed strikes (of as many as sixty planes) that headed straight to the target with no attempt at deception or evasion, the challenge at first was not so much to the CIC as to the fighters that had to fend off the awesome enemy force. To the advantage of the United States, the stereotyped approach employed by the Japanese rendered the raiders vulnerable even to numerically inferior fighter forces, the main reason being the failure of the bombers to keep formation and fight as a team once they had been engaged. Upon being attacked, the raiding force would soon hemorrhage and begin to scatter. Few of the bombers, therefore, ever got through to the task force to make their bombing or torpedo runs, being either shot down or forced to turn back (because of loss of fighter cover, inability to locate the target, or lack of determination).

A later phase of this period covered by the study was characterized by a radical switch in Japanese tactical doctrine. The Japanese now emphasized deceiving the fighters rather than trying to overcome them and began resorting to suicide dives. No longer were strikes executed so straightforwardly. In addition, raids were smaller, occasionally consisting of lone aircraft; even if raids did start out large, they eventually split into smaller groups at different bearings and altitudes. Hence, the challenge shifted to the CIC, which was finding it far more difficult to direct the fighters for interception. Sometimes the link between the CIC and fighter was so strained that some groups of raiders were not intercepted at all, reached the task force, and made their attacks.

OEG decided to analyze these conditions and the effectiveness of the whole fighter defense picture as it related to carrier task forces. The results were quite revealing. First, the study showed that no raid by a single group of planes managed to get any aircraft into position over a task force to make suicide dives. On the other hand, all raids consisting of multiple separated groups approaching about the same time did succeed in getting some planes into position for attack runs. Another finding was that the range at which radar first picked up the incoming enemy aircraft was less than the maximum range of the radar. Significantly, initial radar detection of medium raids (between three and seven planes) occurred about twelve miles farther from the fleet than detection of small raids (one or two planes), and about twenty-four miles farther for large raids. Finally, the maximum detection range was obtained on raiders flying between ten thousand and fifteen thousand feet, with a sharp drop-off in range for altitudes below or above these numbers.

The analysis looked at a variety of factors that influenced these results, including the effect of certain behavioral peculiarities of the radar (associated with the reflection and refraction of the beam) on its ability to detect targets; the interval between detection of the enemy and interception (a function of equipment reliability, accurate fighter vectoring, complexity of radar picture, enemy deception, and so on); the ability of the fighters to spot the raiders once in their vicinity; and the success of the fighters in shooting down enemy planes, given, for example, the relative numerical strength of the two sides.

The significance of the study lay in its foreshadowing of a form of naval combat that was coming into its own. Indeed, over the years, as the projection of power via carrier task forces became a mainstay of the U.S. Navy's global commitment, the issue of fighter defense of the force grew with parallel importance. Once again, although the capabilities of craft, detection and tracking gear, and weapons may have advanced beyond what could have been envisioned with any clarity in 1946—and certainly the potential enemy has different stripes—the underlying principles are as valid today as they were then.

Another prescient piece of analysis addressed the threat to American coastal cities and industrial areas by aircraft or missile-launching ships and submarines. Because land-based early-warning stations were regarded as incapable, alone, of providing adequate protection, OEG decided to study the capabilities of seaborne and airborne units to aid in this effort. A reliable five-hundred-mile warning range was desired, which would allow enough time to concentrate forces where needed and to destroy the attackers before any could get within firing range of their weapons.

The early-warning screen would have to be made up of a mix of ships and planes equipped with radar, to supplement land stations. The value of land and ship stations in the screen lay in the ability of their large radars to detect aircraft; their limitations lay in the negligible ranges at which they could pick up ships and surfaced submarines (or, for that matter, aircraft hugging the ocean surface). Planes were valuable because of their ability to spot ships and surfaced submarines—since they would not be seriously limited by the radar horizon—and to cover a large area quickly. They had two shortcomings, however. On the radar fitted to early-warning planes at the time, small aircraft targets produced blips that were exceedingly hard to notice, and, therefore, an appreciable fraction of targets would be missed entirely. Another problem was that information on detections would have to be relayed to land- and sea-based control stations for identification and tracking. Hence, the suitability of units in the screen would have to be judged not only by their detection capabilities but also by their reporting efficiency. A strong central organization would be needed for each phase of the mission, such as the receipt and evaluation of information and the initiation of offensive and defensive measures. From the study, the group drew a number of conclusions about (and provided some numerical examples of) the requirements of an early-warning screen relating to force levels, the spacing between stations, patrol patterns, the avoidance of weak points, the probability of detection, and so forth.

By early 1947, OEG had virtually completed its efforts to establish a permanent record of the methodologies developed during World War II. Also, by then the group had finished documenting wartime examples of the uses—and triumphs—of operations research and had completed studies (some with roots in the war experience) treating specific tactical or theoretical problems. Despite the enormity of the task, the job was done with dispatch, largely because everyone bore in mind its importance. With the record preserved, the urge to turn to other subjects of a broader nature was irresistible. Now, at last, the group did not have to devote all its time to coming up with quick fixes. Instead, it could begin to examine strategic alternatives, while continuing to devise more sophisticated models and honing its analytical tools.

## Coming of Age

Between the signing of the original contract with MIT and the Korean conflict, OEG underwent changes in its administrative makeup as well as in its research program. The least of these changes involved a move into offices in the Pentagon, considered necessary for two reasons. First, it was easier for the navy to safeguard the appropriateness of the group's analyses, in short, to make sure that the navy's requirements were being met. Second, it enabled OEG to maintain close contact with navy policy makers. Such access was essential if the results and recommendations stemming from the group's studies were to affect naval operations. Furthermore, because a peacetime organization like OEG was new (and perhaps an oddity), the feeling lingered that the adage "out of sight, out of mind" might prove true. Whatever insecurities may have been felt, however, were quickly allayed; the navy was soon calling for the group's enlargement.

The original decision to keep the size of the peacetime group at no more than twenty-five was based on a rough estimate of the amount of analysis the navy would call on it to do. As matters turned out, the needs of the Office of the Chief of Naval Operations were far greater than first envisaged. In fact, there was very little slowing down of the requests for analytical services received by OEG, even though the twenty-five-member scientific staff represented only about a third of the group's wartime peak. During the first year, from November 1945 to November 1946, the group completed a little more than one hundred twenty projects.

Owing to these pressures on the limited number of group members, some projects had to be delayed, and the navy's requests for others had to be turned down. Consequently, Captain R. E. Rose, in the office of Rear Admiral Jerauld Wright (Op-34; Strike Warfare), suggested to Dr.

Steinhardt, OEG's director, that the group be enlarged. But Steinhardt was reluctant to act immediately. He felt that the first postwar year, a transition period, was an anomaly and the inordinate number of requests for studies would not be sustained. Also, the natural turnover of personnel at the close of the war had proven enough of a burden on the maintenance of continuity. Increasing the authorized complement of scientists might hurt the group's efficiency. Too many new people brought in too fast might dangerously dilute OEG's overall level of experience.

This cautious management philosophy was a wise path to take that first year, in view of the number of unknowns. But 1947 saw no letup in the requests for analytical assistance. All indications pointed to the apparently safe assumption that the first year was not an aberration after all, but rather the norm. Indeed, the demands by the navy were still on the increase, to the point that the group was having to forgo opportunities to contribute to the solution of many important problems. Enlargement of the group could no longer be postponed. Fortunately, by that time, the issues of continuity and experience had become inconsequential; the makeup of the group's membership had greatly stabilized. Half of the members were senior scientists with extensive wartime experience, and the other half, though newly hired, had had enough time to become proficient.

A February 1947 memorandum from Admiral Wright to the Deputy Chief of Naval Operations for Fleet Operations and Readiness (Op-03) spelled out the personnel requirements of OEG, as seen under the new circumstances. First, it was necessary to delineate the variety of tie lines between OEG and the navy. At the time, the group reported to Captain Rose, head of the New Developments and Operational Evaluation Subsection (Op-34H), within Admiral Wright's office. Individual members, however, were assigned as scientific analysts or project leaders to different portions of the Office of the Chief of Naval Operations (OpNav). These different OpNav "desks," as they were called, were responsible for the many different warfare areas (for example, antisubmarine, radar, air). A scientific analyst assigned to an OpNav desk was expected to familiarize himself with and help solve the problems of concern to that office. In a way, the scientific analyst arrangement represented a perpetuation of the separate subgroups of the wartime ORG—ASWORG, SORG, AAORG, AirORG, SpecORG—each with its own interests. Now, however, all were within the OpNav structure.

There were eight OpNav desks to which scientific analysts were attached: Antisubmarine (Op-34C2 and Coordinator of Undersea Warfare); Submarine (Op-34C1 and Coordinator of Undersea Warfare); Tactical and Doctrinal Publications Panel (Op-34F); Antiaircraft and Gunnery (Op-34E4); Naval Air (Op-55R); Guided Missiles (Op-57); Radar (Op-413C and Op-34H6);

and Atomic Energy Warfare (Joint Chiefs of Staff Evaluation Board and Op-34E9). It was argued that each of these activities required at least two scientists to ensure that the work would not be interrupted by absences. Short-term field assignments, attendance at conferences, and other duties were expected to take away one analyst or the other from time to time.

In addition to the foregoing, the group was committed to keeping at least two members on the staff of Commander Operational Development Force in the field, plus another two in Washington to back them up. It was also committed to providing lecturers for courses at both the Naval War College and National War College and to maintaining an analyst on the staff of Commander Naval Forces in Europe (on a part-time basis). Finally, members were expected occasionally to take part in fleet maneuvers. Hence, at least one additional analyst had to be added to the group, beyond the four attached to Commander Operational Development Force, to allow for these last commitments. That brought the number to twenty-one.

Next, the group required the services of a scientist to maintain operational statistics and the results of training exercises; a senior mathematician to oversee mathematical computing on all projects; two members devoted to gathering and analyzing technical intelligence; and at least two other "floating" mathematicians, not assigned to any one project. Also, two members not engaged in active research were needed for supervising the preparation of publications and for administrative matters. With the director and his deputy included, the number was brought up to thirty-one. (This number excluded three computer scientists, whose presence allowed the analysts to devote all their time to research.)

Admiral Wright's memorandum setting out the reasoning for OEG's personnel requirements emphasized that the final number was the absolute minimum for carrying out the group's commitments as they then stood. There was no reserve manpower pool to meet new commitments, urgent assignments, or the special project that either strained resources or had to be turned aside. At the time, for example, the group was unable to do work for the Amphibious Warfare Subsection of the Operational Readiness Section, though requests for analytical assistance on pressing concerns were received from them regularly. The same was true of requests from the Assistant CNO for Strategic Plans, the Operational Requirements Subsection, the Ships' Characteristic Board, the Office of Naval Research, the officers attached to the secretary of the navy, and others. On other occasions, special requests were accepted, but only if they could be deferred or given no more than a cursory analysis.

Four additional members would help put OEG in a position to pick up on all these otherwise neglected needs and to avoid having to give short shrift to any study topic. The total, then, came to thirty-five, or ten more than the original peacetime complement. Admiral Wright concluded that "because the value of the group to the Navy Department is now so well known as to require no further explanation," the CNO should ask the Chief of Naval Research to make arrangements with MIT for the enlargement of OEG. The first significant jump in OEG's size occurred in 1949; the group subsequently continued a gradual build-up, as shown in Figure 2-3. However, even over the sixteen years depicted in the figure (from the end of the war to the formation of the Center for Naval Analyses in 1962), the group never regained its original peak of eighty scientists.

In April 1947, just weeks after the group's enlargement had been decided on, other changes to OEG were proposed. The changes, offered to Wright by Steinhardt, emerged from conversations between Steinhardt and John Slater, head of the Department of Physics at MIT and the sponsor of OEG; H. B. Phillips, head of the Department of Mathematics; N. McL. Sage, director of the Division of Industrial Cooperation; and J. R. Killian, filling in for Karl T. Compton, president of the institute. A basic point was that two changes in the relationship between OEG and MIT would enable the group to be of even greater service to the navy.

The impetus for these changes came from a decline during the preceding year in the number of MIT's faculty members directly taking part in the group's work, which happened to coincide with the loss of Professor Morse, who had been granted a leave of absence from the institute to become director of the Brookhaven National Laboratory. The institute wanted to reverse this trend. The contractual feasibility of the proposed ways to do this were discussed with Admiral P. F. Lee and Captain M. J. Lawrence of the Office of Naval Research before Steinhardt approached Wright.

The first of the two suggested changes concerned the transfer of OEG's organizational tie line from the Department of Physics to the Department of Mathematics, the group's operations research work being of greater interest, it was thought, to the mathematical staff than to the physics staff. Professor George P. Wadsworth was to be appointed faculty representative, so that a single point of contact would be available for liaison and coordination. Several benefits were expected from the realignment. Foremost, of course, was the anticipated increase in the desire of department members to become involved in OEG's studies for the navy. Ultimately, too, the change would make available many more people for consultation on long-range or abstract problems, without costing the navy a penny more. Further, and of particular interest to MIT, the work of the group would be more intimately integrated into the institute's teaching and research programs. This feature, in turn, would expose students to operations research, arousing their interest and perhaps easing recruitment.

The second change in the relationship between OEG and MIT is best understood if a few prefatory remarks are made. It has already been

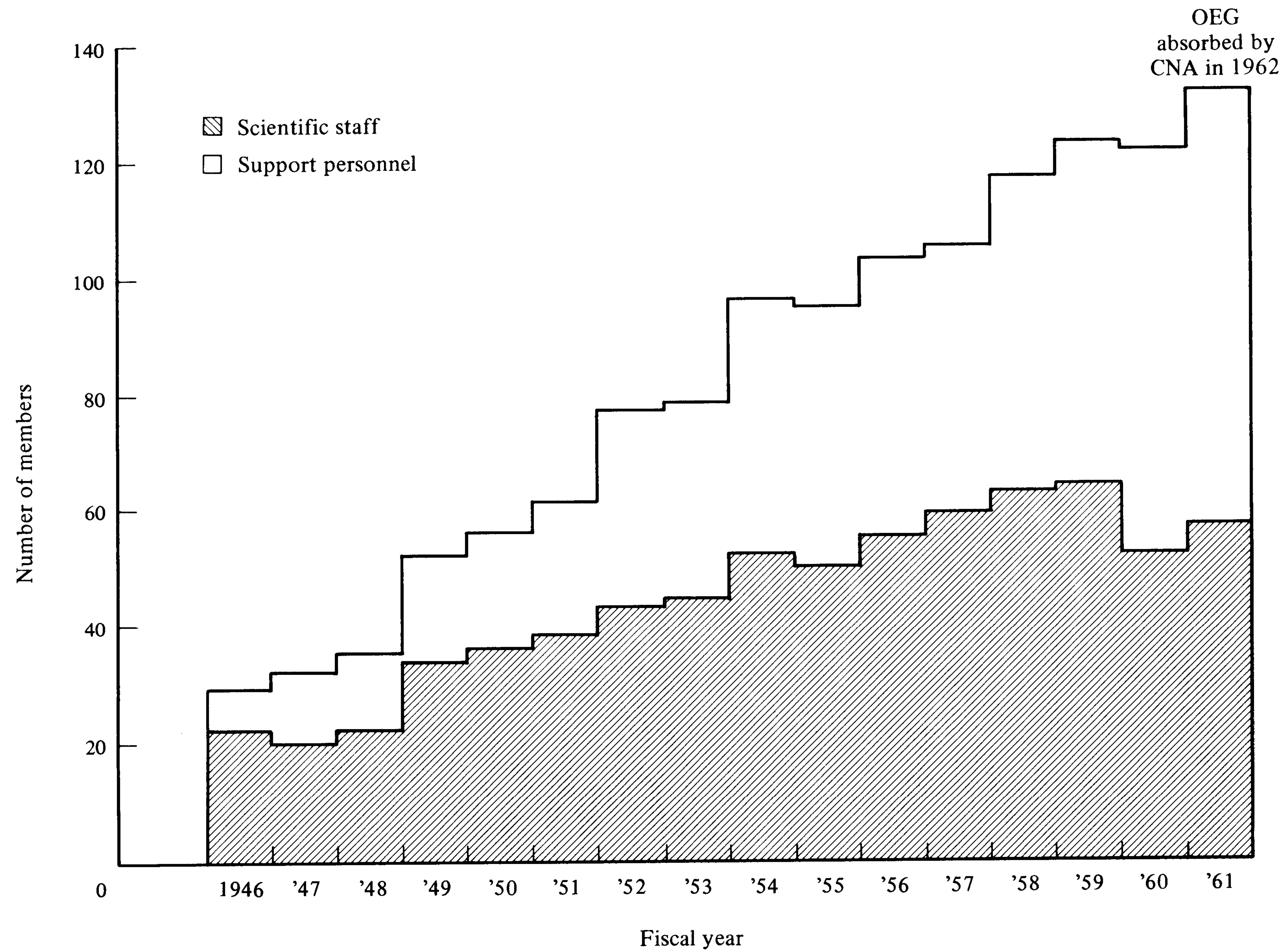



Figure 2-3. Growth of OEG (to 1962)

pointed out that the importance of continuing the group under the auspices of an academic institution rather than as part of the civil service was recognized from the outset, by both the group and the navy. As Steinhardt remarked to Admiral Wright in describing the wartime group, "Much of its unique value was due to the fact that the group was able to provide a fresh, unbiased, scientific viewpoint, because the personnel of the group had either retained their ties with the academic scientific world, or had only recently come from it."

In view of these sentiments concerning the basis of OEG's professionalism, MIT agreed to a scheme that would encourage about 20 percent of the staff in any given year to rotate between Washington and Cambridge. (As it turned out, actual participation was to average well under 5 percent.) It was stipulated that the program would not be allowed to cause the Washington office to run short of analysts. This implied that, if necessary, additional scientists would be hired, exceeding the number contractually agreed to. No increase in funds was anticipated, though, because the transfers to Cambridge would usually involve fewer stipends and less annual leave.

The program aimed at enhancing the professional qualifications of group members, and thus their efficiency, while also attracting candidates for employment with OEG. (A later evaluation of the program supported the original argument that not just more, but also better, people would be enticed to join.) In addition, the rotating of members between Washington and Cambridge presented a way to accommodate an enlargement of the group without further cramping the Pentagon office. Finally, the presence of OEG personnel at MIT would help ensure that analytical assistance by the school's Department of Mathematics was well directed and not tangential.

Admiral Wright agreed with both of Steinhardt's proposed changes, that is, the transfer of OEG from the Department of Physics to the Department of Mathematics, and the rotation of personnel between Washington and Cambridge. In approving the program of rotation, "particularly in view of the advantages that will accrue to the individuals, the group, and the Navy," Wright cautioned Steinhardt to ensure that the work would not suffer and that key people needed in Washington full time would not be away for long.

### Analysis between the Wars

From 1947 until the Korean War, OEG took advantage of peacetime conditions to begin examining broader issues than it could before. The group found that it could now dissect the navy's problems with greater deliberation and aid in the formulation of strategic policy at a scope formerly denied it by the exigencies of war. At the same time, more advanced and sophisticated analytical tools had to be developed.

One example of the several areas that received broader attention was, as might be expected, antisubmarine warfare. An OEG report published in 1948 analyzed ten antisubmarine weapon systems—and tactics for their use—with the goal of maximizing the probability that enemy submarines would be killed, once an opportunity to attack had been presented. For the analysis, data beyond those collected in the war were needed, largely because the operational characteristics of submarines had changed. Sea trials were expensive, slow, and, above all, inaccurate, so it was decided that artificial tests should be run on an "attack evaluator," located at the Surface Antisubmarine Development Detachment at Key West, Florida. Not only would such tests overcome the disadvantages of sea trials, they would also permit a large amount of data to be compiled so that the results would be statistically significant. Later sea trials, it was reasoned, could verify the results and provide a basis for translating test results to actual operations at sea.

OEG members present at the detachment made a detailed analysis of the test data, taking into account the submarine's speed at the time of firing, the effects of target maneuvers, the type of projectile and weapon director, and the firing range. They then measured attack errors, defined as the distance between the center of the submarine and the center of the pattern of charges. Finally, they were able to calculate the probabilities of scoring a kill for the ten weapons employed against high-speed, deep-diving submarines, similar to the advanced Type XXI U-boat developed by Germany toward the close of the war.[8]

Another important piece of work in the area of antisubmarine warfare was done by Shirley Quimby, now well known for his earlier role in heightening America's awareness of the full scope of military operations research. Since those early days as a U.S. naval attache in London, he had become active in U.S. operations research in mine warfare. An OEG study prepared by Quimby evaluated naval ground mines as a weapon for use against submarines. The kinds of mines considered were designed to sit on the sea floor, then explode in response to underwater disturbances typically produced by submarines. Specifically, the mine's firing mechanism could be set to detonate as a result of noise (at some prearranged frequency), local changes in the strength of the earth's magnetic field caused by the metal in a submarine's construction, or changes in hydrostatic pressure as a submarine moved in the water. Any one of these disturbances—or a combination—might be chosen as sufficient to set off the mine. A particular class of submarine could thus be targeted, and the vulnerability of the mines to sweeping would be lessened.

The primary object of the study was to determine the extent to which the operations of enemy submarines could be inhibited and their bases closed by the use of these mines. A related goal was to estimate the kind of effort required to accomplish these results. This encompassed such issues as the accuracy of mine placement by aircraft, the fraction of mines made inoperable by the shock of being dropped, the number of aircraft sorties required, the level of threat desired, and the need to replenish the mine field. A secondary object was to uncover deficiencies in both equipment and mining tactics. An interesting caveat was added to the study, warning of programs then under way in the Soviet Union and elsewhere to develop deadlier antiaircraft weapons. Among the weapons and defensive devices cited were ground and airborne radar warning systems, night fighters, radar night-fighter control systems, radar jammers, and various antiaircraft missiles.

While examining ways to increase the number of submarine kills, OEG began to look at the issues from a somewhat different perspective. That is, it made sense to view U.S. antisubmarine efforts as necessary not just for their own sake, but also for the vital purpose of protecting our shipping. Hence, at the request of the Assistant CNO for Undersea Warfare, the group shifted its analysis from narrow antisubmarine issues to the entire problem of how to protect, and thus maximize, the overseas transport of supplies and troops. This required OEG to consider protective measures not necessarily related to the killing of submarines. Even so, the final report, prepared under the direction of Sidney K. Shear and Howard W. Kreiner, devoted more space to the discussion of the submarine threat than to the mine and air threat, because a great deal more was known about it. Still, the result was an inclusive survey of the capabilities and limitations of dealing with threats to shipping, based largely on old data but with an eye to future developments. To aid in this endeavor, OEG sponsored three conferences (in June and October 1949 and in February 1950) on undersea warfare and overseas transport.[9] Representatives from other agencies within the navy and scientific community were invited to contribute.

All participants acknowledged that the concept of antisubmarine warfare had been transfigured over the four years since the close of World War II. In particular, more formidable submarines (capable of greater submerged endurance at higher speed and armed with longer-range torpedoes) were expected to make it much harder to deal with them once they had reached the high seas. This difficulty focused attention on the possibility of keeping enemy submarines from their operating areas. The most promising means of achieving this goal was offensive antisubmarine mining, in the manner proposed by Quimby. Alternatively, as a last-ditch effort, ways might be found to destroy torpedoes before they could strike their targets, although this approach was still highly speculative.

Of course, hard realities demanded that traditional antisubmarine measures, responsible for the successes against Axis submarines, also be reviewed. One practical consideration, for example, was that the U.S. Navy had to continue relying on its large stockpile of World War II craft and equipment. It would have been unsound to envision a quick and complete replacement of this reserve, in light of its cost. Indeed, even new wartime pressures—and the resultant mobilization—were not expected to alter this fact very much. Hence, no matter how appealing innovative antisubmarine measures might be, the preponderance of the navy's efforts in the near term had to stay with the traditional. In fact, at least five years would probably separate any decision concerning a new means of protecting overseas transport and the introduction into the fleet of the new craft and equipment—allowing for research and development, operational evaluation, procurement, and training.

Although the navy's mission was to minimize the loss of transport shipping by countering enemy action, a study was also made of other, noncombat measures that would, for instance, increase the efficiency of the merchant fleet. The goal was to deliver more cargo per unit time, by reducing the time at sea for each trip and shortening the time spent in port. One way to reduce time at sea was to build faster ships, capable, say, of 20 knots. Too few of the fast ships, however, would be saved from submarine attacks (even if such speeds were reached) to warrant their construction in large numbers. On the other hand, there was a clear need to build at least a small number of them. OEG reasoned that in a world war, situations might arise that would make it extremely important to transport goods to far-away ports with minimal delay. With modern ships able to transit at 20 knots—plus improvements in loading and unloading time—goods could be transferred about twice as quickly than if carried by the old Liberty ships. A further significant gain was that the proposed designs for these faster ships allowed for an increase in size over the merchantmen then in use. The higher cost of the larger and faster ships would likely be offset by the smaller number required to maintain a particular cargo delivery rate, by a reduction in the time during which protection against submarines would have to be furnished, and by a reduction (though small) in losses.

Another way to reduce time at sea was to choose shorter routes. The task of selecting a route for a convoy or an independent ship in wartime, however, was complicated by several factors, other than the natural but somewhat predictable hazards posed by rough seas, poor visibility, shoals, and so forth. Two other factors, which had to do with the threat of enemy attack, were the probable location of enemy bases, and thus the number of submarines that could be sent to patrol a given route, and the availability of land-based air cover. The risks were further compounded by the effect of weather conditions on the ability of defending forces to protect the ships, and equipment-related considerations, such as prevailing sonar conditions.

It is axiomatic that if all convoys were to use routes within a narrow band of ocean for any length of time—because that was where the optimum routes happened to be—enemy submarines would concentrate their patrols along that lane. Therefore, diverse routes, even those plagued by bad weather, had to be used. In that way, the enemy would be forced to dilute his submarine force, thereby reducing the risk faced by each convoy. OEG worked out the procedures by which alternative routes should be chosen, weighing the chance of natural casualties versus casualties from enemy attack.

As for time spent in port, an earlier study had shown that if port time during World War II had been cut by a third, the result would have been equivalent to reducing losses by half. Several approaches to shortening in-port time were considered. One was to modify the design of dry cargo ships so they could be loaded and unloaded more efficiently and to modernize terminal facilities to increase capacity and access. A more radical approach was the possible design of hydrofoil vessels, to be capable of operating at about 30 knots (offering virtual immunity against submarine attacks) and carrying a thousand tons of cargo. The cargo would be transported in two detachable barges that could be dropped off in port for unloading, enabling the hydrofoil to embark on its return trip immediately.

An integral part—indeed, by far the largest part—of OEG's examination of this problem of overseas transport was the various enemy threats and possible countermeasures to them. The threats were analyzed on a near- and long-term basis (the latter beginning no sooner than 1956, six years beyond issuance of the study results). One of the three threats considered was an airborne mining campaign, designed to blockade ports and sink ships. Mine warfare theory had been well developed during World War II. In that war, British planes laid over fifty-six thousand mines, sinking 864 ships and damaging another 843. The German campaign had been just as vigorous. Hence, fairly reliable and realistic predictions could be made, taking into account the number of mines needed to produce one sinking, the type and number of planes available to the Soviets, mine lethality, and so forth. The chief countermeasure evaluated by the group was the interceptor, whose usefulness depended on effective early warning, the fighters' reaction times, the number of enemy raids that could be handled at one time, and the defensive capabilities of the raiders. Antiaircraft fire was another means of preventing successful minelaying. Once the mines were dropped, available countermeasures included removal or inactivation of the mines, minesweeping, and damping of the ships' magnetic and acoustic fields.

The second threat came from direct air attacks. There were three principal ways (exclusive of mining) in which an enemy could use aircraft to harm U.S. overseas transport: direct attacks on ships or ports; reconnaissance to support attacks by ships or submarines; and attacks to cripple minesweeping or antisubmarine forces. All three of these methods were used in World War II. For example, Allied planes attacked port facilities, such as Hamburg and Bremen, and the ships tied up in them. German minesweepers operating in the North Sea were harassed by British Coastal Command Strike Wings. At the same time, Allied antisubmarine planes in the Bay of Biscay suffered attacks by German Ju-88 fighters. Additionally, German long-range aircraft based in France and Norway cooperated closely with submarines. Hence, many data were available for analysis.

It was decided that ships in harbor would not be easier targets than ships at sea, mainly because port defenses were more likely than convoy defenses to bring down attacking aircraft. Furthermore, a percentage of in-port ships would be empty, making raids less worthwhile. Air attacks on ships at sea were considered possible if Soviet planes (particularly the TU-4, which was similar to our B-29) were based in northern or western Europe, as had been done by Germany a few years earlier. Taking into account estimated search rates, weapon effectiveness, tactics, and so on, OEG calculated the threat of such air attacks. Countermeasures were postulated, including ship-to-air guided missiles, antiaircraft fire, and a locally stationed force of small carriers.

Inasmuch as submarines constituted the chief threat to overseas transport in both world wars, much was known about their capabilities and the effectiveness of various countermeasures. It was easier, therefore, to estimate the future submarine threat than the future air or mining threat. Intelligence estimates judged the Soviet submarine fleet of 1950 to be weaker than the U-boat fleet of 1942 to 1945, in terms of numbers and efficiency. The characteristics of the various types of submarines in the Soviet fleet at that time were well known. The potential threat, in even a couple of years, loomed large, however. The Type XXI U-boat—with its enhanced propulsion, improved streamlining, radar-camouflaged snorkel, greater quietness, and advanced electronics—was regarded as the model for the future threat. The main weapons by the mid-1950s were expected to be a long-range, pattern-running torpedo and an improved homing torpedo. Not overlooked were the many German specialists in submarine warfare then available to the Soviets.

Any future war within the time frame of the study was likely to entail an all-out effort by the Soviets to cut merchant shipping between the U.S. East Coast and Britain. The originating points for Soviet submarine patrols would at first be confined to Russian bases, such as Murmansk, but later extend to Bay of Biscay bases, such as Lorient (the latter perhaps being captured by the Soviets a year or so after the outbreak of hostilities). Although the Soviets were expected to assign the bulk of their force to the waters around Britain and Greenland-Iceland, they would likely send one or two submarines to patrol American coastal waters.

Because it was getting more difficult and costly to battle modern submarines once they were within striking range of a convoy, OEG's attention turned to the possibility of preventing enemy submarines from reaching open-ocean transit areas. The use of mines to deny passage in and out of bases was examined from two points of view: "blockade mining," designed to close a port to submarine traffic and cause casualties, and "attrition mining," designed to force the enemy to pay too high a price (in equipment and personnel) to clear the mined area. The minability of about sixty coastal ports and approach channels that were then actually or potentially under Soviet control was evaluated.

The feasibility of sharply curtailing the Soviets' freedom of action was determined. The anticipated results of a hypothetical mining campaign are illustrated in Figure 2-4. At first, the enemy's ability to sweep the mine field parallels the mining effort. After a while, however, the minesweeping force's losses begin to show up as a fairly sharp decline in the sweep rate. Consequently, the backlog of unswept mines rises, so that even the production of new sweepers fails to make a dent in the total number of active mines sitting in the channel. The result is abandonment of the sweeping effort, and effective closure of the port.

Some ports, however, would not be amenable to mining. Alternative means for attacking submarines at their source had therefore to be considered. These included strategic bombardment of facilities used to construct submarines, bombardment of submarines in home waters, and commando raids against the concrete pens in which the submarines were housed.

Despite attacks aimed at the bases, some submarines were expected to make it to the high seas. The classic anti-U-boat effort in the Bay of Biscay pointed to one way to counter a transiting submarine: with antisubmarine aircraft. The area of the Bay that was the focus of Coastal Command's efforts was called the "unclimbable fence" (the darkly shaded rectangle in Figure 2-5). All U-boats based in the Bay had to pass through this area to reach their operating areas. The position and size of the fence was determined by the number of hours (and thus miles) U-boats could travel submerged before having to surface, and the number of hours (miles) they had to remain on the surface before diving again. It was in the rectangle, then, that searches concentrated.

OEG figured that if most Soviet submarines in the near term lacked the submerged endurance of the Type XXI, the width of the unclimbable fence

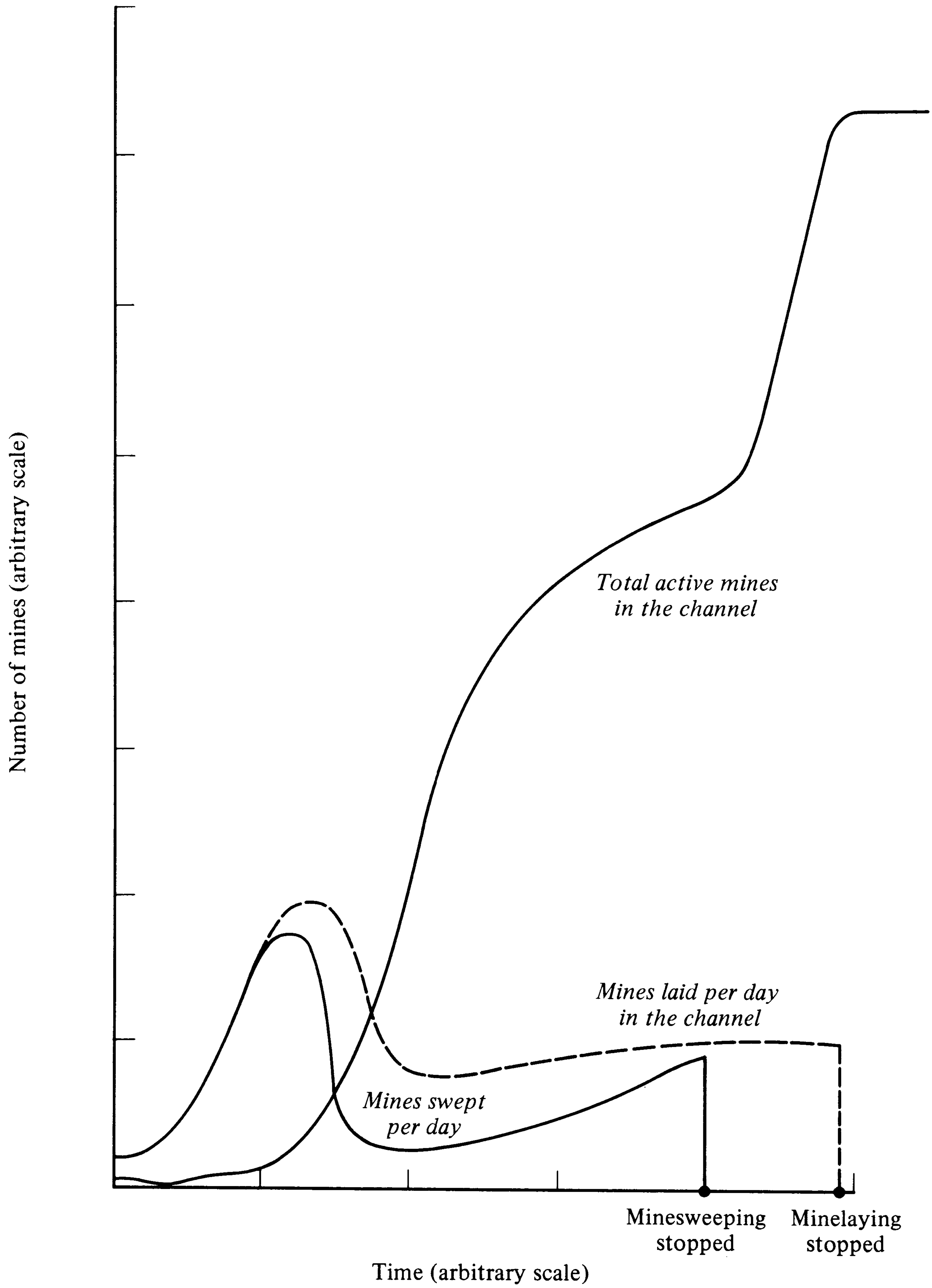



Figure 2-4. Evolution of a Mining Campaign

would stay about the same. Because snorkels had become vulnerable to being spotted by radar (at least with a low sea), Soviet submarines retrofitted with snorkels would gain little advantage in the Bay. If, however, the Soviet submarine force over the long term comprised Type XXI-equivalent boats, with more efficient propulsion and battery size, then the area of the

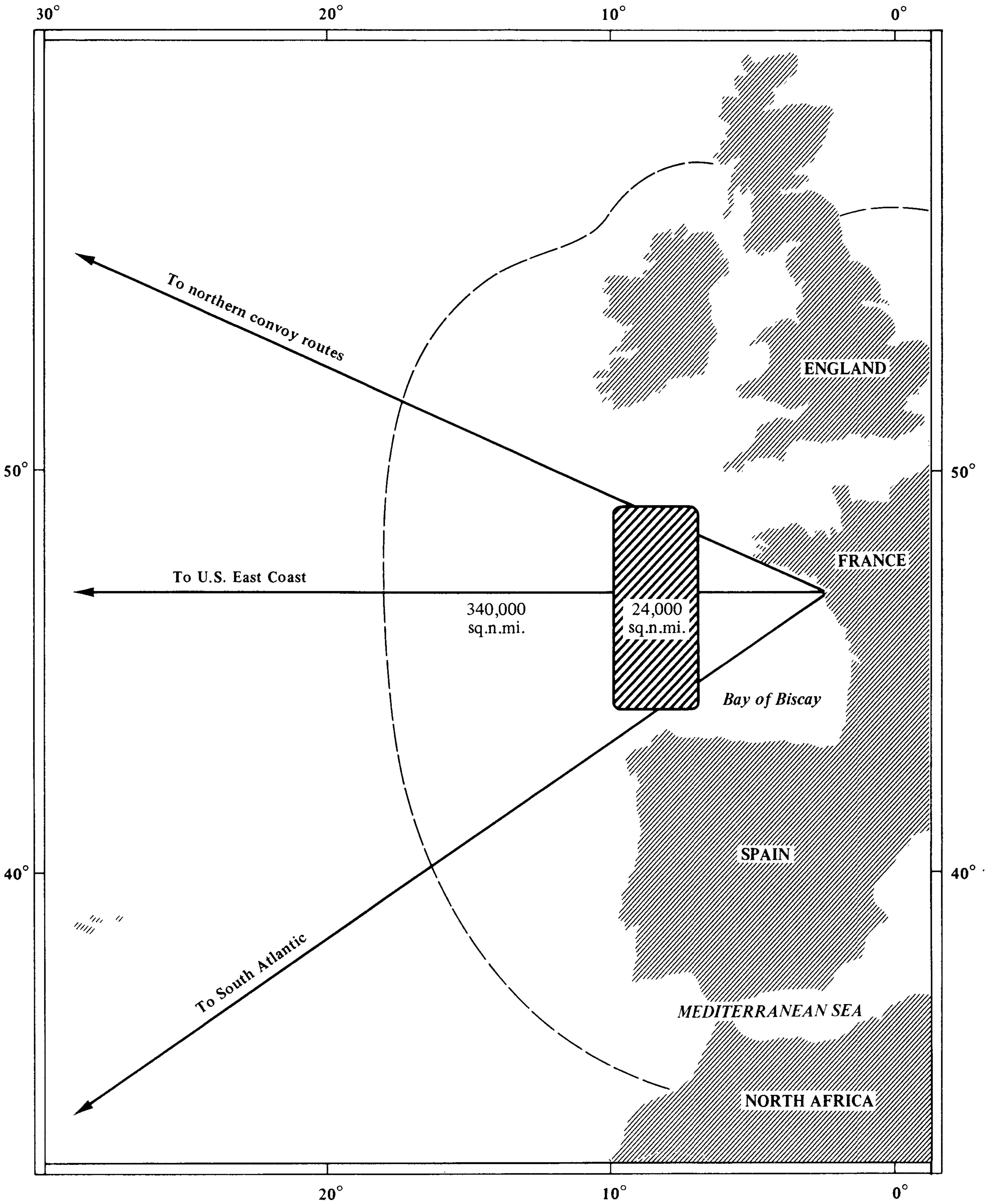



Figure 2-5. Bay of Biscay Antisubmarine Effort and the "Unclimbable Fence"

fence would increase fourteenfold (the area enclosed by the dashed line in Figure 2-5). In addition to producing kills, persistent air attacks would force the submarines to stay submerged longer. The submarines would thus be slowed during their transit, reducing their density in each operating area.

Another way to counter transiting submarines, and one that OEG considered in the overseas transport study, was to employ attack submarines. The analysis assumed that submarine-hunting submarines (designated SSKs) would be deployed along a barrier line across a route traveled by enemy submarines. Several aspects of such a scenario were examined, including the probability that an SSK would be able to close to an attack position once an enemy submarine had been detected, the probability that an attacked submarine would be sunk, and the percentage of transiting submarines that would be destroyed. The analysis gave the navy an appreciation of the effectiveness of an SSK barrier, along with estimates of force requirements and anticipated SSK casualties.

OEG also looked at an entirely different facet of antisubmarine warfare, related to intelligence. Good intelligence on the enemy's intentions and movements was essential. During World War II, information on submarine distributions and movements came from various sources, such as radio direction-finding (RDF) fixes (from intercepted radio reports), sightings, ship sinkings, and, last but not least, Ultra. These accumulated data were then evaluated, entered on the so-called Submarine Position Plot, and passed along to operational commanders. The plot provided a fairly reliable picture of the current situation at sea. It appeared, however, that the task of assembling a submarine plot would become much harder in any future war. For example, the use of snorkels would markedly reduce the number of visual sightings by aircrews. Similarly, an enemy policy of not using radio communications or of employing much shorter signal pulses would greatly interfere with the United States's ability to exploit RDF fixes. Conversely, the ability of convoys or independent ships to deny enemy intelligence gatherers information on a convoy's movements would add to the safety of overseas transport.

In analyzing measures for the protection of overseas transport, OEG had to take a new look at the pros and cons of convoying versus independent shipping. Convoying, as a strictly defensive measure, still had the basic goal of making merchant shipping safer. Its advantages were threefold. The most manifest advantage was that each escort vessel could protect a large number of ships when escorting a convoy. Also, because a submarine enjoyed only a negligibly better chance of spotting a convoy than a single ship, it would make fewer contacts as a result of the considerable drop in target density. Finally, very large convoys could be assembled with no increase in losses over smaller convoys. Sailing independent ships had its advantages, too. First, independent ships could spend less time in port, as a result of not having to wait for convoys to form and not having to queue for loading and unloading. Second, they could transit as fast as their engines were capable, without having to slow to the pace of a convoy. Hence, with limited numbers of merchant vessels and escorts, a carefully planned mix of convoyed and independent ships had to be worked out.

The advantages of independent ships meant that during a short war (or the early phase of a prolonged war), these ships would carry enough cargo to offset losses. During a long war, however, ship losses would eventually result in less cumulative cargo being delivered than if convoys were used. Based on World War II figures, graphs were drawn (Figure 2-6) to illustrate this phenomenon, allowing for the same initial number of convoyed and independent vessels.[10] In short, ship losses accounted for the crossing of

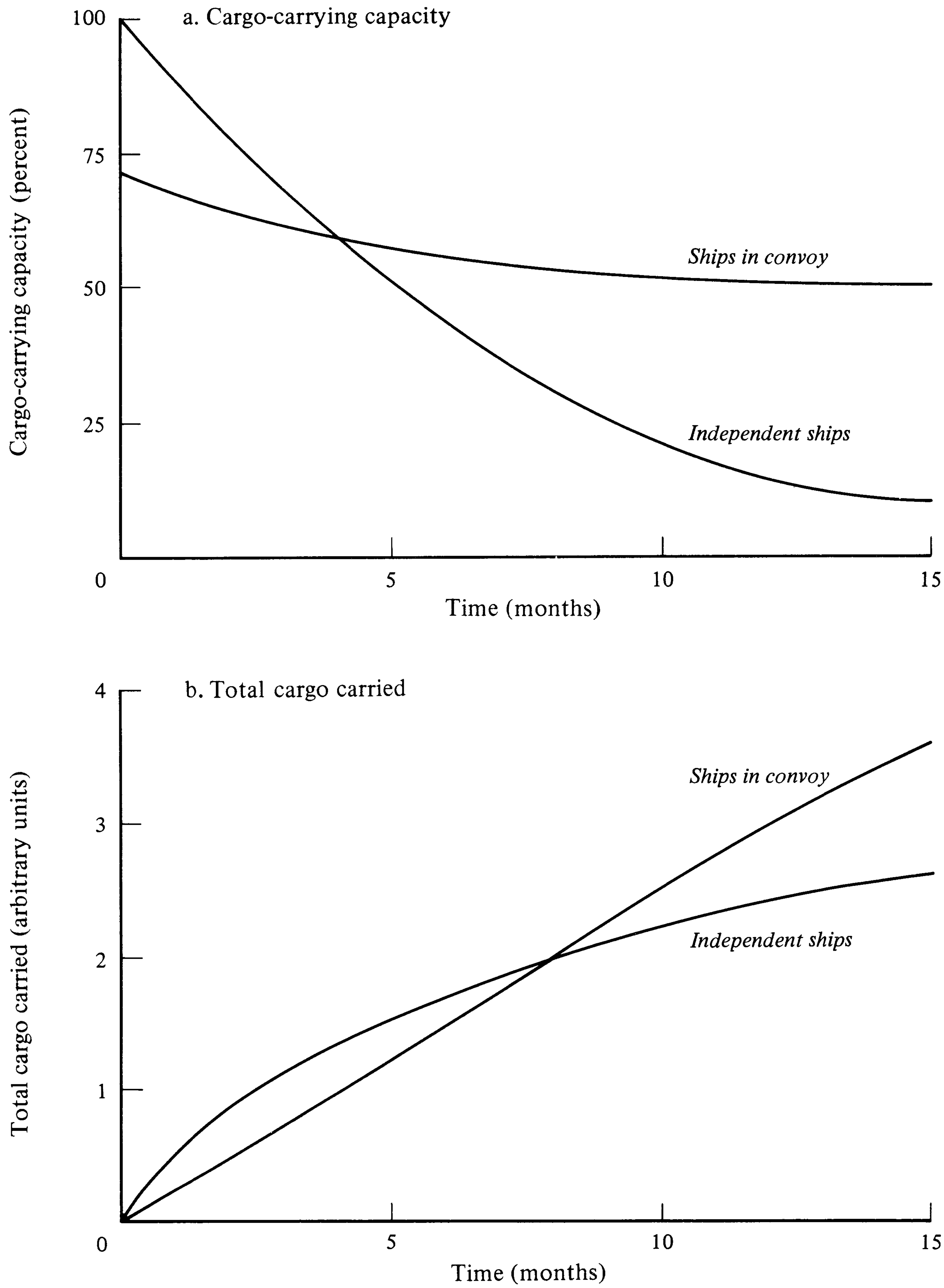



Figure 2-6. Relative Effectiveness of Convoyed and Independent Ships

the curves. The second graph in the figure shows that the seven-month mark was the cutoff point after which independent ships would no longer have an advantage over convoys, given the World War II-derived assumptions.

One last important subject OEG considered in the study was that of screening convoys. The purpose of aerial and surface ship screens was to protect convoys from submarines that had escaped destruction from attacks while at home base or in transit. It was in this terminal phase that the submarine would have to reveal itself, if by no other means than its sinking of a merchant ship. To get within firing range of a convoy, the submarine would first have to elude detection by a screen of planes. Once detection of a trailing or closing submarine had occurred, the plane could conduct an attack or call other aircraft or ships to the area; also, the alerted convoy could change course. OEG therefore considered various scouting and screening plans and their measures of effectiveness.

If the submarine managed to pass through the aerial screen undetected, it would then have to contend with the second line of defense, an inner screen of surface escorts. The purpose of these sonar- and radar-equipped ships was to detect and counterattack the submarine, both to prevent it from inflicting damage on the convoy and to augment the enemy's attrition rate. If the submarine were already close enough to the convoy to fire a torpedo, the escort's immediate role was harassment—to throw the submarine off stride—followed by attack. Ideally, of course, the screen should be impenetrable, preventing submarines from reaching their maximum firing ranges and covering all possible approach angles. Owing to the limited availability of escorts, however, actual screens had to be arranged in patterns that would maximize the probability of detecting every encroaching submarine, though they would unavoidably fall short of the ideal. Based on data from the previous war, the number of convoyed ships sunk per attacking submarine decreases in a virtual linear relationship as the number of escorts made available to that convoy increases.

In the short term, OEG pointed out that the Soviet threat to the inner convoy screen stemmed from the fact that there were too few escorts to protect transatlantic convoys properly for at least the first several months of a war. In the long term, torpedoes with much longer ranges (probably to twenty thousand feet) were expected to pose an enormous problem, perhaps requiring a trebling of the number of escorts for the same degree of protection. Because improvements in sonar might help counter the advantages accrued by the Soviets from these torpedoes, OEG urged that an extensive study be done of this subject, particularly in light of an all-out program then under way to upgrade the navy's underwater listening capabilities. In addition, the inclusion of many more Type XXI-equivalent boats in the Soviet fleet was seen to have far-reaching effects. Specifically, their greater speed would enable them to attain a favorable firing position more easily. Such submarines could also take advantage of their greater underwater endurance and speed to hide under a convoy they had attacked, until a reasonable chance to escape presented itself.

As a result of these projected dangers to surface escorts, alternative ways to protect overseas transport were considered. The most important of these was the helicopter, equipped with "dipping sonar." The procedure was for the helicopter to fly to the search area, lower (dip) its sonar in the water while hovering, then try to pick up indications of a submarine's presence. If a submarine was detected, the helicopter would attack, using an antisubmarine mine. Two other protective means were blimps towing echo-ranging gear and armed with homing torpedoes, and sonobuoy barriers laid parallel to the direction of the convoy.

OEG's study of the protection of overseas transport—in effect, a compendium of measures and countermeasures—had enormous scope. Its most distinguishing mark was clearly its inclusiveness; another was its emphasis on predicting future circumstances rather than on reconstructing past performance. The group's judgments and recommendations, moreover, profoundly influenced the portions of the navy's research and development program that were addressed by the analysis. For instance, systems that seemed the most promising in view of U.S. needs and the potential Soviet threat were supported.

The timing of the study proved critical because of the apparent usefulness of the work to an exhaustive report being prepared on the subject at MIT. Thirty-three scientists had been brought together at the institute for three months during the summer of 1950 to work on what was called Project Hartwell. The goal was similar to OEG's: "To study the problems that confront the Navy in the performance of its responsibility to protect overseas transport and its own task forces; to appraise the efficacy of present planning and equipment to solve these problems; and to . . . recommend means by which gaps may be filled and deficiencies remedied."[11]

The Hartwell report encompassed a wider range of topics than did OEG's study—not surprising, since this one project commanded the attention of about as many scientists as made up all of OEG—including a discussion of nuclear weapons,[12] communications, and underwater propulsion systems. The bulk of the topic areas did, nevertheless, overlap. The scientists of Project Hartwell could thus make extensive use of OEG's analysis in evaluating the Soviet threat to overseas transport and in suggesting actions the navy might consider with regard to such subjects as weapons systems, detection systems, and ports and shipping.

The broader scope of the group's new analytical bent was not by any means confined to antisubmarine warfare. After the war, the navy had become seriously concerned with what it viewed as a formidable threat from air attacks and an apparent decline in our air defenses. Consequently, in July 1947, the Chief of Naval Operations established the Air Defense Committee (later the Air Defense Board), which aimed to "provide policy guidance for improving the air defense of the Navy through coordination of operational procedures and of military requirements for new developments."[13] To help the committee acquire a comprehensive understanding of the subject, the navy decided that a study should address the long-term operational requirements of interceptor aircraft for air defense. Hence, in September of that year, Admiral Jerauld Wright, chairman of the Air Defense Committee, asked OEG to do the study, to be "pursued at high priority."

As with the study on overseas transport, OEG decided to conduct a series of conferences. The first was held in January 1948; the last, and sixth, in May 1949. The group was to function as a clearinghouse for information on air defense, gleaned from a variety of organizations. Participants included many of the laboratories, bureaus, research offices, and test stations of all three military services; defense contractors; operations analysis groups from both here and abroad; and, of course, the offices of the Secretary of Defense and the Chief of Naval Operations. OEG's Martin L. Ernst, John L. Everett, Russell C. Coile, and Oscar A. Hoffman were responsible for heading the effort, with assistance from many other group members, including Edward S. Lamar, James M. Dobbie, Frank W. Lamb, and Douglas L. Brooks—some of whom had been members of ASWORG. The conferences—each with its own theme—proved an excellent medium through which to explore the subject and its aspects needing further study.

The fundamentals of air interception were thoroughly examined, with emphasis on control and on guided missiles. First, planes approaching the fleet had to be picked up by early-warning radar and identified as the enemy. A controller would then be assigned to track the raiders on his scope and to determine their position, course, and speed. Based on this information, he would vector those interceptors under his control (some already in the air on patrol, others still on the carrier's deck) to the position where he expected the enemy planes to be by a certain time. Using ordinary radio communications, he would continue directing the fighters until they had sighted the enemy and were able to take over for the duration of the battle.

This type of interception, termed "close control," depended largely on the controller, less on the pilot. The system, though adequate during most of World War II, now faced two serious problems, one being the shorter time available to complete interception. Bombers were becoming faster, thereby cutting down on the time between detection of the enemy and the launching of his weapons. Faster enemy planes were also harder to detect with radar, effectively reducing detection range. In addition, the advantages of speed and maneuverability enjoyed by the interceptors were diminished. Finally, longer-range guided missiles, capable of being launched by the raiding bombers from as far away as thirty nautical miles from the fleet, again meant that the interceptors had less time to get to the enemy. The second serious problem faced by close control arose from an anticipated change in enemy tactics. Historically, formations of bombers were met by formations of fighters, simplifying the controller's job. Future tactics, it was thought, would call for large numbers of individual, dispersed bombers that might saturate one or more links in the control system.

There were two possible approaches to overcoming these problems. The navy could upgrade those links in the control system that seemed the most vulnerable, for instance, the detection range of search radars, and also let increased automation help prevent saturation of the radar scopes, communications, or other parts of the system. More radical, however, would be the development of a new procedure rather than a patching of the old one. In the new procedure, called "broadcast control," more of the interception effort was placed in the hands of the fighter pilot. Because of this shift in responsibility, interceptors would be required to carry crews of two, to permit quick and accurate in-flight solution of navigational problems. After detection and identification had been achieved by the controller—as was the case with close control—the new procedure called for the controller to begin playing a secondary role. That is, he would transmit the position, course, and speed of the enemy, but otherwise subordinate his role. The interceptors would then rely on their own navigational equipment to ascertain their position and to make their way toward the approaching bombers. Long-range (twenty-mile) air intercept radars were expected to enable the fighters to spot the enemy quite far away, making it possible to correct for positioning errors. Anticipated increases in automation promised to improve the system even more. With the new procedure, the controller would be able to handle more simultaneous raids than before.

It was assumed that although the Soviets' air forces at the time were primarily for ground support—their army was indisputably their main arm of defense—the Soviets would readily divert these forces to attack threatening naval units. Moreover, the Soviet naval air force, believed to be assigned to operate against enemy fleets and convoys, was being enlarged and modernized. By the late 1950s, the Soviets were projected to have a sizable force of 500-knot bombers, armed with air-to-surface guided missiles with a range of up to twenty miles. Attacks would likely be much more dense than any experienced by U.S. Naval forces in the past, perhaps consisting of as many as two hundred fifty planes approaching individually over the course of an hour.

The many facets of air interception examined by OEG included the probability that the enemy could launch attacks within required penetration distances; maximum interception ranges, given current and anticipated equipment; search radar accuracy and data rate; interceptor and control saturation; the probability of a kill for forward- and rear-hemisphere attacks, taking into account such factors as weapon sights, aerodynamics, and armament; the effects of bomber evasive maneuvers on interceptor successes; and optimum tactics for both sides in duels between fighters and bombers. As with the study on the safety of overseas transport, the results of this far-reaching analysis were illuminating and influenced considerably the navy's research and development program and tactical doctrine.

The brief interval between the wartime ORG and the peacetime OEG—made remarkable by the relative ease with which customary bureaucratic hurdles were surmounted—proved to be beneficial to both OEG and the navy. As far as the group was concerned, the speedy transition presented the opportunity to pull together the diffuse fragments of war-related analysis while many of the principals were still on hand. At the same time, the group was able to record the large body of methodologies pioneered during those hectic four years. The situation also made it possible for OEG to keep intact its carefully cultivated ties with all echelons of the naval hierarchy—ties that might well have been eroded by a protracted period of transition. Because the group's links to the navy were preserved, permitting the free flow of ideas on the improvement of operations, its effectiveness was preserved, too.

The navy benefited equally, by ensuring that there would be continued unbiased input into its policy making. In the face of a dramatically changing world, and an inchoate Soviet threat, the navy could not afford to succumb to inertia. The quick and smooth transition meant that OEG could help prevent this. Having gotten the postwar year of consolidation behind it, the group did indeed begin to turn its attention more and more to the Soviet threat. The outcome was an important series of studies that probed the nature of this threat and its possible evolutions over the next five to ten years. Findings and recommendations took full account of how warfare on the high seas was being transformed. The need for continued analytical ingenuity was very evident.

The early postwar years had clearly brought about a maturing of OEG, in terms of its analytical wherewithal, its makeup, and its influence on naval decision making. Yet no sooner had the group begun to settle into this comfortable niche than an unlikely event forced a change. The event did not spring from within the borders of the Soviet Union, where most people's eyes were turned, but rather from within the Korean peninsula.

The unleashing of North Korean troops across the 38th Parallel on 25 June 1950 signaled new problems for the U.S. Navy, and, for OEG, an inevitable redirecting of commitments.

# 3

# A Decade of Change for OEG: from Korea to a New Strategic Balance

## Eruption of the Korean Peninsula

The driving force behind creation of the 38th Parallel as a boundary through Korea's midsection was the fear that Soviet forces—which had entered the war against Japan on 8 August 1945—might steamroll down the entire peninsula before U.S. forces could join the fray. The threat of having the Soviets become Korea's new occupiers rather than its liberators meant that imposition of the 38th Parallel as a check on Soviet advances proved fortunate, indeed. Efforts to keep abreast of events as a result of the sudden end to the war in the Pacific led Washington to make hasty preparations for Japan's impending surrender. The terms of surrender drafted by the secretary of war on 11 August provided for Japanese forces north of the 38th Parallel to surrender to the Soviet commander, and for those south of that line to surrender to the U.S. commander. Joseph Stalin made no objections to the arrangement.

This settlement marked only the beginning, however, of what came to be a running conflict between the United States and Soviet Union over the supposed permanence of the 38th Parallel. America had never intended for the line to be anything more than a temporary expedient—there was no geographic significance to it. The Soviets clung to a contrary view. They wasted no time in sealing off the line and forbidding passage across it. The upshot was creation of two Koreas: the Republic of Korea in the south, under the presidency of Syngman Rhee, and the Democratic People's Republic of Korea in the north, under the premiership of Kim Il-Sung. A period of ceaseless saber rattling and inflammatory rhetoric then ensued. The Kim regime lost no time claiming jurisdiction over the whole country; Rhee, for his part, did not shy away from declaring his willingness to unify the country through force.

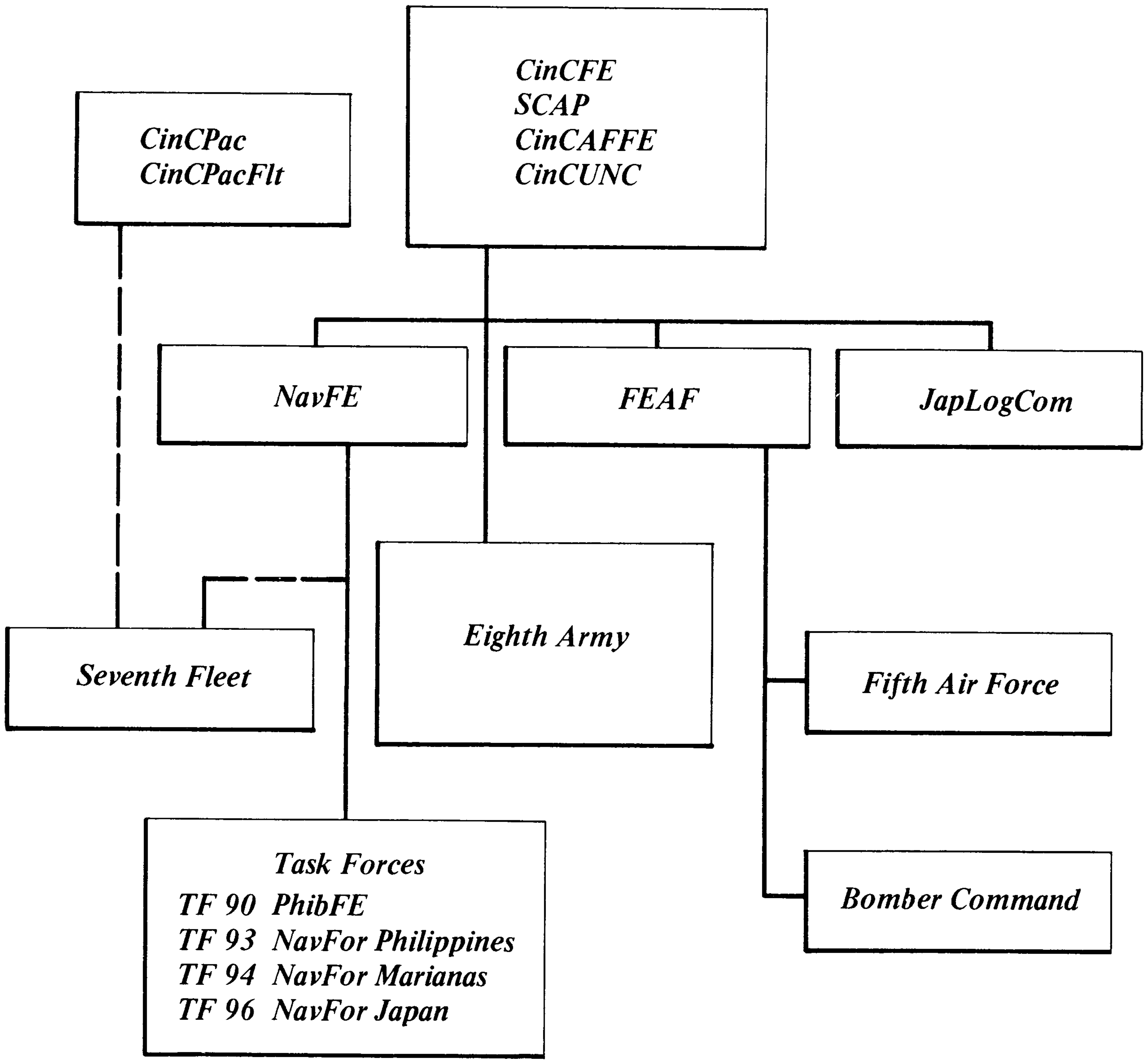
Meanwhile, President Harry S. Truman decided to withdraw the fifty thousand American troops that had been stationed in Korea since VJ-Day. Withdrawal was completed by June 1949, with just a five-hundred-man U.S. Korean Military Advisory Group (KMAG) left behind to train the south's forces. Calling the peninsula an ideological battleground, Truman arranged for continued appropriations for both military and economic aid. Still, the military situation in the south looked bleak. Partly as a consequence of Rhee's own aggressive posturing, South Korea was left no tanks, heavy artillery, or planes with which it could realistically protect itself. When the war broke out, South Korea had just ninety thousand troops—little better than a constabulary—equipped with light arms. Its navy, established in 1948, consisted mainly of former U.S. and Japanese minesweepers and picket boats that had to be kept going by cannibalization until spare parts could be delivered. The notion that Korea lay outside the U.S. defense perimeter had become so entrenched in American policy that the south was left in a sorry military condition that officials would later rue.

North Korea fared considerably better. After Soviet forces withdrew in December 1948, about one hundred fifty advisors remained with each army division. Even as early as 1946, thousands of North Korean troops were being sent to the Soviet Union for specialized training. At the beginning of the war, North Korea's forces numbered one hundred thirty-five thousand, outfitted with heavy equipment and supported by a tank brigade. Its air force, created in 1946, replaced its obsolete Japanese planes with improved Soviet models. Its navy, of far less significance, comprised some forty-five small craft, including a few Soviet-made torpedo boats.

Continued posturing by the north plus stepped-up raids into the south caused considerable alarm. Intelligence acquired by the Far East Command in Tokyo pointed to an unprecedented buildup of forces in North Korea and the menacing deployment of regular divisions along the 38th Parallel—though many key officials remained unconvinced by the dispatches. At 4:00 A.M. on 25 June 1950, however, there was no more room for doubt. After an artillery and mortar bombardment, six North Korean infantry divisions, backed by about one hundred fifty Soviet-made tanks, large numbers of heavy artillery pieces, and air support, streamed across the 38th Parallel. All they encountered were thinly spread, ill-equipped, and poorly trained defenses. The utter surprise of the assault was evident from the absence of President Truman from Washington, who happened to be visiting his family in Missouri when official word of the "all-out offensive against the Republic of Korea" arrived from Ambassador John J. Muccio in Seoul.

That same day, the president gathered all of his defense chiefs for a meeting at Blair House. It was unanimous that the North Korean challenge had to be firmly contested in order to short-circuit this threat to world peace and to "contain" communism. As a result of this and a second meeting on 26 June, the Joint Chiefs of Staff (JCS) issued a strongly worded directive: " . . . the Commander in Chief, Far East (CinCFE) [Gen.

Douglas MacArthur] is authorized to utilize Navy and Air Force elements of the Far East [Figure 3-1] to attack all North Korean military targets (troop columns, guns, tanks) south of the 38th Parallel in order to clear South Korea of North Korean military forces . . . . He is authorized to use naval forces of the Far East Command in the coastal waters and sea




*Legend (in order of appearance in chart):*

| | |
|---|---|
| *CinCFE* | *Commander in Chief, Far East* |
| *SCAP* | *Supreme Commander for Allied Powers* |
| *CinCAFFE* | *Commander in Chief, Army Forces Far East* |
| *CinCUNC* | *Commander in Chief, United Nations Command* |
| *CinCPac* | *Commander in Chief, Pacific* |
| *CinCPacFlt* | *Commander in Chief, Pacific Fleet* |
| *NavFE* | *Naval Forces Far East* |
| *FEAF* | *Far East Air Forces* |
| *JapLogCom* | *Japan Logistical Command* |
| *PhibFE* | *Amphibious Force Far East* |

Figure 3-1. Far East Command (Summer 1950)

approaches of Korea without restriction."[1] At the same time, the United Nations passed a resolution calling on its members to help South Korea "repel the armed attack and to restore the international peace and security in the area."

South Korean forces proved weaker than anyone expected, crumbling rapidly under the assault. Seoul fell on 28 June, despite air and naval support. The next day, General Douglas MacArthur confirmed what had already been surmised in Washington, namely, that U.S. ground forces would have to intervene or all would undoubtedly be lost.

On 30 June, Truman ordered U.S. ground troops stationed in Japan—the first two companies of the 24th Infantry Division (part of the Eighth Army)—to proceed to Korea. From Pusan, they reached the battlefield on 4 July, only to find themselves understrength for the task at hand. The following three weeks involved bitter fighting as the reinforced but still too-few and outgunned American troops kept falling back while attempting to delay the enemy's advance (Figure 3-2). By 1 August, just the extreme southeast portion of the peninsula, behind the so-called Pusan Perimeter, remained as a lodgment for the arrival of reinforcements.

The struggle became even more fierce as ground forces tried to reverse these initial North Korean gains. None too soon, additional troops began to arrive. The first goal was to hold the Pusan Perimeter over the following several weeks, despite the enemy's constant probing of both flanks and the Eighth Army's undermanned and undersupplied state. Then, in mid-September, the Eighth Army was ordered to break out of the perimeter and push northward. At the same time, X Corps was to land at Inchon, on the coast west of Seoul, to draw North Korean forces away from the Pusan Perimeter and, in the process, to retake the South Korean capital. By 1 October, U.N. forces had pushed their way back to the 38th Parallel (Figure 3-3), threatening the North Korean army with total collapse. Six days later, the U.N. General Assembly approved a resolution to permit entry into North Korea.

Back in the United States, meanwhile, it had become popular to think in terms of an all-out victory—that is, to push on to the Yalu River so that *all* Korea could be freed. The notion of simple containment no longer attracted much sympathy. The new secretary of defense, George C. Marshall, sent a message to General MacArthur encouraging the advance forward: "We want you to feel unhampered strategically and tactically to proceed north of the 38th Parallel." Accordingly, on 9 October, the Eighth Army made a general crossing of the Parallel.

In response, the Chinese sent into Korea the first of what was to number over a million men. Undeterred, the Eighth Army entered Pyongyang, the capital of North Korea, on 19 October, and South Korean forces reached Chosan on the Yalu River seven days later, well ahead of the main U.N.

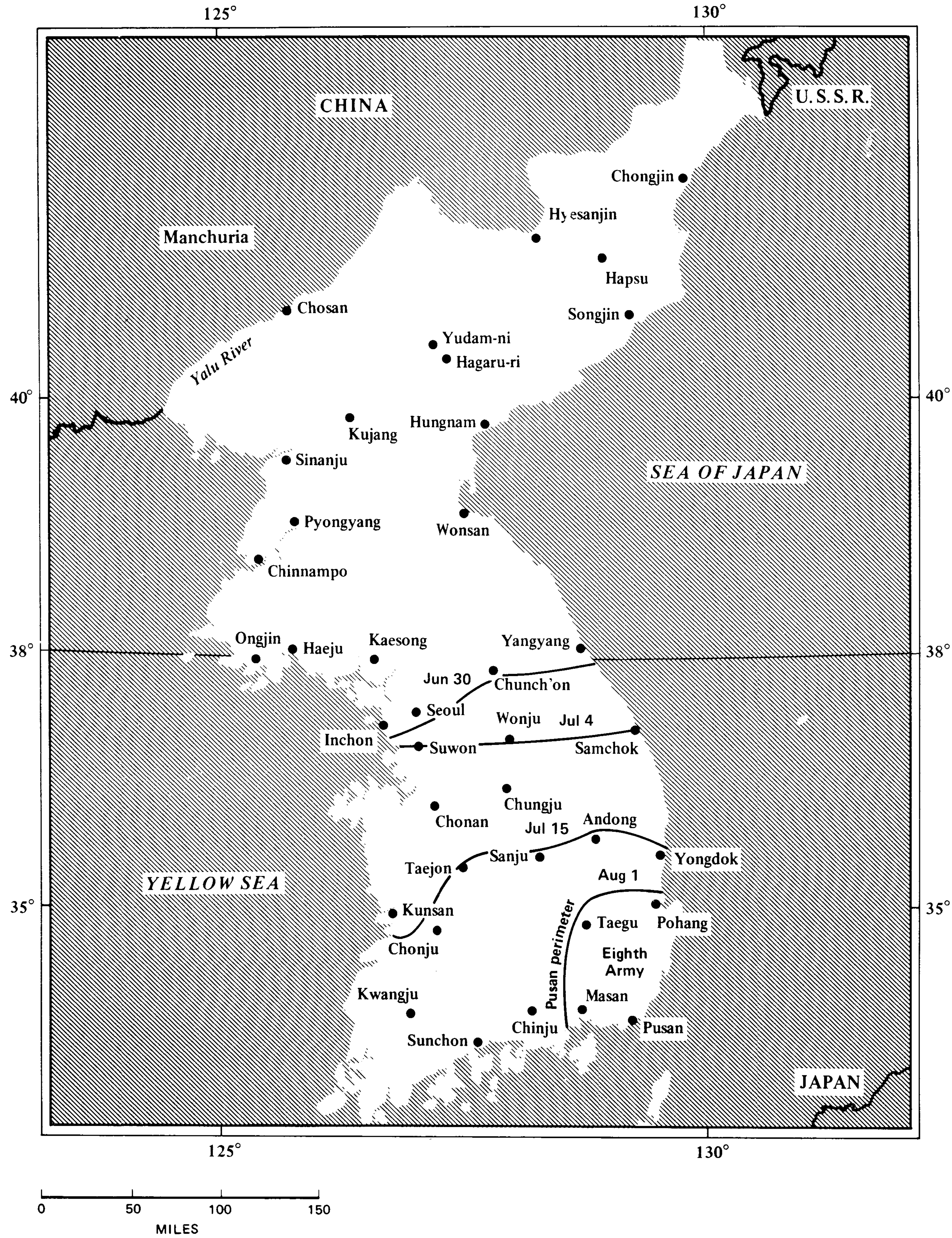



Figure 3-2. Main North Korean Lines of Advance during Their Surge Southward (End of June to Beginning of August 1950)

line of advance. By this time, the push south by Chinese troops had begun in earnest, forcing the U.N. troops once again to give up one perimeter after another and to retreat, by Christmas, back below the 38th Parallel. Seoul was reevacuated on 4 January 1951. Three weeks later, and thirty miles to the south of Seoul, the Chinese were finally halted. The battle,

Six U.S. Navy landing ships beached during Wonsan invasion to unload men and equipment. (Official U.S. Navy photo.)

meantime, had turned into a war of attrition, with casualties so high that any illusion that this was still a "police action" had to be discarded. Then, by 31 March, U.N. troops fought their way back to the 38th Parallel, where they settled into a stalemated position that seldom took them much beyond the Parallel for the remainder of the war. Following failed spring offensives by the Communists, negotiations got under way on 10 July 1951 in Kaesong (and later Panmunjon), where they dragged on for two years because of several points of disagreement. The points of disagreement were finally resolved, resulting in the signing of an armistice on 27 July 1953.

The U.S. Navy played an important supporting role in the war, without which the outcome might have been quite different. Most especially, the war demonstrated once again that effective seapower is a prerequisite to victory on land. Just how this was so in Korea merits attention, before we turn to OEG's involvement.

**The Navy's Role in Korea**

Traditionally, navies have won glory through their exploits on the high seas, engaging other navies and setting their enemy's ships ablaze. The war in Korea, however, presented quite a different situation. What occasioned

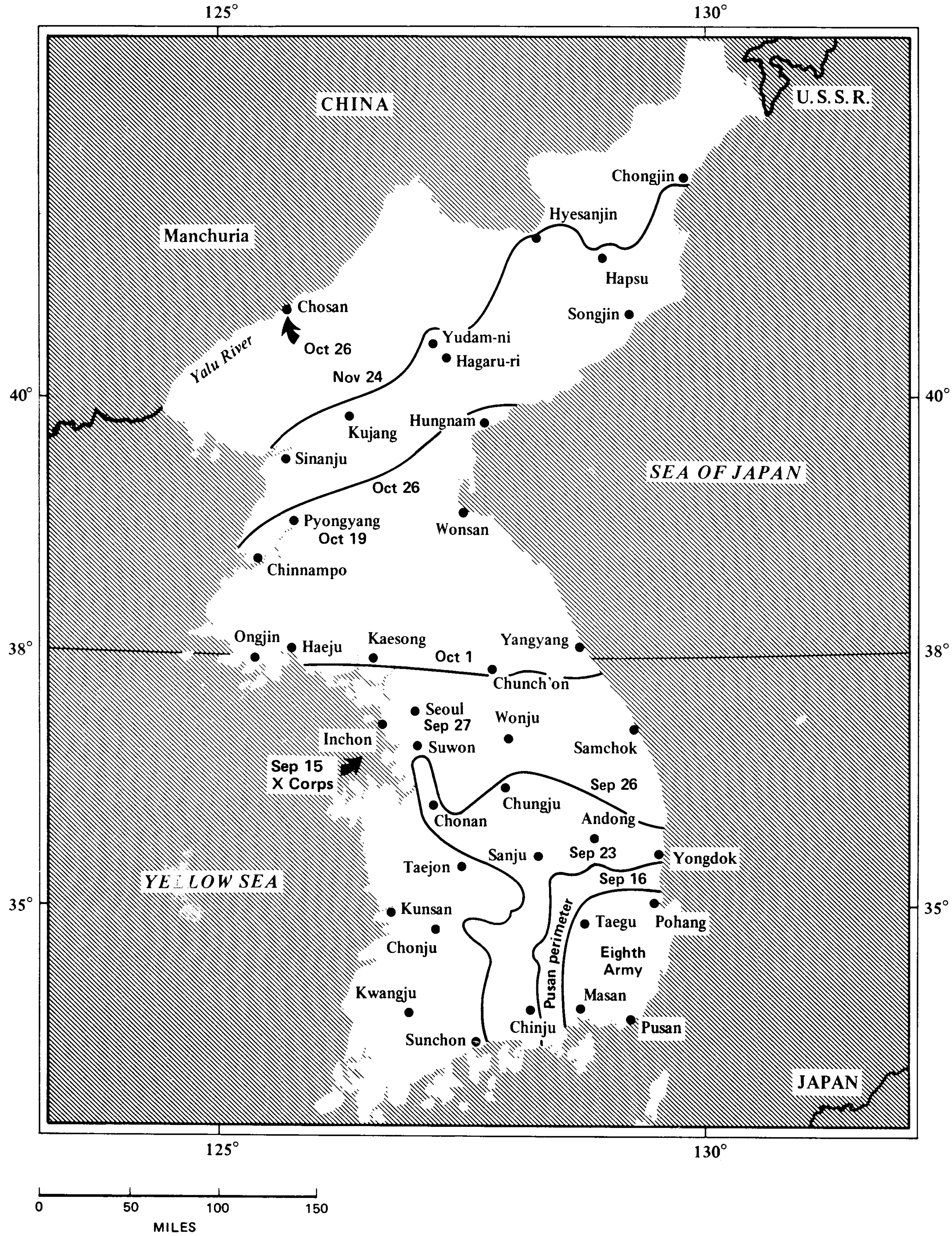



Figure 3-3. Main U.N. Lines of Advance during Their Surge Northward (End of September to End of November 1950)

this change in the U.S. Navy's role was the weakness of North Korean naval forces, making the battle for control of the seas lopsided. There was, in short, no way for the enemy to wreak havoc on our ships, despite attempts to do so through a tenacious mining campaign. Hence, the U.S. Navy's role became one of providing support to U.N. ground forces. But, as

U.N. forces at the Yalu River, just outside the city of Hyesanjin. A bridge felled by an air attack still burns in the valley below. (Official U.S. Army photo.)

we shall see later, the navy was quite unaccustomed to many aspects of this role in Korea and had to modify its operations accordingly.

The imbalance between the two sides' naval forces was just as well, given the scarcity of U.S. ships in Japanese waters when the war erupted (Table 3-1). Under the control of Vice Admiral C. Turner Joy, Commander Naval Forces Far East (ComNavFE), these vessels had been assigned the role of a peacetime occupation force, with Tokyo headquarters staffed by only twenty-eight officers and one hundred sixty enlisted men. About seventeen hundred miles away, with its main base on the island of Luzon in the Philippines, stood the more formidable—although in World War II terms, still modest—Seventh Fleet (Table 3-2), ready to make a quick transit to bolster Admiral Joy's forces. Two days later, on 27 June, the redeployment and gradual concentration of U.S. Naval forces got under way. The Seventh Fleet, under the command of Vice Admiral Arthur D. Struble, began heading northward to Sasebo, Japan, in accordance with instructions to neutralize Formosa. In the middle of its transit, however, the fleet's destination was changed to Buckner Bay, Okinawa, to avoid getting too close to the Soviet air base at Vladivostok. Once adequate units were in place, the tasks of evacuating American citizens, supporting the South Koreans, and blockading North Korea could get under way.

An early show of force, and one in which North Korea's vulnerability to U.S. Naval forces was made evident, occurred on 3 and 4 July. Four days earlier in Tokyo, Admirals Struble and Joy and General MacArthur had decided that the strike capability of the aircraft carrier *Valley Forge* could best be put to use against military targets in the area of the North Korean capital of Pyongyang. It took just two days for Task Force 77 (accompanied by British ships) to steam to its launching point off the west coast of Korea, only about one hundred fifty miles from the target area (but also only one hundred miles from the nearest Chinese airfield). One of the British ships, the *Triumph,* began the raid at five in the morning. Twelve Fireflies and nine Seafires were launched to attack the airfield at Haeju,[2] just north of the 38th Parallel. Fifteen minutes later, the *Valley Forge* launched sixteen Corsairs armed with eight 5-inch rockets each, and twelve Skyraiders armed with two 500-pound and six 100-pound bombs each, to attack the airfield at Pyongyang. Immediately behind them were launched eight F9F-2 Panthers, their higher speed enabling them to reach the target area ahead of the other planes.

As the jets swept in over the Pyongyang air base, they encountered only light resistance, with antiaircraft fire both sparse and inaccurate. Two

Table 3-1. U.S. Naval Forces in Waters around Japan (25 June 1950)

Task Force 90. Amphibious Force, Far East (RAdm. J. H. Doyle)
- *Mt. McKinley* (amphibious force flagship)
- *Cavalier* (attack transport)
- *Union* (attack cargo ship)
- LST 611 (tank landing ship)
- *Arikara* (fleet tug)

Task Force 96. Naval Forces, Japan (VAdm. C. T. Joy)
- Task Group 96.5. Support[a]
  - *Juneau* (antiaircraft light cruiser)
  - *Mansfield, DeHaven, Collett, Lyman, Swenson* (destroyers)
  - *Remara*[b] (submarine)
- Task Group 96.6. Minesweeping[c]
  - *Redhead, Mocking Bird, Osprey, Partridge, Chatterer, Kite* (motor minesweepers)

[a]Also included the frigate HMAS *Shoalhaven.*
[b]Submarine on loan from Seventh Fleet.
[c]Also included, in reserve or reduced commission, the fleet minesweepers *Pledge, Incredible, Mainstay,* and *Pirate.*

Table 3-2. Seventh Fleet (25 June 1950)

Seventh Fleet (VAdm. A. D. Struble)
- Task Group 70.6. Fleet Air Wing I
  - Patrol Squadron 28 (nine P4Y-2 Privateers)
  - Patrol Squadron 47 (nine PBM-5 Mariner flying boats)
- Task Group 70.7. Service
  - *Piedmont* (destroyer tender)
  - *Navasota* (oiler)
  - *Karin* (refrigerated stores ships)
  - *Mataco* (fleet tug)
- Task Group 70.9. Submarine
  - *Segundo, Catfish, Cabezon, Remara*[a] (submarines)
  - *Florikan* (submarine rescue vessel)
- Task Force 77. Strike (VAdm. A. D. Struble)
- Task Group 77.1. Support
  - *Rochester* (heavy cruiser)
- Task Group 77.2. Screening
  - *Shelton, Eversole, Radford, Fletcher, Maddox, Samuel L. Moore, Brush, Taussig* (destroyers)
  - Task Group 77.4. Carrier
  - *Valley Forge* (aircraft carrier)

[a]Submarine on loan to Task Force 96.

airborne North Korean Yaks were shot down and a third damaged; nine other enemy aircraft were caught and destroyed on the ground. The Corsairs and Skyraiders, meanwhile, were making runs at the hangars, ammunition dumps, fuel storage facilities, and runways, leaving little intact. In contrast to the damage inflicted on the enemy at both Haeju and Pyongyang, the raiders returned unscathed. In the afternoon, the *Triumph* and *Valley Forge* launched a second strike, this time against the railyard at Pyongyang and the bridges across the Taedong River. Over twenty locomotives were either destroyed or damaged, as were repair sheds, boxcars, and tracks; the bridges, though hit, remained standing.

The attacks were first scheduled for just the one day. A message to the task force from CinCFE, however, later authorized strikes "past the first day in view of the rapidly deteriorating Korean situation." The Pyongyang railyard took the brunt of the second day's strikes, resulting in the destruction of ten additional locomotives, more significant damage to the Taedong River bridges, and the sinking of several small boats (possibly gunboats) situated in the river. This time, opposition was more fierce, with antiaircraft fire damaging four of the planes.

The extensive harm inflicted on the Pyongyang area accomplished much more than could be summed up by simply tallying the enemy's physical losses. There was also the psychological impact of an air attack against the enemy's capital, conducted by a seaborne force able to maneuver and strike at will. That fighters could be brought to bear in this manner, in complete disregard to the location of *land* air bases, helped to undermine the north's confidence. An even more tangible consequence of the raids was pointed out later by an American commander, who remarked: "It is quite possible that the early appearance of the Panthers . . . over northern Korea on July 3 had a quieting effect on Russian and Chinese plans to provide North Korea with large numbers of obsolescent propeller-type aircraft." The usefulness of the U.S. Navy's capabilities in the Korean conflict thus became clear to everyone, friend and foe alike.

Shortly after these air strikes, there came yet another display of naval power, although of a different kind. On 27 July, 8-inch guns were used for the first time against the North Korean troops, who by this time were threatening to drive retreating U.N. forces off the entire peninsula. For eleven days, the cruiser *Toledo,* employing her main battery of nine 8-inch guns and a secondary battery of twelve 5-inch guns, fired on troop concentrations on the east coast of Korea, just north of Pohang. Aided by a fire-control group from the 24th Division and by air patrols, the *Toledo*'s fire was accurate enough to interfere with the enemy's advance at that point along the battleline.

So that her large, 8-inch guns could be used against something other than just troop concentrations, the *Toledo* subsequently steamed north about seventy miles to Samchok. There, on 7 August, she opened fire against a variety of targets that had been revealed by aerial photographs. Covering about twenty-five miles of coastline, the *Toledo* destroyed a bridge, chewed up several major roads, and sealed off two tunnels. The cumulative effect of one after another of these shore bombardments contributed to the easing of pressure on the beleaguered U.N. forces, and, later, to the harassing of North Korean forces as they lost ground to the U.N. push northward.

Shore bombardment was not the only way in which the navy came to the assistance of besieged ground forces. Another, which had its genesis in the amphibious landings of World War II, was "close air support." The practice entailed using aircraft to attack enemy troop positions that were close to, and thus threatened, friendly forces. Though easily defined, close air support was acutely difficult to execute and required the coordination of each air attack with the needs of ground commanders.

One of the times close air support proved its worth in Korea was on 23 July 1950. The Eighth Army, fearing a collapse of the Pusan Perimeter under the weight of the North Korean offensive, urgently requested naval air support. Admirals Joy and Struble reacted immediately to General Walker's message; on 24 July, the Seventh Fleet moved into position. Because of the lack of training, however, unsatisfactory communications between ground and air resulted in ineffective operations during the morning of the 25th. In a dispatch later that day, Struble summed it up thus: "The results of the morning sweeps and strikes were very minor due to a dearth of targets . . . . Will continue afternoon strikes, but under [these] conditions, the prospects appear poor. Consider it mandatory that proper communications be arranged . . . . "

Of course, little could be done to correct the situation on such short notice. Without adequate training in the appropriate procedures, only patchwork solutions seemed available. Consequently, several subsequent raids produced only modest successes, with some degenerating into "general air support" (or "deep support") as pilots had to resort to using up their ordnance against random targets of opportunity well away from the front. Still, while many of the difficulties persisted, conditions did generally improve over the following weeks. Ground control parties were supplemented with spotter planes, helping to minimize the number of snafus that had impaired communications.

At the beginning of August, attack planes from the *Valley Forge* produced much better results, using bombs, rockets, and napalm to kill a large number of enemy troops and to destroy a supply dump, trucks, and a tank. The repeat of such attacks slowly wore at the enemy as his losses mounted. Then, on 31 August, another urgent message came in to the Seventh Fleet from Pusan, indicating the need for close air support to help halt an all-out enemy offensive that once again threatened the perimeter. Strikes were launched the next day, consisting of Skyraiders armed with three 1,000-pound bombs each, and Corsairs armed with one 1,000-pound bomb, four rockets, and cannon. The planes strafed, rocketed, and bombed troop concentrations, supply dumps, bridges, rolling stock, artillery emplacements, and several small boats in the Naktong River. By this time, close air support had proved its value.

Perhaps the high point of the navy's involvement in Korea came in mid-September 1950, during the amphibious landing at Inchon. The landing was the brainchild of General MacArthur, who had long believed that North Korean supply lines were becoming overextended as the enemy advanced southward. An assault on Inchon, he felt, would cut their supply lines while simultaneously opening up a second front and placing recapture of Seoul (just eighteen miles to the east) within reach—a grand scheme to turn the tide of the war. Though Operation Chromite, as the landing was called, at first drew strong criticism, MacArthur's powerful oration in defense of the plan generally won over the skeptics.

The final plan called first for neutralization of the island Wolmi-do, which controlled access to the harbor. This was to be followed by an assault on the city of Inchon, the capture of Kimpo airfield, and, finally, the seizure of Seoul. The going was expected to be difficult because of a number of hazards: strong currents, a channel pocked with shoals and reefs, extreme tides that at their low point exposed a huge mudflat, and a landing site consisting of twelve-foot-tall seawalls which, once scaled, would deposit the troops in the heart of the city. Despite the odds, it was the navy's job to get X Corps ashore. Responsibility for this task was assigned to Rear Admiral J. H. Doyle, in command of the Pacific Fleet's Amphibious Group One.

After five days of being shelled by the cruisers and destroyers of Gunfire Support Group Six, and of being attacked by planes from Task Force 77, Wolmi-do was reduced to shambles. This systematic softening up of the island's defenses by the navy enabled the troops to take Green Beach with relative ease (Figure 3-4), marking the beginning, on 15 September, of the actual assault phase. MacArthur declared in a message to the Seventh Fleet's Admiral Struble: "The Navy and the Marines have never shone more brightly than this morning."

In the assault on Red Beach, Admiral Doyle made the difficult decision to leave the eight landing ships grounded on the beach so that the troops could be ensured access to adequate logistical support. This time, naval bombardment of the landing area had to be more discriminating, hitting only military targets and leaving the rest of the city sufficiently untouched to be suitable for occupation. At both Red and Blue Beaches, where simultaneous landings were planned, the troops were faced with large stone seawalls. The walls proved troublesome to the landing craft, but were overcome. Resistance was fairly light, except in a few spots, leading to a successful operation that resulted in few casualties among our own forces. Kimpo airfield fell just three days later, on 18 September, with the liberation of Seoul completed by the 27th.

The landing at Inchon had considerable significance for the navy in that questions concerning the navy's effectiveness were resolved. For example, General Omar Bradley's 1949 prediction that, in light of the atomic bomb, "large-scale amphibious operations will never occur again," had been put to rest. The landing at Inchon demonstrated otherwise. Finally, those persons who had predicted that the nuclear age would make the navy as a whole obsolete were similarly disabused of that notion.

### OEG's Wartime Mobilization

The preceding chronicle of events shows that the Korean War forced changes on the navy, reminding it that it must remain innovative. The urgency of the situation filtered through to OEG, spurring the group to

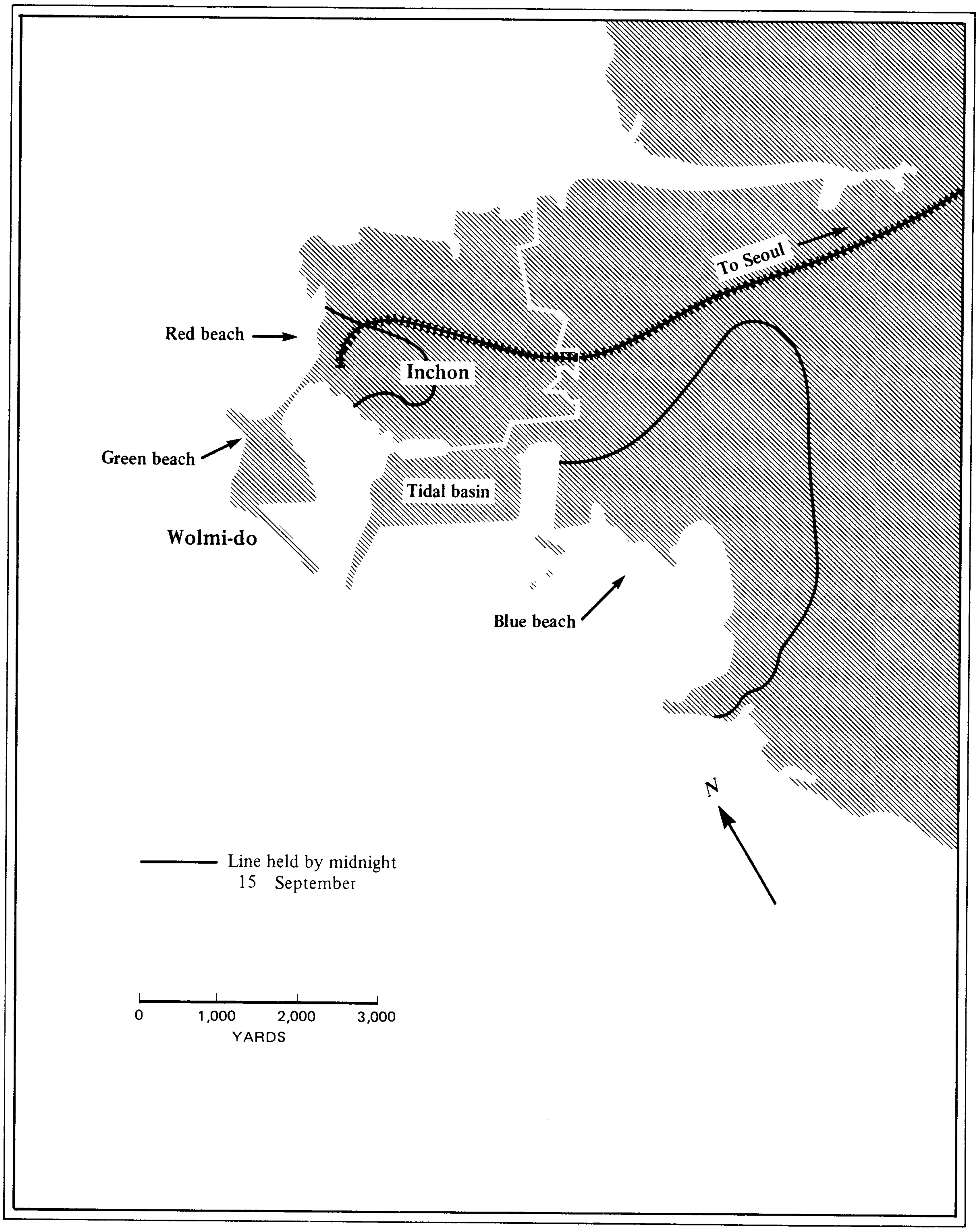



Figure 3-4. Assault on Inchon

gear up its operations to respond to the navy's new requirements. Emergency conditions meant that all available analytical manpower would be needed. Academic and vacation leave was therefore cancelled, and recruiting efforts stepped up. The group grew from less than forty scientists in mid-1950 to just under sixty by the end of the war. Fortunately, there was a wide choice of personnel available during the war, found generally in high university and industrial positions. About two-thirds of these had

Four U.S. Navy landing ships unload prodigious quantities of equipment on the beach of Inchon. (Official U.S. Navy photo.)

backgrounds in physics and mathematics, with the remainder split among the other sciences. In addition, the group occasionally borrowed people from government laboratories to tap into their particular areas of expertise. (The laboratory personnel, for their part, got the chance to see how their equipment held up under the demands of the battlefront.) Despite the disruption such rapid and extensive personnel changes might cause, OEG managed to adjust with minimal dislocation.

Between 1945 and the Korean War, OEG could ill afford to send its members out to the field, because of its small staff. The only consistent assignment had been to the Operational Development and Evaluation Force (later called the Operational Test and Evaluation Force), where members helped to test equipment and tactics under combatlike conditions. In large part, then, the field program had to be placed in abeyance until the staff had grown enough to permit the program's reinstitution. Consequently, a vital aspect of what enabled the group to influence fleet operations had to be forsaken during that period.

The conflict in Korea, however, reemphasized the importance of an adequate field program. Encouragement also came from the navy itself. Shortly after the outbreak of war, requests for analytical assistance began to come in from those naval commands directly involved in the conflict. The group therefore sent many of its members to overseas assignments over the next three years. Some of these scientists–including Edwin A. Uehling, John L. Everett, John R. Pellam, James M. Dobbie, David M. Boodman, and Douglas L. Brooks–were sent via the staff of the Commander in Chief, Pacific Fleet (CinCPacFlt). Others–including John P. Coyle, Joseph A. Neuendorffer, William F. Offutt, and Frank W. Lamb–were assigned to the Commander of Naval Forces in the Far East (ComNavFE), to be sent on to such commands as Task Force 77 and the First Marine Air Wing ashore in Korea. Usually, only one analyst was assigned to each operating command, on a rotational basis; at Pearl Harbor, however, CinCPacFlt had as many as four OEG members assigned to the staff of his Evaluation Group.

These analysts helped to solve tactical problems and suggested new procedures for improving operations on the spot. With the rush of events posed by wartime conditions, it was imperative that each analyst exercise his special talent for sorting out, from all the alluring problems that he encountered, those that had the greatest practical bearing. Also, as in World War II, the analysts in the field communicated regularly with those in Washington, so that the latter could contribute to the solution of some of the same operational problems. Meanwhile, of course, the many scientific analysts assigned to the warfare "desks" within the Office of the Chief of Naval Operations (Figure 3-5) likewise supported the war effort.

The subjects worked on by OEG's analysts at the CinCPacFlt Evaluation Group included a scheme for conducting successful interdiction missions, the relative effectiveness of various weapons for shore bombardment, the ability of naval forces to blockade North Korea, the difficulties of providing close air support, and the desirability of increasing the tempo of carrier night-fighter operations. Some of the subjects examined by group members stationed with ComNavFE included weapons selection for naval aircraft attacks against tactical targets, the interdiction of land transportation, North Korean minelaying operations, and force requirements for different types of campaigns. Much of the information accumulated during the war (for example, on aircraft losses and combat sorties) provided a useful data base for research over the next decade.

One disadvantage of the sudden deployment to the field of many of the group's most experienced personnel was its tendency to crimp the research program back in Washington. Fortunately, the problem did not become too serious during the war because of the availability of a large enough reserve of experienced people to train the new recruits and to keep the Washington office's analysis on track (Figure 3-6). Maintenance of the field program did prove more burdensome after the war, however. (See Figure 3-7 for the field assignments made during and after the Korean conflict.)

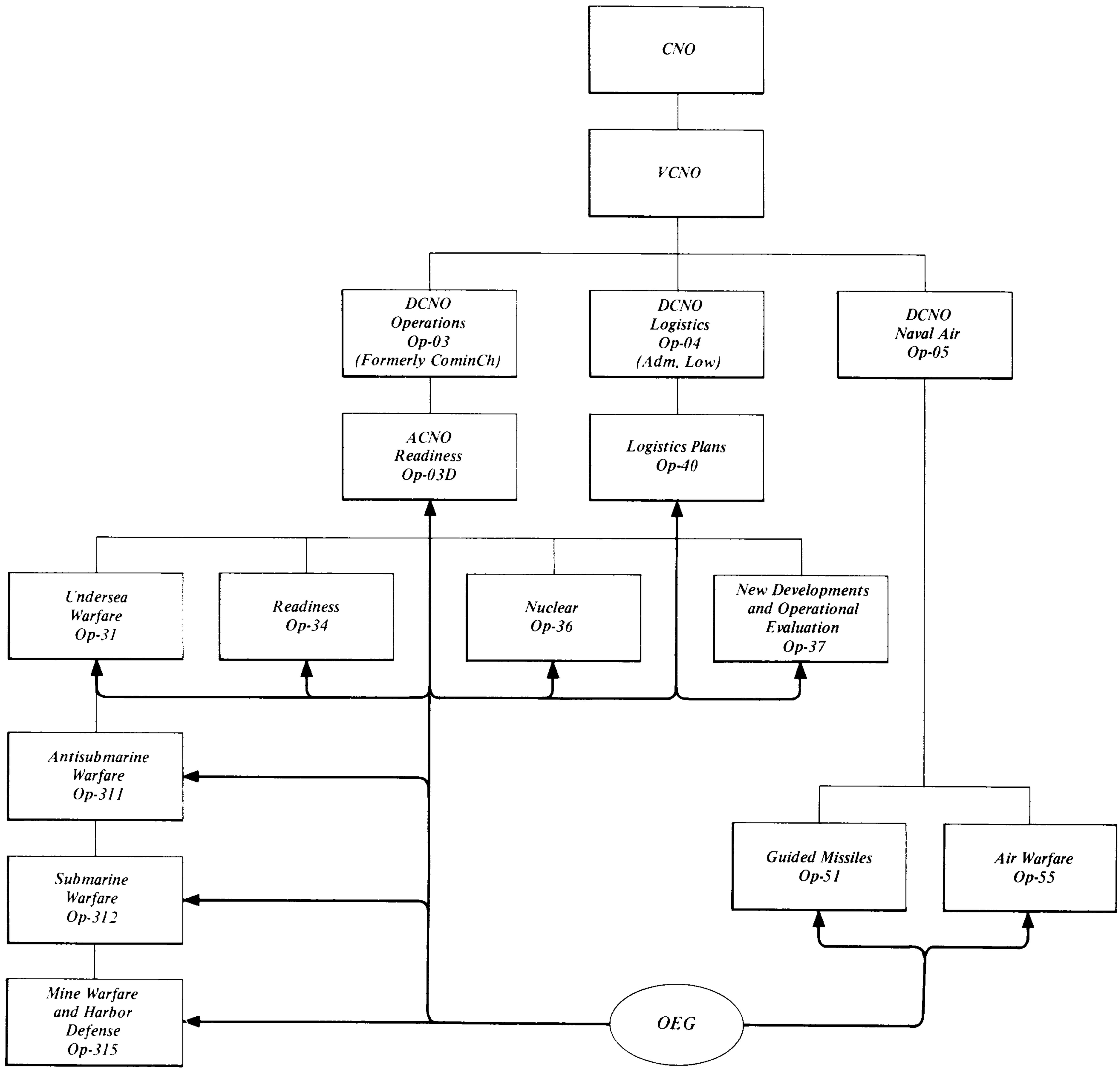



Figure 3-5. OEG Scientific Analyst Structure during Korean War (Tie Lines to CNO)

The risk of harm to analysts assigned to commands engaged in a war became conspicuously clear during this time. Unlike World War II, in which all field analysts survived largely untouched despite the precariousness of some of their situations, the Korean War produced an OEG casualty. On 14 May 1952, less than three months into his assignment with ComNavFE, Dr. Irving Shaknov was killed when the plane in which he was collecting data was shot down during an interdiction mission. After the war, on 7 May 1954, Shaknov was posthumously awarded the Medal of Freedom by the secretary of the navy. Dr. Shaknov's death sparked considerable debate over how close to the fighting an OEG scientist—or, for that matter, any civilian scientist—should be permitted to get. The need to observe operations firsthand seems essential if analyses are to be both relevant and realistic; additionally, a good rapport with military personnel is definitely an asset. Yet, the untoward death of a member, or the potentially serious

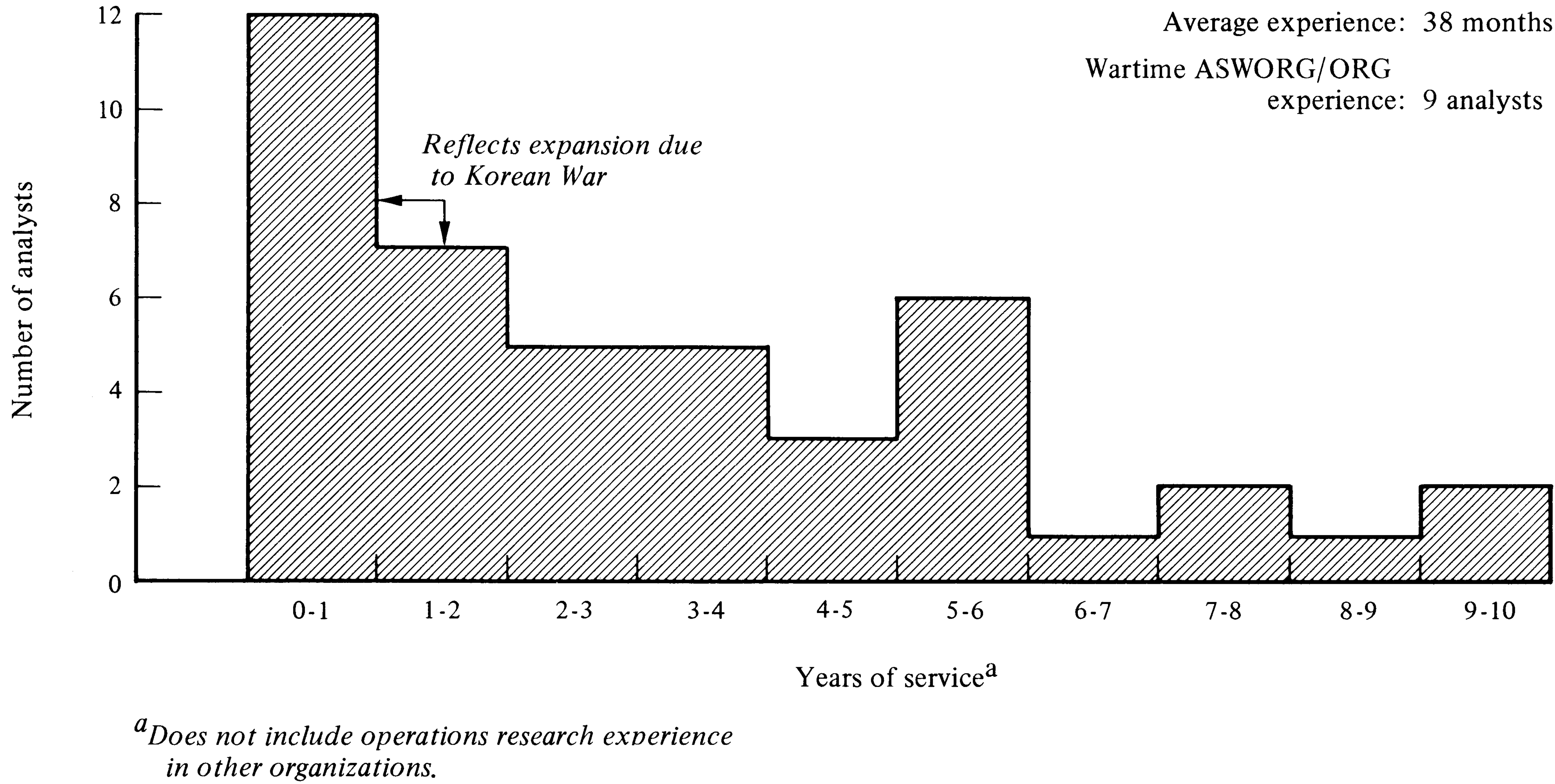



Figure 3-6. Length of Experience of OEG Members (January 1952)

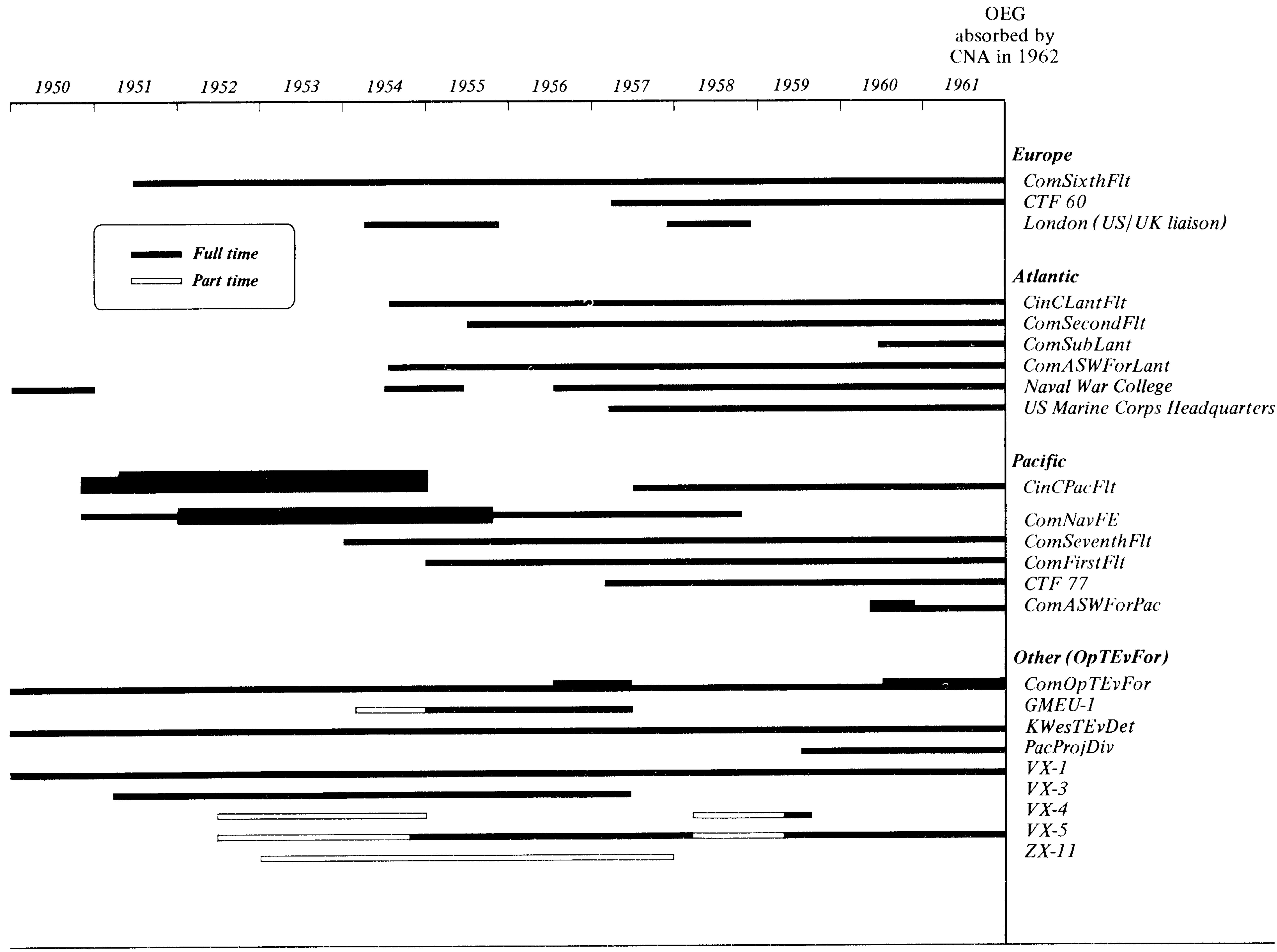



Figure 3-7. OEG Field Assignments (to 1962)

intelligence breach that could occur if an analyst were captured alive, must be considered in any policy decision.

The expanded field program—along with generally accelerated recruitment—represented, of course, major elements of OEG's efforts to adjust to the new circumstances brought about by the war. But the most important element was undoubtedly the group's analyses. Because the nature of the war in Korea differed markedly from that in World War II, the navy's role had to change accordingly, as already mentioned. For instance, the "Navy had not, in World War II, had the important responsibility of attacking land targets. They supported forces on the beach or back of the beach, but they did not have the responsibility of airfield or highway interdiction on a large scale."[3]

Consequently, OEG's research program had to take into account a wholly new set of issues:

> Many of the problems we worked on during the Korean War were new to OEG, if not to the Navy. This was the first time the Navy had to expand its major aviation effort in continual support of our forces in combat during a major and protracted campaign ashore. Consequently, we had a chance to learn about the capabilities and limitations of carrier forces in attacking land targets: how to plan for close air support of land troops in contact with the enemy, how to use naval gunfire in shore bombardment, how to wage major campaigns designed to lay on a blockade and to interdict land transport, and how to plan for the proper use of conventional weapons for naval air attack on tactical targets. Here, again, several major themes for OEG's continuing research program were initiated, such as the determination of planning factors for carrier operations.[4]

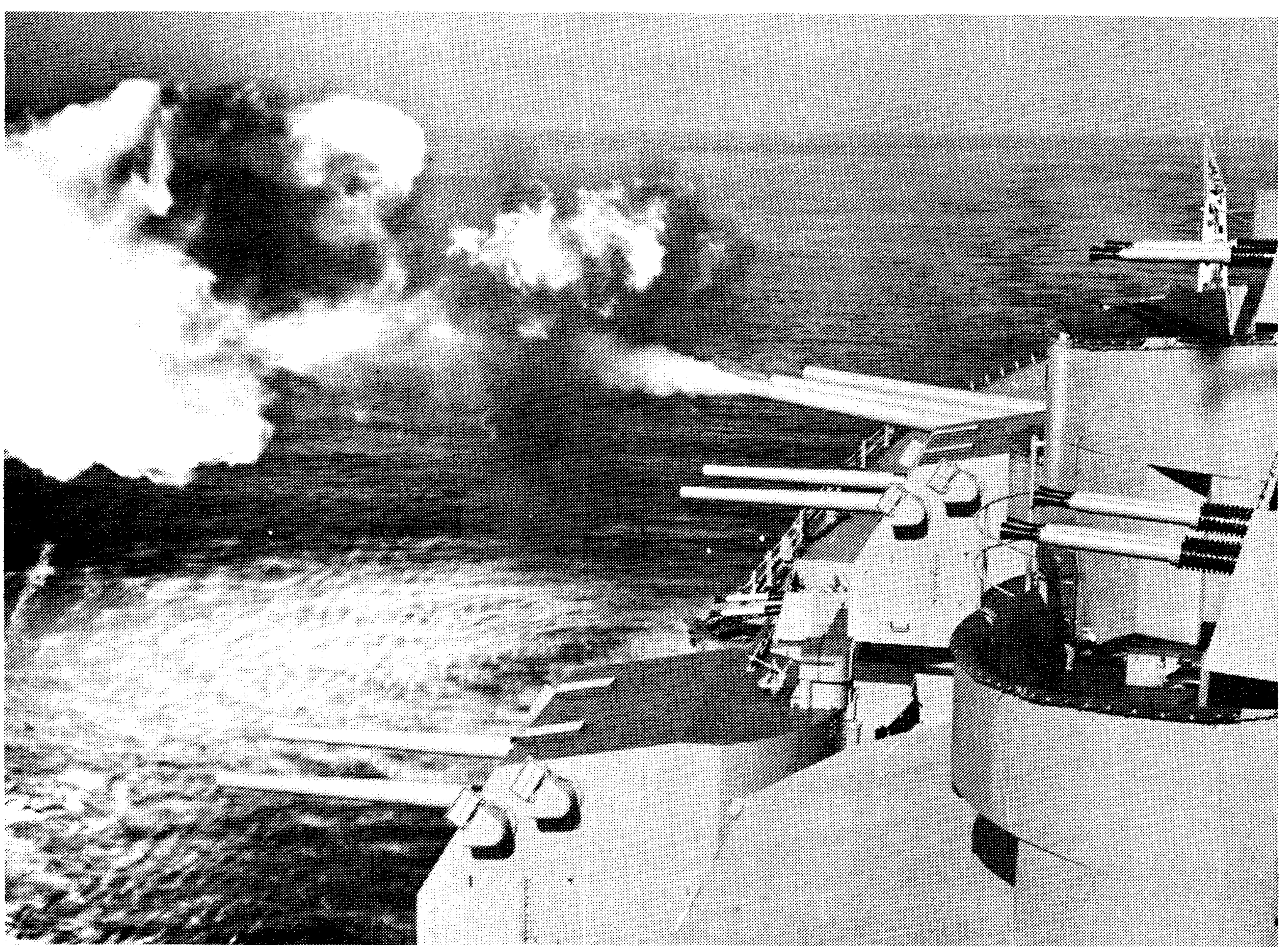
It would be worthwhile to examine more closely what some of these problems were and, more significantly, how OEG attempted to tackle them.

### Operations Analysis during the Korean War

With the important exception of the Inchon landing, naval gunfire in the Korean War was used differently than in the previous war. In World War II, naval bombardment of land targets generally involved saturating an area with highly intense but brief fire, usually in support of an amphibious assault. In Korea, on the other hand, naval gunfire often supplemented artillery and air attacks against precise targets. In anticipation of this extensive use of naval guns against land targets, the Pacific Fleet Evaluation Group began, in October 1950, to supply Gunfire Support Cards to ships of the fleet, on which they were to record information about each mission conducted against shore targets. OEG decided to analyze this information, covering an eleven-month period from May 1951 to March 1952. During this period, U.S. ships fired almost half a million rounds on over twenty-four thousand missions, providing a large statistical base for analyzing both effectiveness and efficiency.

The main areas of gunfire activity for the period examined by OEG's Charles W. Karns were the battlelines during two major U.N. offensives (Figure 3-3): the Wonsan area (against the city, transportation targets, and shore batteries); the area between Hungnam and Chongjin (against shore installations, railroads, and highways); and the area between Haeju and Chinnampo (in support of commando raids). The number of rounds and missions cited above reveals the magnitude of the effort in these areas. Of the half a million rounds expended, by far most (over 90 percent) were by 5-inch batteries. The heavier calibers (6-, 8-, and 16-inch) together made up the remaining rounds.

There were seven major categories of targets: troop concentrations, transportation (bridges, tracks, highways, trains, vehicles, tunnels, and so forth), weapons installations (shore batteries, gun emplacements, mortar positions, and bunkers), shore installations (factories, warehouses, and oil tanks), military installations (supply, fuel and ammunition dumps, airfields,



The 16-inch guns of the USS *Iowa* shell transportation facilities along the east coast of North Korea. Ranging up and down the coast, the *Iowa* fired her guns for eighteen hours on her first day in combat since World War II. (Official U.S. Navy photo.)

and command posts), "areas" (towns, industry, docks, and so on), and naval targets (ships, small boats, and landing craft). The 5-inch guns on the thirty-one destroyers for which information was available were used mostly against the enemy's transportation system, reflecting the general importance of the interdiction campaign during this period. Weapons installations also became important targets–largely to silence shore batteries–but still turned up as a distant second. The 8- and 16-inch guns on the five heavy cruisers and two battleships, however, were employed mostly against troop concentrations. Much of the rest of this fire was directed at the transportation system and at military and weapons installations, in that order.

That naval gunfire during this period had the goal of a long-term payoff–instead of the short-term gain of traditional saturation bombardments–was apparent from the emphasis placed on destruction instead of harassment, interdiction, or neutralization.[5] Indeed, the data showed that for most gun calibers, from a half to two-thirds of the missions were for destruction, and about a quarter to a third were for harassment and interdiction (that is, to hamper enemy movements). Attempts at neutralization, moreover, were very infrequent.

OEG decided that the most reliable way to gauge the relative effectiveness of the various calibers of gunfire was to determine their success in missions of destruction. The reason was that such missions were the most common, thereby providing a large statistical base. Consequently, achievement of a mission's goal could be ascertained with a higher level of certainty than, for example, for harassment. Even so, the relative effectiveness of each mission type was also assessed, to complete the analytical picture.

The group had to contend with two serious shortcomings. The first was that only visual observations could be made, often under trying conditions, to assess a mission's outcome. Owing to the lack of precise criteria for reporting the degree of success accomplished in a mission, the observer had to rely on his highly subjective judgment. As expected, this problem more adversely affected the data on harassment and neutralization, which were much harder to judge, than the data on destruction. Still, in the absence of photographic verification, no other means were available.

The second shortcoming was that, in general, nearly half of the gunfire went entirely unobserved, although, again, missions of destruction fared considerably better. The significance of this fact lay in a rather curious set of circumstances. It was known that for observed missions the more rounds expended, the better the results (all other things being equal). It was also known, however, that fewer rounds were expended for unobserved missions than were expended to achieve only negligible successes in observed missions. Hence, because success seemed to be proportional to the number of rounds fired, the unobserved missions could be expected to score fewer complete successes. If these less successful missions had actually been observed and recorded, and thus figured into the study, the results would have been a bit more unfavorable.

Bearing in mind these two limitations, it was possible to determine the degree of success achieved for each caliber of gun in missions of destruction (Figure 3-8). The 16-inch batteries could boast of the highest percentage of successful missions and the lowest percentage of unsuccessful missions. The 8-inch batteries, it was found, ranked second in terms of successful missions but happened to experience the largest percentage of unsuccessful missions. Oddly, the 6-inch guns produced the lowest percentage of satisfactory missions, but also the lowest percentage of negligible results. The outcome for the 5-inch batteries on the heavy ships was about the same as on the destroyers.

Since destroyers accounted for most of the supporting gunfire, their degree of success in the various types of missions could be more readily discerned from the Gunfire Support Cards. OEG found that missions of destruction were carried out more successfully than missions of harassment and interdiction and of neutralization (Figure 3-9). Besides being the least

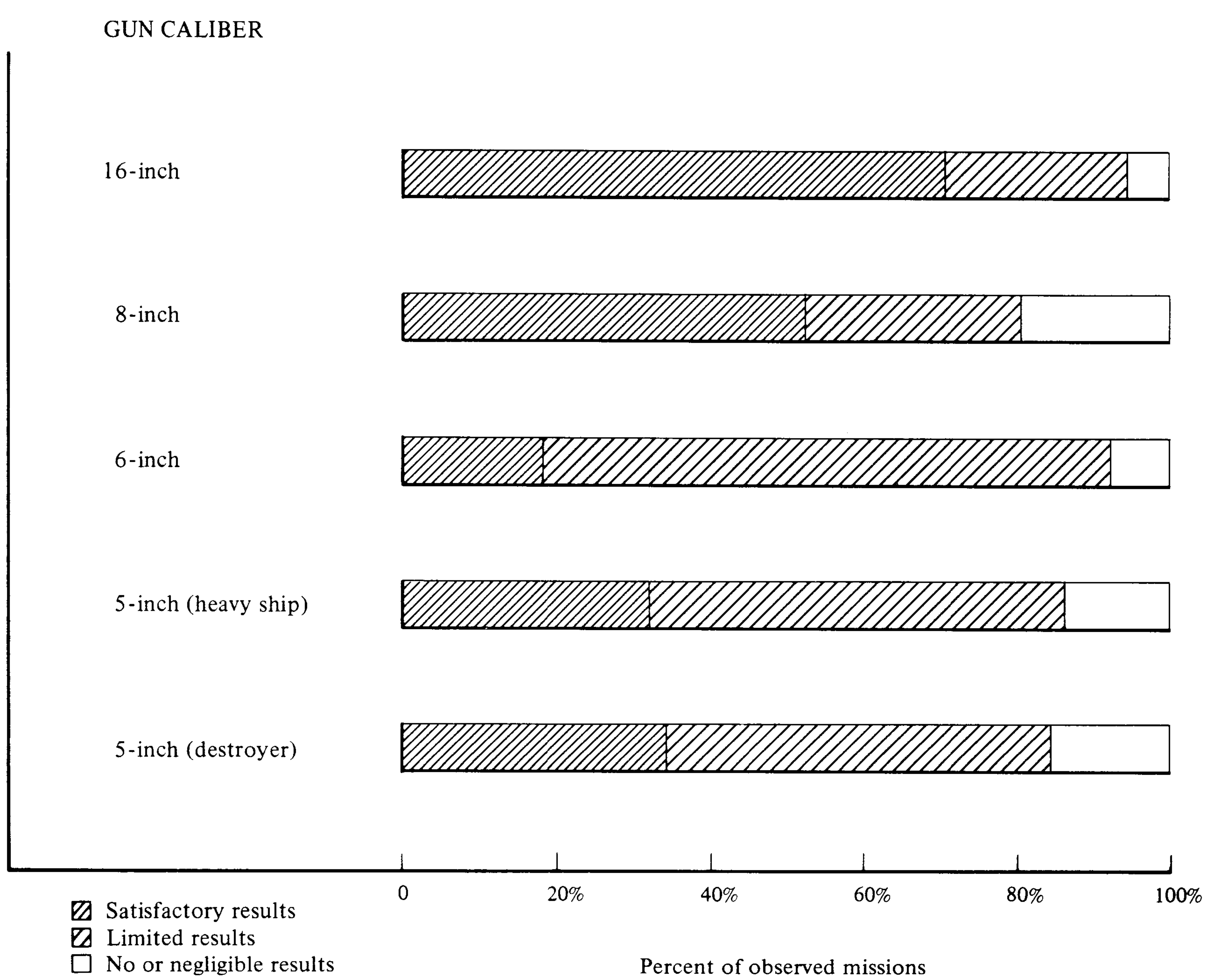



Figure 3-8. Effectiveness of Various Gun Calibers in Missions of Destruction

The heart of U.S. Navy striking power is pictured under the 5-inch guns of the aircraft carrier USS *Oriskany* in Korean waters. Fast carrier Task Force 77 spearheaded the navy's attacks against the central and eastern part of North Korea. (Official U.S. Navy photo.)

successful when they were observed, missions designed to harass and interdict the enemy were largely unobserved (in fact, about 70 percent were conducted unobserved). Therefore, if it is assumed that this large percentage of unobserved missions were even less successful than the observed category, as pointed out earlier, then the results shown in the figure for harassment and interdiction would likely be still poorer.

The study showed that the method of spotting (that is, the means of directing gunfire) had an influence on the effectiveness of fire. In general, ground spot, involving the use of fire control parties on shore, was the most successful. Air spot by planes and helicopters provided the second-best results, with ship spot next, and, of course, with no spot last. Ground and air spot, however, were often quite close in terms of effectiveness, depending on the caliber of gun. This point is evident in Figure 3-10, which illustrates the results for 5-inch batteries. These results were highlighted because they came from data submitted by the destroyers, which used spotting of one kind or another in about two-thirds of their missions.

Because of biases in some of the information reported on the Gunfire Support Cards—for example, probably only the more accurate missions

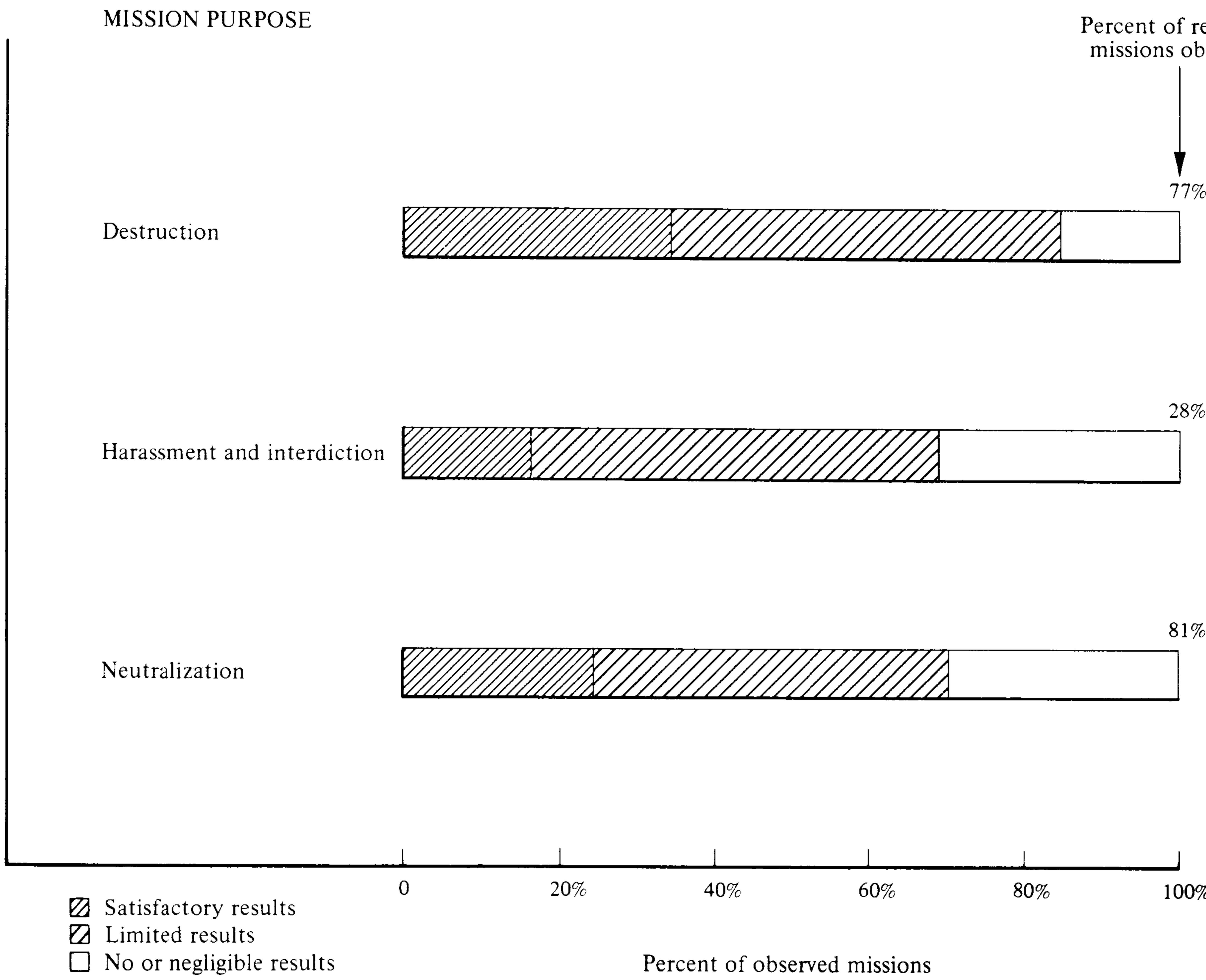



Figure 3-9. Effectiveness of Various Gunfire Support Missions Conducted by Destroyers

were reported when ships entered the number of salvos for a first hit—it was impossible to answer some questions with sufficient reliability. Some of these questions concerned the important issues of weapons selection and force requirements. In those cases, subjective assessments by ships often substituted for the more desirable quantitative information required for useful analysis or future planning. Nevertheless, enough other accurate information was available on the way naval gunfire was employed in Korea that OEG was able to reconstruct an informative picture of this crucial facet of the navy's effort in the conflict. In conjunction with related studies (for example, one that focused on missions performed by the battleship *Missouri* during the first part of 1951), the group's findings confirmed that gunfire support was being used to good advantage.

Earlier, we mentioned the difficulties U.S. forces were experiencing in supplying close air support to ground troops. To learn more about this phase of operations, and to help the navy better understand whether such missions were being used to as good advantage as gunfire support, OEG chose to evaluate the effectiveness of close air support for a one-month period of the war. The month was September 1951, during which the First Marine Division was engaged in the most bitter fighting since its arrival in

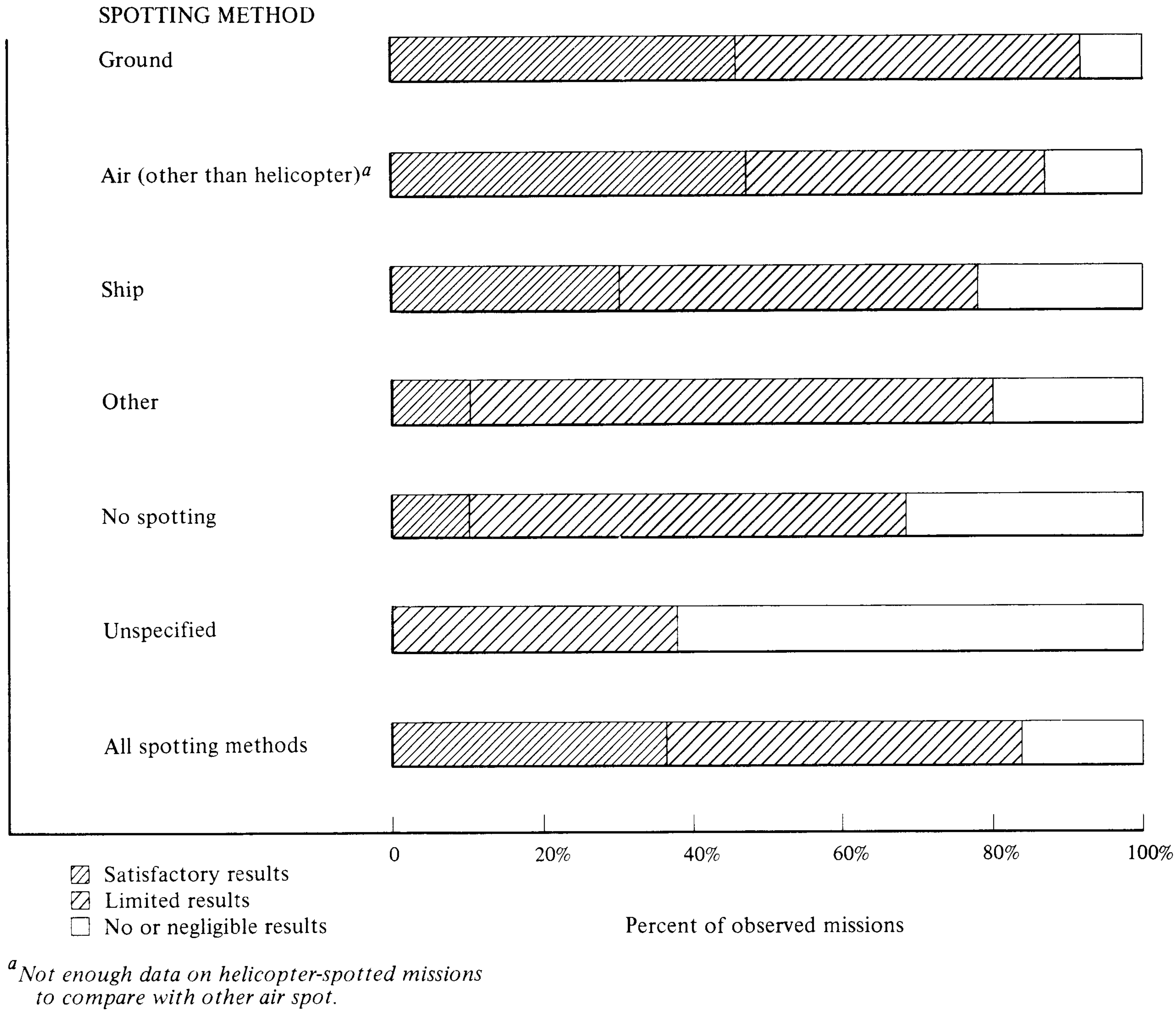



Figure 3-10. Effectiveness, by Spotting Method, of 5-Inch Batteries on Destroyers Conducting Missions of Destruction

Korea. The offensive began in the high mountain ranges in the eastern part of Korea, about fifteen miles north of the 38th Parallel. By 22 September, all major objectives had been seized, taking the troops about ten miles farther north, to the so-called Minnesota Line. For the remainder of the month, the division concentrated on defending and solidifying its hold on this area.

Navy, marine, and air force planes provided close support to the division during this period.[6] All three services employed day conventional fighters: F-4U Corsairs by the navy and marines, F-51 Mustangs by the air force. The marines also flew day jet fighters (the F-9F Panther), as did the air force (the F-84 Thunderjet and F-80 Shooting Star). Two other types of planes involved in this skirmish were naval fighter bombers (AD Skyraiders) and marine night fighters.

Briefly, the system for arranging close air support during fighting by the First Marine Division involved the following procedures. The first step was for a Tactical Air Control Party (TACP), assigned to frontline ground forces, to radio a request for close air support to the Tactical Air Direction Center (TADC), near the division command post. The TADC, in turn, would forward the request to the division Fire Support Coordination Center (FSCC) for approval. Final clearance of the request would be gotten from the Joint Operations Center (JOC) at Fifth Air Force Advanced Headquarters. From there, the request would be transmitted to selected bases so that planes could be dispatched to provide the necessary support. In a few instances, planes already in the air were diverted from other missions. In over 90 percent of the calls for support (in September), aircraft were asked to arrive as soon as possible. In the remaining cases, desired arrival times were specified, sometimes to coincide with the planned movement of troops.

Whenever a request for close air support came into the TADC, tactical air report forms were filled out, containing such information as the date and time the request was received, the number and type of aircraft desired, a description of the target, and the distance of the target from the frontlines. After the mission, additional information was recorded, including the number and type of planes that actually took part, the ordnance expended, and an assessment of the damage inflicted. These data, then, became the basis for OEG's study. Supporting data included air support logs filled out by the division FSCC, along with action reports and historical diaries maintained by the First Marine Aircraft Wing.

The data indicated that the division made a relatively high number of requests for close air support during the critical days of the offensive, between 1 and 22 September (Figure 3-11). When the weather was good, the average number of daily requests was about twelve. Interestingly, the average number of requests for the defensive period when the division was fighting to hold onto its gains (that is, from 23 September to the end of the month) was over nine, indicating just a small drop despite the change from offensive to defensive tactics. (In an earlier study, OEG found that during May and June 1951, the number of requests in the defensive phase dropped to a third of those in the offensive phase.)

It is apparent from Figure 3-11 that 40 percent of the requests for close air support recorded by the TADC went unfilled. Either the JOC canceled a call for support because planes were unavailable, or the division FSCC did so because the target was assigned to artillery instead. These reasons occurred with about equal frequency, and together accounted for a little more than half of the unfilled requests. Since the reassignment of targets to artillery meant that the targets were still subjected to some form of bombardment, this significant category, though technically under the heading of unfilled requests, should really be excluded. Doing so would reduce truly unfilled requests to 30 percent. Other reasons for unsatisfied

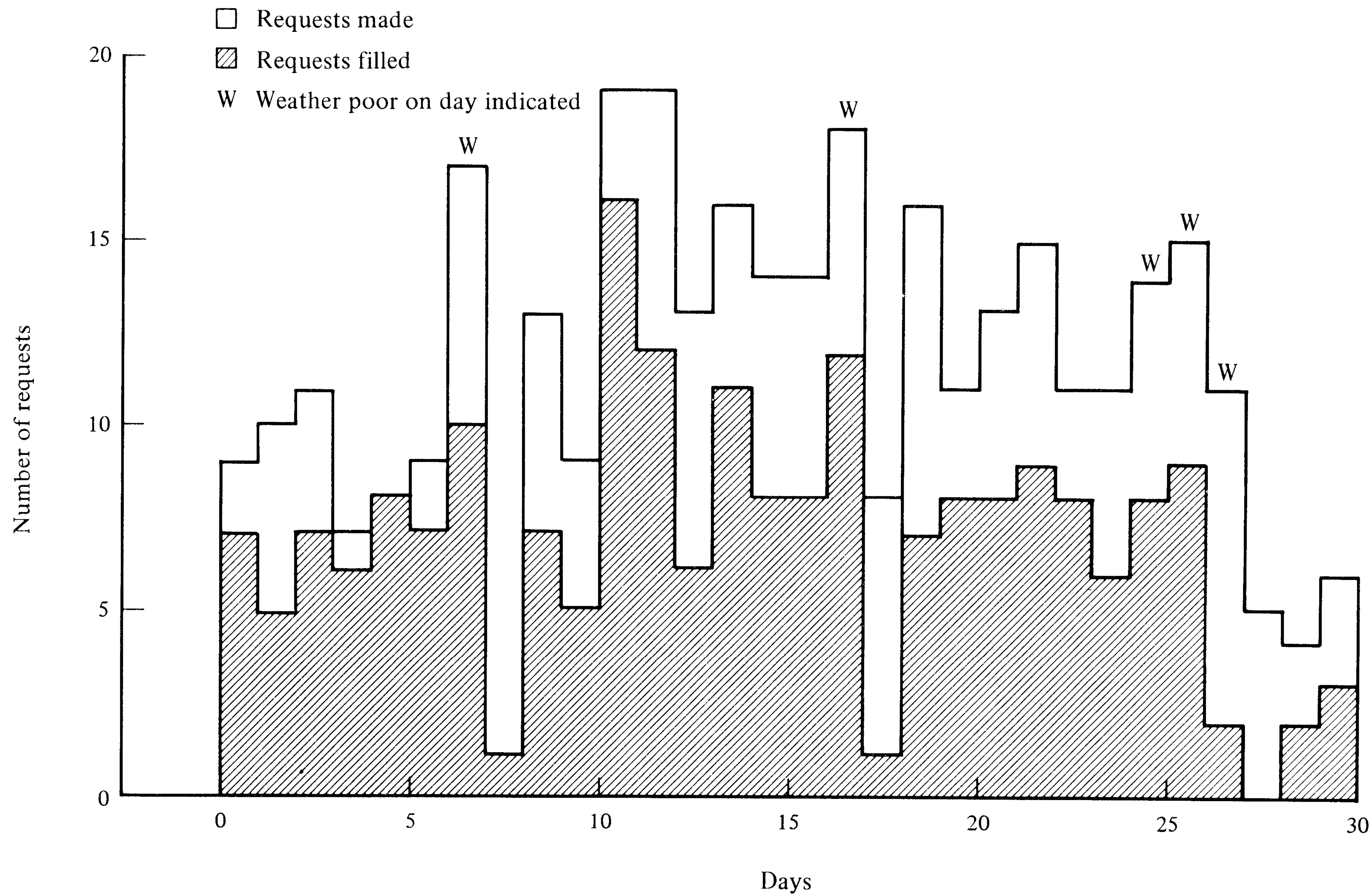



Figure 3-11. First Marine Division Requests for Close Air Support during Offensive of September 1951

calls for support included bad weather, poor communications, and aborted missions.

In the analysis, OEG also examined two time-related issues. The first concerned delays in the arrival of planes that had been requested. It was found that, on the average, almost two hours elapsed from the moment the TADC received a call for support until aircraft arrived. An appreciable percentage of the missions experienced considerably longer delays. The second, and perhaps more meaningful, issue concerned the time of day close air support was provided and its correlation to the time of day support was requested (Figure 3-12). An important finding was that less than a third of the early-morning requests, between 6:00 and 9:00 A.M., were filled. The seriousness of this deficiency in operations cannot be overemphasized, because it was precisely during those hours that ground assaults usually got under way.

The frequency with which different types of targets were attacked by the supporting aircraft was determined. In order of frequency of requests, these were the four major target categories: troops, often well sheltered in bunkers, foxholes, or trenches; mortars and machine guns, lumped together because of their mobility and proximity to the frontlines; gun emplacements, consisting of heavier artillery farther from the frontlines; and forward installations, including observation and command posts and supply and ammunition dumps. The order remained the same when the number of missions flown against each target type was considered, except for the very few night and radar-controlled missions for which the order of the first three categories was understandably reversed. Also, of the four target types, enemy troops were the closest to the frontlines (about sixteen hundred yards away, on the average). Mortars and machine guns were next (at an average distance of twenty-one hundred yards), followed by forward installations (twenty-seven hundred yards), and finally gun emplacements (forty-three hundred yards).[7] By far most targets, then, fell well within two miles of the frontlines. In looking at target type, the group also decided to ascertain the kind of ordnance used, for example, bombs (their size plus whether they were general purpose or fragmentation), napalm, rockets, or guns.

OEG was able to gauge the effectiveness of these missions in two ways. The preferred approach was to obtain damage assessments from members of the TACP, situated close to the frontline ground forces, and from the pilots themselves. In those cases where damage could not be assessed, however, the alternative approach was to determine how well the dropped ordnance covered the area in which the target lay. To depict these assessments, group members had to convert into numerical form the descriptive phrases used by observers to report on damage and "coverage." The chance for error was expected to be minimized by the fairly large number of cases

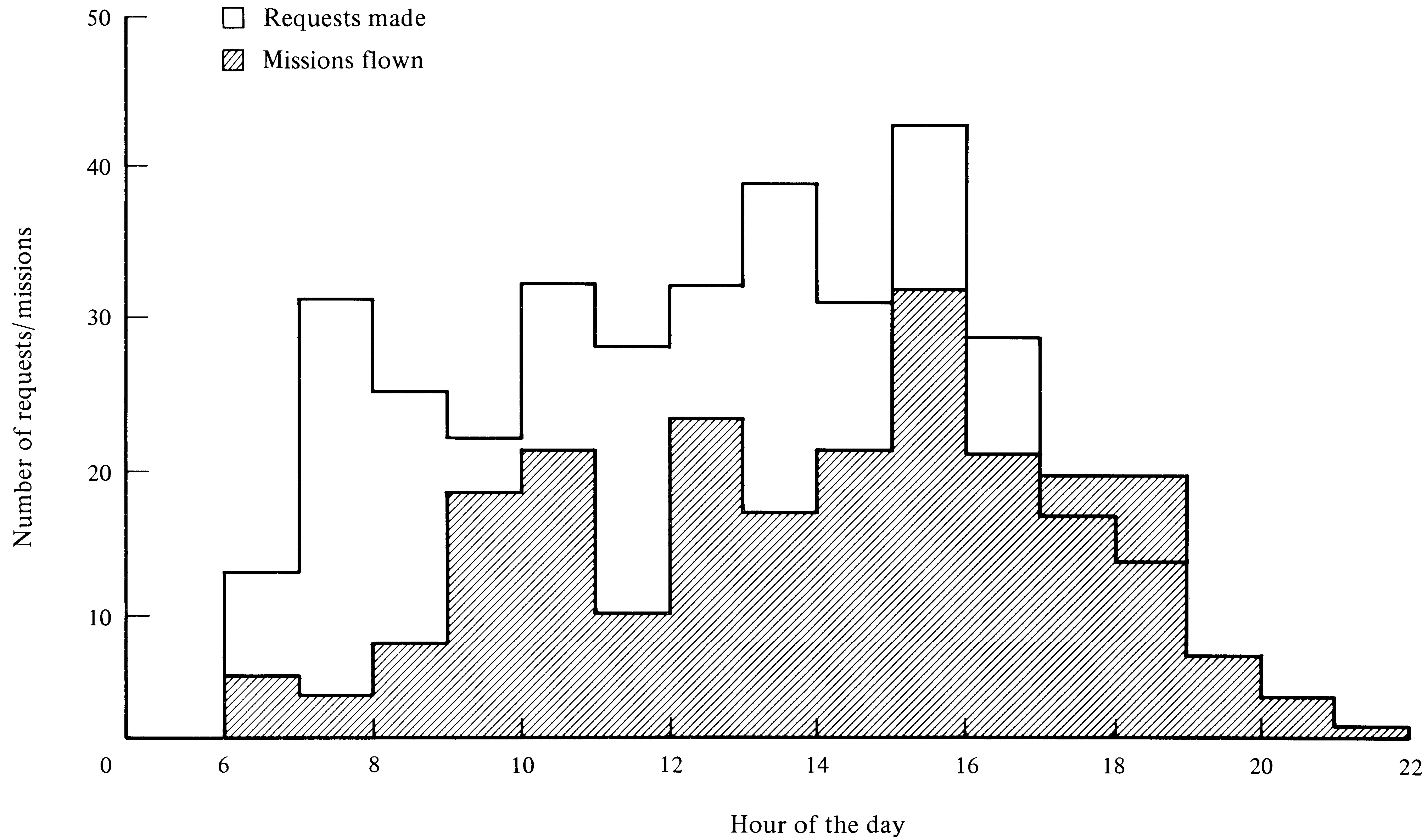



Figure 3-12. Time of Day Close Air Support Requested and Missions Flown

A Corsair offers close air support to ground units brought in close contact with enemy forces. (Official Marine Corps photo.)

examined. The effectiveness of close air support against the four major target categories was then worked out, based on how much damage or coverage was achieved (Figure 3-13). It was found that against gun emplacements, damage was relatively high but coverage relatively low. In this case, however, damage was more important than coverage because the purpose was to knock out the North Korean guns. For the other targets, such as troops, coverage was relatively high and damage relatively low. Since the main purpose against troops was to harass them and to neutralize the area, the results were considered good. The analysis further indicated that missions conducted by the navy and Marine Corps reported slightly higher damage and coverage assessments than did those by the air force. Even so, the study revealed that still better means were needed to assess more precisely the effectiveness of close air support, in terms of its contribution to allied ground forces.

The question of effectiveness of operations extended to yet other aspects of the Korean conflict, none of which was more important than U.N. attempts to maintain an impenetrable blockade of the coastline. On 4 July 1950, a message was sent to all shipping in the Pacific Ocean, declaring that "the President of the United States, in keeping with the United Nations Security Council's request for support to the Republic of

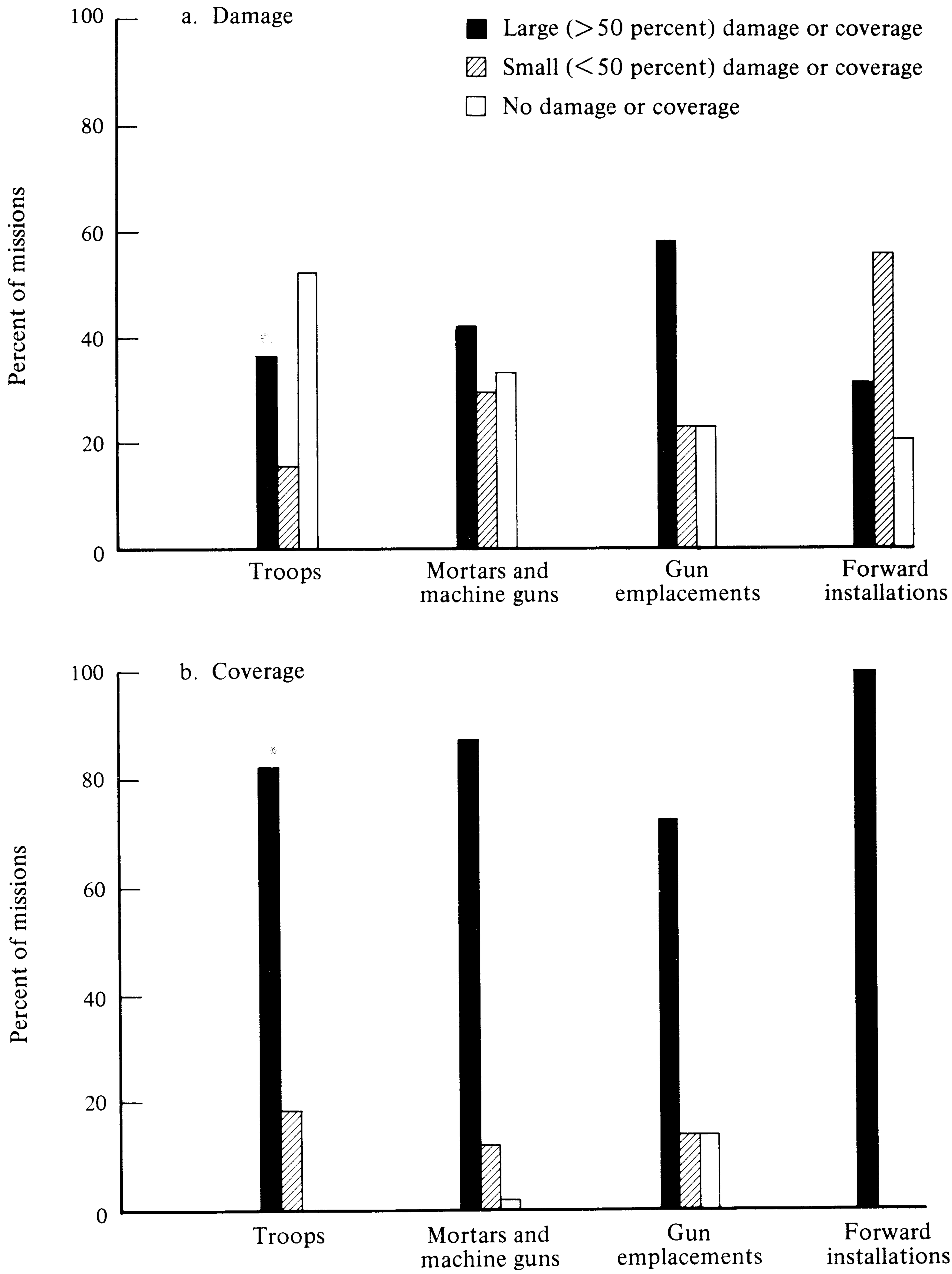



Figure 3-13. Assessment of Damage and Coverage by Target, as a Gauge of Mission Effectiveness

Korea . . . has ordered a naval blockade of the Korean coast." Yet, although opposition to U.N. naval forces by the enemy ranged from minimal to nil, imposition of the blockade posed its own kinds of problems. The west coast, for example, was marked by innumerable islands, mudbanks, shoals, and estuaries, in addition to extraordinarily high tides. The east coast, for its part, was especially suitable for an aggressive enemy mining campaign. Furthermore, the blockade force was small and, of course, thousands of miles from home.

OEG came into the picture when nettlesome doubts about the blockade's effectiveness began to circulate in high circles. The apparent failure of attempts to halt the flow of supplies to the advancing North Koreans, combined with the erroneous belief that air interdiction had successfully cut off all land routes, quickly led to the contention that the sea blockade was being penetrated. Speculation and rumors were rife, as was some finger pointing. Vice Admiral Joy, ComNavFE, later observed:

> During this period, I was frequently asked to intensify my naval blockade of Korea. Many felt that [enemy forces] were getting a large proportion of their supplies by water, possibly in small leapfrogging operations at night. The west coast, with its hundreds of islands, made this supposition easy to come by.
>
> Frequent aircraft reports were received during this period that large numbers of junks or other ships had been sighted, here one day, there another. Immediately it was assumed that these fleets were supply armadas, and I was so informed. I had conferences with my commanders—Rear Admiral Higgins, Rear Admiral Hartman of our east coast blockade forces, and Rear Admiral Andrewes, the British west coast blockade commander.
>
> All of us agreed that while a small amount of sea traffic might be moving, it was very slight and not significant. Admiral Andrewes offered to employ his aircraft from HMS *Triumph* to photograph every port and inlet on the west coast to corroborate that the supplies were not coming by sea.[8]

The questions did not go away that easily, however. Hence, in the spring of 1951, OEG's John R. Pellam undertook the task of evaluating the tightness of the sea blockade. The period looked at extended from the holding of the Pusan Perimeter to just before China's entry into the war. The analysis was complicated by the participation of three nations—the United States, Britain, and South Korea—in the blockade.[9] The U.S. Navy had primary responsibility for patrolling the east coast, where the clear coastline could be approached by heavy ships. The British and South Korean navies had responsibility for patrolling the west and southern coasts, where the hundreds of islands and shallow water necessitated reliance on small craft.

Air coverage for both sides of the peninsula was supplied by the U.S. Navy, thus providing at least one element of uniformity to the blockade effort. Throughout the period under review, the navy maintained an average of about one air reconnaissance patrol each day along the enemy-held portions of each side of the peninsula (including the southern coast during the Pusan beachhead period). It was rare for bad weather to create gaps in this coverage. In addition, the radar fitted on the Neptune patrol planes enabled the searchers to sweep a wide (about seventy-five-mile) band along the coast. The east coast patrol was eventually extended all the way to Vladivostok, while the west coast patrol encompassed the entire northern coastline of the Yellow Sea. In conjunction with these continuous air sweeps of the coast, surface ships set up barrier lines in strategic positions. It was concluded, then, that the coverage was sufficient to prevent any appreciable leakage of the blockade to *large* shipping.

Although large shipping was ruled out, it remained to be seen whether small craft were filtering through with supplies. That the enemy was at least attempting to do so (irrespective of his success) became obvious from the number of sightings made by South Korean patrol craft during searches through the labyrinth of waterways leading around the hundreds of islands. During this period, eighty-three sightings occurred, mostly in daylight, with each contact reporting an average of four to five enemy craft. Not all of the leakage resulted at day; however, just how much took place at night was unclear. Commander Task Group 96 claimed that "the enemy made it a practice, after sustaining initial damage, of moving seaborne traffic only at night, hugging the coastline, taking advantage of all natural routes to avoid detection, and hiding inshore during daylight hours." Yet, a review of the results of night radar operations by the Neptunes did not fully support this; in fact, little significant movement at night was noted.

To acquire a better understanding of the actual scale of enemy operations, OEG decided to examine the early reports of encounters by the South Korean navy. Beginning in the third week of July 1950—by which time South Korean craft had corrected their earlier tendency to patrol too far from shore—contacts increased in frequency, with the peak reached just before the Inchon landing. (It was natural to witness a decline in the number of contacts shortly after the Inchon landing, because of the resultant decrease in enemy-held coastline.) Because fairly complete records of cargo carried by destroyed enemy vessels existed only for the first two weeks of August, that particular period was taken as representative.

The disposition of surface forces at the beginning of August is shown in Figure 3-14. The British ships, which had been patrolling the headland since 27 July, are shown because of their overall importance to the west coast blockade. After a week, the three South Korean vessels on the southeast coast moved to the southwestern region. The places where enemy craft were encountered are numbered to indicate their order of occurrence.

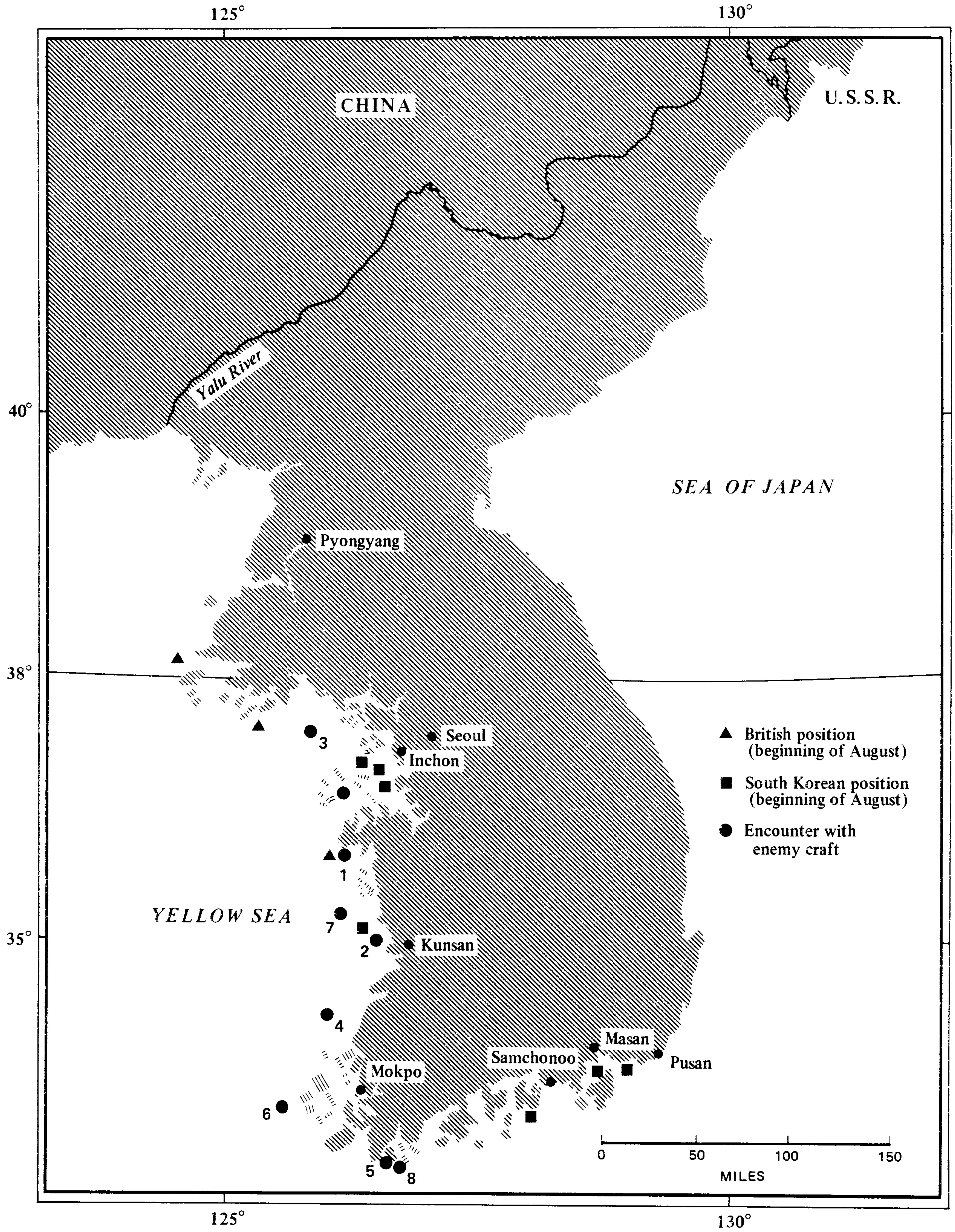



Figure 3-14. Disposition of Blockading Force and Location of South Korean Encounters with Enemy Vessels (First Two Weeks of August 1950)

The first encounter was with seven small sailboats loading supplies. The second and third clashes were with small- to medium-size motorboats, but nothing was learned of the boats' intentions. The fourth and fifth incidents resulted in the sinking of four small and one large sailboat, respectively; the boats were caught resupplying off-shore islands. Encounter six was with a large sailboat loaded with troops, while encounters seven and eight involved enemy motorboats engaged in what was described as intelligence. The two-week period was closed out by an enemy attempt to transport about five hundred troops from the extreme southwest of Korea to a location farther north, which ended in a dramatic chase. Although the troops, upon spotting the South Korean pursuer, managed to beach their vessels and make it to the mountains, all of their craft—forty-three small boats and two 30-ton boats—were either sunk or captured.

With all the data in hand, OEG then made some deliberately pessimistic assumptions. One such assumption, for example, took the amount of leakage through the blockade to be as high as 80 percent. Another assumption consisted of an excessively low estimate of the fraction of the total transit (that is, land plus sea route) that was represented by the excursions made by these small enemy craft. Yet, even with these pessimistic assumptions, the group concluded that the amount of shipping eluding the island blockade was inconsequential. The amount of supplies and number of troops that got through amounted to but a trickle, compared with what was needed to maintain the invading enemy. The net effect of the study was to permit U.N. forces to concentrate their attention on land supply routes.

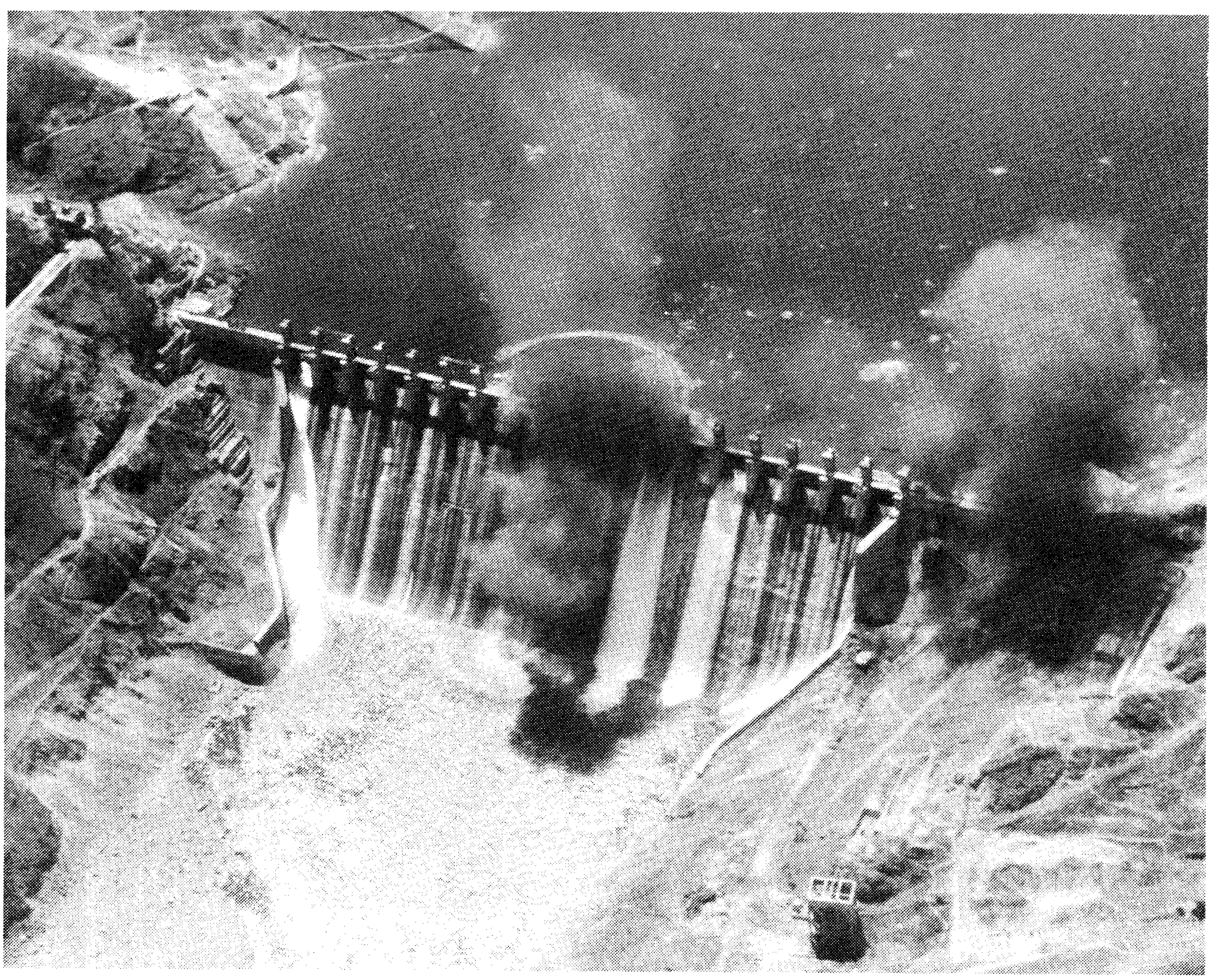
On first look, the Korean peninsula, being narrow and mountainous and saddled with a comparatively primitive rail and road network, appeared to offer an excellent opportunity for conducting an interdiction campaign against land supply routes. Furthermore, enemy air and naval forces were too weak to pose a serious challenge. However, on 4 March 1951, army intelligence warned that the enemy had retained the capability of supplying some half a million troops. Evidently, attempts at interdiction had in large measure failed. The same conclusion, in fact, had been alluded to three months earlier. In a message to Generals Mathew B. Ridgway and Earl E. Partridge, Vice Admiral Struble remarked that "experience here in Korea had demonstrated that . . . the results to be obtained from [interdiction] are only partial." It was a subject that lent itself to the kind of operations analysis engaged in by OEG.

In December 1950, the Far East Air Forces (FEAF), which had general responsibility for land transportation targets, divided Korea north of the 38th Parallel into eleven zones. These zones were shaped to follow the main transportation routes. A total of 172 targets (railroad and highway bridges, tunnels, marshaling yards, and supply centers) were selected within the zones, with the provision that others might be added if the tactical situation warranted. (In fact, the Target Analysis Section of FEAF issued a daily status report that covered some nine hundred targets in North Korea, of which almost three-fourths bore some relation to the interdiction.) ComNavFE, Vice Admiral Joy, agreed that the navy would assume responsibility for the three zones on the east coast, where there was an extensive system of railroads and highways.

On 20 February 1951, Admiral Joy sent a message to Seventh Fleet outlining the interdiction campaign to be carried out, using both ship batteries and aircraft. The plan subdivided the three naval zones into ten areas, stretching from Wonsan north to Chongjin. The areas contained about sixty targets that fell within range of naval gunfire. In addition, Task Force 77, operating in the Sea of Japan, sent in aircraft to attack another fifty targets (mostly highway and railway bridges).

As a rule of thumb, the navy assumed that cut bridges were repaired within forty-eight hours, and therefore planned its reattacks accordingly. In contrast, the air force did not reattack its targets until thirty days had lapsed, unless information came in suggesting that it was necessary to do otherwise. Photographic evidence confirmed that the shorter repair period assumed by the navy was the more realistic. Generally, a bridge with one or two spans dropped was repaired well within forty-eight hours, and occasionally within half that time. In the winter, bypasses were easily set up by taking advantage of the frozen rivers. At other times of the year, the rivers were often shallow enough to be forded. One popular means of mending a sagging road bridge was to level it off with sandbags. If the piers of a bridge remained standing, emergency ramps could be erected. Where a track was broken and repair was not feasible, cargo was carried by hand or truck to another train on the other side of the break. The repairs were done chiefly at night, and little thought was given to safety. Night sorties designed to heckle such work hampered but did not stop the proceedings.

In light of the findings, it had to be concluded that effective interdiction—that is, a campaign by which the enemy was left isolated from his rear supply areas—had not been attained. Further, it seemed that not much more than a halfhearted attempt had ever been made to accomplish the goal. Worse still, OEG doubted that long-term interdiction would ever be feasible, believing that after a fairly short period, the campaign degenerates into a war of attrition. Still, OEG's William F. Whitmore recommended that a systematic interdiction campaign be implemented, but with emphasis on tracks and roads rather than on bridges (the latter being harder to destroy and easier to bypass). In addition, it was suggested that pilots be briefed on the need to cut all alternative supply routes simultaneously, and only then to reattack previously cut links. Improved reconnaissance—especially at night—was regarded as essential, to ensure that the supply system had indeed been cut and that no gaps remained. OEG proposed tactical changes, too. For instance, carrier-based ground attack aircraft and fighter-bombers seemed ideally suited to interdiction, because of their particular bomb load and the training of their pilots in such tactics as low-altitude bombing. The study even suggested that sabotage and

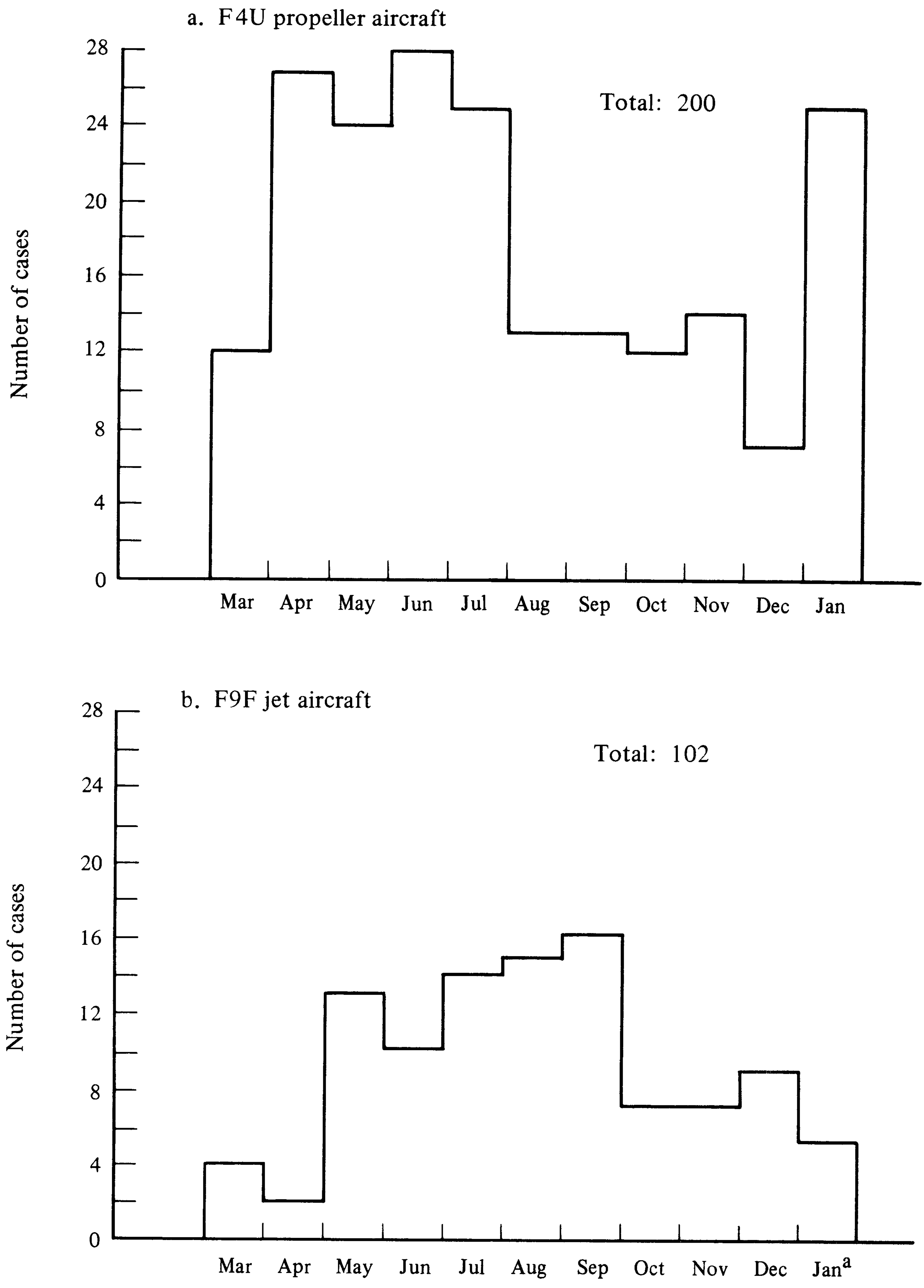


Top: An F4U Corsair fires a missile at ground facilities as part of the interdiction campaign. (Official Department of Defense photo.) Bottom: The Hwachon Dam is heavily damaged by U.S. Navy AD Skyraiders using aerial torpedoes for the first time during the Korean War. The dam was attacked in order to break up a mounting enemy grouping preparing for a spring offensive. (Official U.S. Navy photo.)

commando raids, if orchestrated in conjunction with the main air campaign and not at random, might prove valuable. It added that "the best way to be sure that an explosive reaches the desired target is to place it there by hand." Finally, a detailed interdiction program was offered, indicating goals, exact locations where attacks should be concentrated, target types and the number of hits required for destruction, and weapon selection.

This last point, the selection of weapons, became the object of much additional analysis over the next several months because the navy lacked a comprehensive manual on the subject. OEG's work resulted in the preparation of just such a guide, to help the navy decide what the best weapon and force level would be to conduct air attacks not only against interdiction targets, but also against such target types as airfields and close-support targets. Whenever possible, quantitative measures were given for the effectiveness of alternative weapons. Combined with estimates of the performance capabilities of squadrons, plus assumptions about tactics and accuracies, these measures made it possible to determine the forces required to inflict a particular amount of damage with any of the alternative weapons. A basic but important step that had to be taken was to discard a previously accepted measure of effectiveness that evaluated the success of air attacks on ground targets in terms of damage caused per ton of explosive dropped. OEG substituted a new measure in which success was evaluated as damage caused per sortie flown. The discarded measure—damage per ton—was considered misleading because many naval planes had load limits determined not by the weight of the bombs they carried, but by the number of places on the plane that bombs could be carried. Importantly, considerable flexibility was built into the recommendations, so that values given in the guide could be modified to suit situations other than those initially assumed by the group.

Although naval planes met little opposition in the air, they did, nevertheless, suffer casualties from ground fire. A difference between jet and propeller ground-attack aircraft, in terms of their risk of being hit by antiaircraft fire, caused concern in the navy and prompted an investigation by OEG. To look into the matter, Douglas L. Brooks and Origen K. Bingham concentrated on the combat operations of two squadrons, one consisting of propeller-driven F4Us and the other of jet-powered F9Fs. Data were collected between March 1951 and January 1952 from air attack reports, aircraft vulnerability reports, and historical diaries. First, data on self-inflicted damage (caused by the aircraft's own bombs and rockets) had to be filtered out so that damage caused by antiaircraft fire could be determined for the two types of planes. The overall risk of being hit was then found to be about twice as high for the F4U as for the F9F (Figure 3-15), even though the planes flew comparable numbers of sorties and




[a] *Incomplete*

Figure 3-15. Incidence of Antiaircraft Damage Inflicted on Propeller and Jet Aircraft hours of combat. At issue, then, were the various factors that affected the risk of being hit.

Since both types of aircraft flew similar missions, their difference in vulnerability to hits could not be attributed to that. The types of targets attacked on these missions, however, did have a bearing on relative vulnerability. Specifically, the F4U was more prone than the F9F to being hit while attacking troops or towns; the F9F, on the other hand, was more likely to be hit while attacking buildings and supplies, highway bridges, and railroads. The implication of these findings was that the F4U was more likely than the F9F to be hit by small-arms fire.

OEG also examined the effect tactics had on relative risk. As expected, the two types of planes conducted their missions differently, reflecting their respective performance characteristics. For example, after takeoff from Pohang airfield, the F4U would climb to an altitude of five thousand to ten thousand feet for its flight to the target area, drop to eight hundred feet to search for the target, then, after an attack, climb to between one thousand and three thousand feet to prepare for another attack. The F9F, on the other hand, would approach the target area at an altitude of fifteen thousand to twenty thousand feet, drop to four thousand feet for the search, then, after an attack, return to between four thousand and six thousand feet before striking again; on its return to base, the plane would climb back to between fifteen thousand and twenty-five thousand feet. The jet aircraft, therefore, was more often at an altitude that kept it out of the range of the kind of weapons considered in the analysis.

There were differences in attack procedures, too. The F4U, for instance, would dive toward the target at an angle of 50 degrees and a speed of 250 knots, with release of its bombs at twenty-five thousand feet. The F9F would dive at 40 degrees and 350 knots, with release occurring at thirty-five hundred feet. Standard tactical doctrine not only took the F4U lower than the F9F, but also caused it to deviate more often below specified altitudes. Clearly, the propeller-driven plane was more vulnerable to hits than the jet because of both altitude and speed differences. In fact, when hits were distributed according to altitude, more than twice as many occurred below one thousand feet for the F4U than for the F9F. The higher speed of the jet meant that gunners on the ground had a harder time tracking the plane and that the plane was at the lower altitudes—and thus exposed—for less time. The two planes also differed in tactics during rocket and napalm attacks, again generally to the disadvantage of the F4U. Related to this was the attitude of the planes when they received the most or fewest hits. Most strikingly, OEG found that the F4U was reportedly hit about twice as often during postattack pullouts.

Another issue concerned the relationship between an aircraft's position in a formation and its vulnerability to being hit. Pilots tended to believe that the last aircraft in an attack ran a much larger risk than the first, if for no other reason than that antiaircraft crews would have time to recover from the initial surprise. To the contrary, however, the group found that the last aircraft was hit the least often. The reason, quite simply, was that by the time the last plane reached the target, antiaircraft stations were heavily damaged—and their crews shaken up—by ordnance already dropped.

Other factors were similarly examined, such as the calibers of projectiles that accounted for the hits and the effect of type of attack (bomb, rocket, napalm, or strafe) on the risk of being hit. It was also shown that when only damage from antiaircraft fire was considered, the probability of a loss from a hit was about 50 percent higher for the F4U than the F9F. Because of these findings, OEG was able to recommend changes to the standard tactical doctrine employed by the combat pilots in Korea, thereby lessening the risks run (especially by the F4U).

Of course, only a sampling of the Korea-related work undertaken by OEG can be discussed here, and even that in only fairly simple terms. It should be evident, nonetheless, that the group's analysis went to the core of the navy's day-to-day involvement in the conflict. This meant, for the most part, having to adjust to a morass of tactical and equipment problems that bore little and sometimes no semblance to past experience. Vice Admiral Joy, in returning home from the war, made a different but related and equally valid point:

> From the standpoint of battle effectiveness, the Korean War has reemphasized lessons which were almost lost sight of in the years that closely followed World War II. We know now that there is no quick, easy, cheap way to win a war. Sole reliance for our security cannot be placed in any one weapon or in any one branch of the services. We cannot expect the enemy to oblige by planning his wars to suit our weapons. We must plan our weapons to fight war where, when, and how the enemy chooses.

Hence, the mix of new requirements and old lessons evinced the need for OEG's analysts to become thoroughly familiar with the peculiar challenges confronting the navy, before venturing to isolate particular problems for study. Those group members assigned to commands engaged in the war were in an especially advantageous position to gauge the navy's needs, as dictated by the ebb and flow of the battle. Moreover, they were in the position to witness, for example, how critically needed evaluations of, and changes to, standard doctrine led to operational improvements that in turn produced tangible results in actual campaigns.

Despite OEG's increased commitment in direct support of the operating forces in Korea, the group was still able to make important contributions to the stock of methodologies associated with the science of military operations research. One such contribution involved broadening the application of game theory beyond its original use in deriving optimal screening plans for ships escorting convoys. Its application was extended to include such problems as the optimization of armament for both sides in a fighter-bomber duel and the design of mining and mine-countermeasure campaigns.

Of particular importance, too, was a pioneering use of queuing theory. The purpose of the study was to present a mathematical method for dealing with those problems in which facilities of a fixed capacity have to handle a varying load. For convenience, the study applied the method to the operation of seaports; however, the method could be applied to close air support, air defense, communications networks, or any number of other military systems. To show how this is so, a sample set of equivalent elements follows: for seaports, cargo-handling facilities and ships; for close air support, planes available and requests for close support; for air defense, gun directors and target aircraft within range; and for communications, encoding/decoding facilities and messages coming in or going out.

For the sake of realism, the Japanese port of Yokohama was taken as a model seaport. The basic procedure was for ships to arrive in port and, if a berth was available, proceed to it for either loading or unloading. If no berth was available, the ships had to wait idly by until one became available. Ships were then served by the berths in the order of their arrival. Complete randomness was assumed for both the arrival of ships and the discharging of cargo, that is, there was no schedule. Hence, an observer could not expect that the rate of ship arrivals or the rate of discharge per berth would be high or low at any given time. The rate of discharge, for instance, would be influenced by the amount of cargo to be handled and the effort expended by the longshoremen. One final assumption was that the port was operating under normal day-to-day conditions; that is to say, anomalous conditions, such as the sudden availability of new berths or the first few days of operation of a newly captured port, were excluded from consideration.

A number of descriptive measures could then be associated with the operations of the model port. These measures included the probability that a randomly chosen ship entering the port would not have left after a particular number of days; the probability that such a ship would have its cargo unloaded after a particular number of days; the average amount of time ships entering the port would have to wait before gaining access to a berth; and the fraction of the port's maximum capacity being used. Various parameters were also taken into account, such as the number of berths available and the average number of ships in port, waiting for berths, and in berths. The group was then able to relate the descriptive measures to each other and, as a test of their validity, apply them to the real port of Yokohama.

Among the various conclusions was that the more berths in a port, the greater the percentage of maximum use the port can stand before prohibitively long delays begin to occur for incoming ships. In short, exceeding this percentage leads to an increasingly rapid rise in delays. In a five-berth port, for example, the rapid rise in the probability of ships having to wait begins as soon as about 80 percent of the port's total capacity is being used; in a twenty-berth port, however, the figure is more like 90 percent before serious problems occur. From a practical standpoint, the various conclusions enabled OEG to predict what benefits could be attained—say, minimizing waiting time—by changing port operations. These conclusions, though important, were nevertheless of only secondary interest. Rather, the principal aim was to demonstrate a mathematical method that could be applied to innumerable other examples of queuing, both military and civilian.

## Decennial Conference on Operations Research

In spite of the somewhat dyspeptic mood of the country because of the protracted war in Korea, there was cause for some celebration in OEG, for in the spring of 1952, the group turned ten years old. The Chief of Naval Operations, the Office of Naval Research, and OEG decided that a conference to commemorate the occasion was in order. Initial plans for what came to be titled the "Decennial Conference on Operations Research" were thus hatched. Arthur A. Brown, associate director of OEG (and a World War II member of ASWORG), was appointed chairman of the Decennial Committee, in charge of organizing the conference under Dr. Steinhardt's direction.

The event was to be much more than just commemorative, however. Rather, OEG wished to create a forum for synopsizing past and present developments of operations research—accomplishments and shortcomings—and for ruminating on prospects for the future. As summed up in the foreword to the proceedings, the conference was also intended to "provide an opportunity for those in the field to compare problems and methods of solving them, to suggest new directions and applications for operations research, and to explore the administrative and organizational questions that are raised by the unique melding of scientific and military attitudes that successful operations research demands."

The conference was held on 7, 8, and 9 May 1952, with most of the proceedings accommodated by facilities provided by the National Archives in Washington, D.C. Well over two hundred people attended, representing a variety of organizations. Secretary of the Navy Dan A. Kimball was there, as was Assistant Secretary of the Navy (Air) John F. Floberg. Also attending on behalf of the secretary of defense were the Research and Development Board and the Weapons Systems Evaluation Group. Of particular interest, Rear Admiral Wilder D. Baker—who, as a captain in 1942, set the wheels in motion for creation of ASWORG—agreed to give a talk on the historical reasons for establishing an operations research group. At the time of the conference, Baker was commandant of the Eleventh Naval District. Vice Admiral Francis S. Low, former chief of staff to Admiral King during the days of the Tenth Fleet, was also in attendance. Appearing as Deputy Chief of Naval Operations (Logistics), Low briefed the conference on the World War II background of OEG.

There was a foreign contingent, consisting mainly of representatives from the British War Office, Admiralty, Army, and Joint Services Mission. In light of the close liaison maintained with British operations research groups and its military services during and since World War II, this comparatively large group was understandable. In addition, Canada's Defense Research Board sent its director of operational research.

The U.S. Navy, naturally, had extensive representation, with several people from the Office of the Chief of Naval Operations (including Rear Admiral M. E. Curts, Assistant CNO for Readiness). Under the auspices of the Office of Naval Research—whose Chief of Naval Research, Rear Admiral C. M. Bolster, opened the conference—came delegates from several laboratories and bureaus. These included the Naval Research, Naval Electronics, and Naval Underwater Sound Laboratories, and the Bureaus of Aeronautics, Ordnance, and Ships. Also, under the auspices of the Operational Development Force came representatives from the Surface Antisubmarine Development Detachment, and from Air Development Squadron One and Airship Development Squadron Eleven. The Naval War College and Postgraduate School sent people, too, as did the Marine Corps. The army's participation in the conference was extensive, consisting of a forty-five-person group from its Operations Research Office (affiliated with Johns Hopkins University) and a representative from its Ballistics Research Laboratories. On behalf of the air force, there were delegates from the Operations Analysis Division and Rand Corporation.

An array of private organizations sent people, also. Several of these people were former OEG (and, in some instances, former ASWORG/ORG) members, indicating just how far-flung the group's alumni were by that time. For example, there was, among others, John B. Lathrop in attendance for Arthur D. Little, Inc.; Robert F. Rinehart for the Case Institute of Technology; George E. Kimball and Bernard O. Koopman for Columbia University; John R. Pellam for the National Bureau of Standards; Glen D. Camp for Melpar, Inc.; and R. G. Brown for the Willow Run Research Center at the University of Michigan. Professor Morse was there as one of eight representatives from MIT. Among the many other participants—too many to list in their entirety—were the Applied Physics Laboratory of Johns Hopkins University, the Civil Aeronautics Administration, the Institute of Air Weapons Research, the National Research Council, and George Washington University.

The conference comprised seven sessions. The first, on operations research in the U.S. Navy, was chaired by H. P. Robertson, director of research for JCS's Weapons Systems Evaluation Group. Besides talks by Admirals Low and Baker on the historical development of OEG, extensive remarks were made by the Assistant CNO for Readiness, Rear Admiral Curts, on how his office viewed OEG's analytical support to the navy. Not only did Curts share in OpNav's oversight role, but he had also been a direct user of OEG's studies since World War II, first as a communications officer in the Tenth Fleet, and later as Commander Operational Development Force. His approbation, in part, went as follows:

> As a customer, I know that the Operations Evaluation Group, by timely advice and by its correct solutions to many problems, has saved the U.S. Navy many, many times its cost in dollars, and, what is more important, increased the efficiency of the Navy . . . . They have saved us effort—a tremendous amount of effort—they have saved us time, and they have contributed to the Navy's readiness and efficiency far more than even they know.[10]

Two additional talks, one by the Chief of Naval Research and one by the chairman of the Research and Development Board, helped define OEG's position in relation to the navy itself and to the military research and development program under way at the time.

The second session, led by OEG's director, Dr. Steinhardt, was devoted to the broad subject of how military operations research could best be applied. The first talk was given by E. C. Williams, director of operational research for the Admiralty, who in World War II had done analysis for the famous Bawdsey Research Station (later the Telecommunications Research Establishment).[11] Because of his background, Williams was able to provide a unique historic perspective to his discussion of the application of science in the study of military operations. Then, one of OEG's deputy directors, Martin L. Ernst, provided a detailed update of the group's organization and functions. Among the many points touched on by Ernst was how OEG's analysis would track the complete evolution of an issue. Ernst gave an example of this from work done on guided missiles:

> Four and five years ago, when guided missiles were first being put under really active development, our work was concerned almost entirely with the operational and tactical requirements for new types of missiles. Now that the missiles are coming off the production line, we are becoming much more interested in the question of how to

> test these missiles, and our reports consider such matters as how many shots you must fire to be sure you are giving the missiles a good test, and how accurately you will determine the missiles' capabilities with these shots. A couple of years from now, when missiles have been accepted for fleet use, there is every reason to expect that our reports will deal increasingly with tactics and techniques for using the missiles, and with the question of how they best fit into integrated air offense and defense . . . . The results of tests and analysis of tactical uses of missiles should in turn lead to new sets of requirements for the development of newer missiles.

The third session, chaired by Professor George E. Kimball from the Chemistry Department of Columbia University, covered nonmilitary operations research. In four discussions of various industrial applications of operations research, it elaborated on the general theme of the session, on the balancing of production and inventories in a manufacturing plant, on the traffic pattern of air commerce in the United States, and on running a chain store. The use of operations research for business purposes was beginning to flourish, and portions of the nonmilitary world no longer viewed the field as arcane and unapproachable.

A particularly interesting industrial application of operations research techniques was given during the session. The illustration involved a problem that appeared ideally suited to the search theory developed by OEG during World War II. Specifically, a large company engaged in drilling for oil tended to conduct its searches and commit its resources to any single site in a random fashion. The problem, then, could be broadly defined as the need to determine the amount of money the company should spend in its search, the rate at which money committed to the search should be spent (taking into account the activities of competitors), the number of times searches should be conducted in a particular area, the thoroughness of each search, and so forth. In reviewing search theory, it became clear that two measures were essential to help solve the problem: the value of the oil being sought and the probability that the oil would be found in any single search. The company was not used to viewing the problem in quite these terms; futhermore, the desired values were thought to be hard to derive. Still, it was demonstrated that use of these procedures would greatly enhance knowledge about the probability of eventually finding oil in a chosen location.

L. J. Henderson, associate director of Rand Corporation, served as chairman for session four. The speakers aimed at clarifying the respective roles of the military service, the sponsoring university, and the civilian analyst who worked together to derive maximum benefit from operations research. The university's perspective, with regard to sponsoring an OEG-type organization, was laid out by the president of both Johns Hopkins University and the National Academy of Sciences, D. W. Bronk. The role of the military service, meanwhile, was discussed by Steinhardt. He devoted his talk to the issue of what the armed service, rather than the civilian scientist, could do to ensure the most profitable employment of operations research. Among his recommendations was that military officers should make full use of whatever civilian operations research services were available, and not exclude any problems from the scientist's purview. Another point was the importance of providing adequate links between the operations research group and those departments or agencies most in need of the study results. Steinhardt observed that the navy was the "pioneering armed service in this country in recognizing the value of an operations research group," and that the navy had "consistently foreseen or sensed many of its needs, and acted promptly and with ingenuity and imagination to create the conditions under which [OEG] would flourish."

The next session, the fifth, was on technical methods. It was run by the assistant director of research for the Weapons Systems Evaluation Group, George I. Welch. Three of the four talks were given by OEG members, who provided examples of naval problems that the group had recently attacked successfully. One of the talks was given by Bernard O. Koopman, chairman of the Mathematics Department at Columbia University and a one-time member of ASWORG/ORG. Koopman spoke on the mathematics involved in solving queuing problems, citing OEG's application of queuing theory to the ability of seaports to handle a random flow of incoming shipping. Koopman then explained some of the mathematical methods that had been used to achieve a better understanding of such operational problems.

One of the other presentations, given by OEG's David M. Boodman, centered on the effect a system's complexity might have on its operational reliability. Of particular interest was how the complex design of air intercept radars might have had a bearing on their susceptibility to breakdown. In addition, Oscar A. Hoffman discussed the vulnerability of U.S. Naval aircraft in Korea to antiaircraft fire, an important piece of analysis described earlier in this chapter. Finally, Harold A. Knapp described the results of an analysis of film taken by U.S. fighters during attacks on MiG-15s in Korea. The film was made by F-84s and F-86s during the firing phase of each engagement. In examining the film frame by frame, the group was able to put into quantitative terms what happened from the time the U.S. fighter opened fire until he disengaged. The kind of information gleaned was the range at which firing took place and at which hits occurred, the number of hits and their location on the target, and the angle of the fighter off the target's tail during the course of the attack. The goals of the study included determining the effect of firing tactics on the number of hits scored, the average number of hits required to produce a kill, and the effect of evasive maneuvering by the target on the number of hits achieved.

Led by Professor Morse, session six, on new opportunities and open problems in operations research, provided a natural follow-up to the preceding talks. Speakers outlined examples of work still to be done, and discussed the need for as-yet-undeveloped methods of analysis. A rundown of some of the areas in need of further examination was given by John L. Everett, one of OEG's deputy directors. One set of problems still to be tackled related to the operations of a carrier task force. Although some issues of concern to carrier operations had been explored fairly thoroughly over the years—and, as Everett noted, in Korea theory and fact matched quite well—other issues evoked considerable uncertainty. Offensively, for example, the effect of strong enemy countermeasures on the effectiveness of attacks by carrier-based planes was not satisfactorily understood at all. The anticipated availability of surface-to-air missiles in the enemy arsenal posed serious questions about our own future force requirements. Likewise, little was known about the effect of our attacks on the enemy's military capabilities, pointing to a major hole in the analyst's grasp of the problem of effective reconnaissance on such missions as interdiction.

The defense of a task force also gave rise to several vexing and high-priority concerns that would have to be addressed in the near future. First of all, the level of defense was probably going to change dramatically because of the threat of nuclear warheads. It was projected, for instance, that the threat of nuclear attack would make it necessary to destroy *all* incoming enemy aircraft. Before, when it took several surviving planes to inflict serious damage on a carrier, much more lenient requirements sufficed. In addition, to estimate with any desirable degree of reliability the capabilities of antiaircraft guns in defense of the task force required three things: a theory of fire-control radar equivalent to the well-established blip/scan theory of search radar; accurate estimates of the vulnerability of enemy targets; and knowledge of the distribution of shots about an evasive and nonevasive target. The extent to which radar countermeasures by the enemy might undermine estimates of the effectiveness of these guns was yet another consideration. One final concern that further clouded the subject of task-force defense was the difficulty of applying conventional fighter tactics to near-sonic interceptors.

After mentioning a couple of other specific areas in which OEG expected to help the navy in the immediate future, Everett turned to the broader subject of new methods and applications of operations research. One of his examples had particular historical significance, for it dealt with the advent of nonlinear mathematics in the field of operations research:

> The first [issue] that comes to mind . . . can be expressed succinctly by remarking that war is a highly nonlinear situation. With great

> effort we have analyzed the effect of one weapon used in one tactic, and such studies have been of value in elucidating equipment performance. We have also attempted, in theory and in operational trials, to study the interaction of large masses of military power. But it is very difficult to relate the pieces to the whole. There are effects of saturation, of forced diffuseness in the weight of attack (both in space and in time), of correlation, and of just plain confusion. As is usual in engineering, the mass problems are linearized by drastic approximation and omission, with the customary results that the reassembled parts bear no obvious relation to the original, except at very low levels of accretion. It is fair to say that nonlinear mathematics is in its infancy, and that much improvement may be expected. But I question whether operations research has made much effective use of even the present progress of the art. Remember that the most typical nonlinear results are general indications as to the nature of permissible solutions. Surely it is just this sort of rough indication that operations research has used so effectively in the past. But the formulation of valid nonlinear models will require great insight and experience.

The final session of the decennial conference had as its theme the internal administration of operations research, with Arthur A. Brown as chairman. It was essentially an administrators' meeting that encompassed such subjects as the recruitment and training of operations analysts and the definition of what makes an effective analyst. A somewhat less orthodox topic was the setting up of standby groups of analysts that could be readily mobilized in the event of an emergency. The scheme provided for these standby analysts to continue working full-time for whatever institutions normally employed them, until such time (as in a war) that their skills were needed elsewhere. Three years later, in April 1955, the idea of standby groups was incorporated into a formal OEG plan that established procedures the group was to follow in the event of a war. Among the proposed steps were (1) to postpone the callup of OEG members holding reserve commissions and to defer the induction of draft-age members; (2) to relocate the group away from areas considered to be priority targets for enemy attack; (3) to provide duplicate files of essential reference material at Norfolk, Virginia, and Key West, Florida; and (4) to issue Federal Civil Defense Administration identification cards to OEG's director and some of his senior analysts, making it easier for them to get to their place of work under wartime conditions. Finally, the plan suggested that negotiations begin with the University of California for the organization of a reserve pool—or "standby group"—of scientists, as had been suggested at the conference.

In addition to the seven formal sessions, an anniversary dinner was held at the Carlton Hotel on 8 May. About one hundred eighty people attended, with a portion of the U.S. Navy band supplying the music. Robert Rinehart acted as toastmaster. Informal after-dinner talks were given by the secretary of the navy, the assistant secretary of the navy for air, and the vice president and provost of MIT. The main address of the evening was given by Professor Morse, who offered a sanguine forecast of the future of OEG-type organizations.

Twenty-seven newspapers and magazines were invited by the Information Office of the Office of Naval Research (ONR) to attend the reception and dinner, as well as the opening meetings of the conference. Among those invited were *The Washington Post, The New York Times,* and *The Wall Street Journal*; *Time* and *Newsweek*; *Scientific American, Science,* and *Physics Today*; and the Associated Press and United Press International. During and after the conference, requests came in to ONR from a number of publications—both lay and professional—for information beyond what had already been released as a matter of course. Copley Press arranged to interview Rear Admiral Baker (of ASWORG fame), and Washington television stations WTOP and WTTG aired programs, such as one by Mark Evans, covering various aspects.

With the conference over—and, more to the point, with the Korean War wound up—OEG was ready to go on to other things. Although the decade had opened in a dramatic way, quieter times did not lie ahead. Various circumstances, both within and outside OEG, were to propel the group through a succession of major changes.

**The Operations Research Group**

After the signing of the Korean armistice, as after the previous war, OEG again enjoyed a brief period of consolidation. But brief it was. The severe chilling of relations between East and West, which stemmed from the bitter fighting of the previous three years, resulted in renewed national resolve and a concomitant steady increase in the size of OEG to a total of more than seventy scientists by the turn of the decade. Additionally, considerable outside pressure—from the Soviets' explosion of a thermonuclear bomb to the immense costs of maintaining an adequate defense—demanded innovation and change.

The first change affecting OEG's organization involved the creation of a spin-off group. Impetus for this move arose from a desire by the Office of Naval Research (ONR) to become more intimately involved in the field of operations research. OEG, after all, reported first and foremost to the Office of the Chief of Naval Operations (OpNav). Therefore, early in 1953, ONR approached MIT about the possibility of the institute establishing another operations-oriented group, located under ONR's roof and tasked to work on ONR problems only. MIT was reluctant, however, to set up a second group in Washington, for fear of becoming too entrenched in nonacademic commitments. Notwithstanding its initial misgivings, the institute nevertheless agreed to this new partnership with the navy. The Operations Research Group (ORG) was thus formed in June 1953, bearing the same name used by OEG during the last year of World War II. The role of technical director was assigned to Harvey Hall of ONR's Naval Sciences Division; and George P. Wadsworth, who was OEG's formal point of contact in MIT's Department of Mathematics, became MIT project director for ORG.

Because ONR wished for the new group to begin supplying it with sound analysis immediately—rather than having to bide its time while the group passed through a learning phase—it arranged to have OEG scientists assigned to ORG on a rotational basis. (The staff, incidentally, never exceeded a modest eight scientists.) Furthermore, ONR expressed its preference for field-tested members of OEG to fill ORG's manpower needs, an implicit acknowledgment of the merit of OEG's field program. Although the justification for setting up ORG was for ONR to have its "own" operations group, the bond between ORG and OEG remained so strong that for all practical purposes, ORG functioned as little more than an adjunct of OEG. This was further underscored by the fact that OEG's director, Dr. Steinhardt, served simultaneously as ORG's director, and that Russell C. Coile, also an OEG member, occupied the position of ORG's director of research.[12] The contract establishing ORG was thus amended in July 1954 (a little more than a year after the group's inception) to formalize what had in practice already been taken for granted. The revision read: "It is intended that ORG work closely with the Operations Evaluation Group (OEG), and that it make all possible use of [OEG's] accumulated experience, training facilities, and other resources."

ORG picked up additional OEG people as a result of the wholesale shift to it of OEG's three-member Research and Development Review Section. Formed at about the same time as ORG, the section was conceived as a means of centralizing for the navy vital information on the navy's research and development program. The object was to make it easier to keep abreast of how much money actually went to each of the many areas of research being funded. The section's efforts led to vastly more detailed and accurate records of expenditures than had ever been compiled in the past. But, what the section did had nothing whatsoever to do with operations research, other than possibly to contribute data to those studies aimed at redirecting the navy's research and development priorities. Hence, the section was transferred to ORG, where it could be of more direct use to ONR—the rationale being that keeping track of naval research expenditures was really an ONR concern.

The official statement of ORG's functions made the point that the group's studies were to be "aimed at major long-term improvements in

Naval capabilities." Inclusion of the qualifier "long-term" was an attempt at differentiating ORG's role from OEG's. In fact, more than half of the statement of ORG's functions was taken up by examples of how the two groups were intended to differ. Also listed were the four major study areas on which ORG was to set its sights. These study areas (paraphrased here) were: analysis of the possible effects of scientific research and development on naval operations; analysis of new threats and U.S. countermeasures—and of the possibility of increasing our offensive strength—to be considered by the navy during long-term research and development and operational planning; development of new methods of operations research; and (most general of all) "matters" relating to the collection and analysis of "research data of a military nature."

Shortly after ORG was formed, a preliminary list of projects was prepared, designed to translate the philosophical purposes of the new group into a concrete research program. One of the most ambitious of the proposed projects called for a study of those aspects of naval operations most hampered by inadequate technology, and hence most in need of scientific advances. Among the problems believed to fall into this category were the inability of ships to effectively detect planes flying below the radar horizon or near land masses; the inability of a carrier task group to control effectively *all* of its planes when faced with roughly an equal number of enemy planes; the inability of aircraft to conduct large-scale night operations, particularly against small land targets; the inefficiency of mine-hunting systems; the impracticality of torpedo countermeasures; the inadequacy of means to classify targets detected by sonar; and the inadequacy of measures to counter enemy radar. Other suggested areas of analysis included the possible uses of air-to-air guided missiles in the defense of a fast carrier task group, the research and development effort required for producing a balanced weapons system on submarines, the possible use of guided missiles by cruisers and battleships, and the application of new weapons systems to amphibious warfare.

In January 1954, ORG decided to run a series of colloquia on operations research, mainly for the benefit of analysts working in the Planning and Analysis Sections of ONR's Naval Sciences Division. The format included six informal sessions, one each week throughout February and into March, in which speakers discussed case histories illustrating how operations research had been applied to various naval problems. OEG furnished some of the speakers. The sessions covered a wide range of subject areas and generally proved to be effective in explaining the various practical applications of operations research to recent problems.

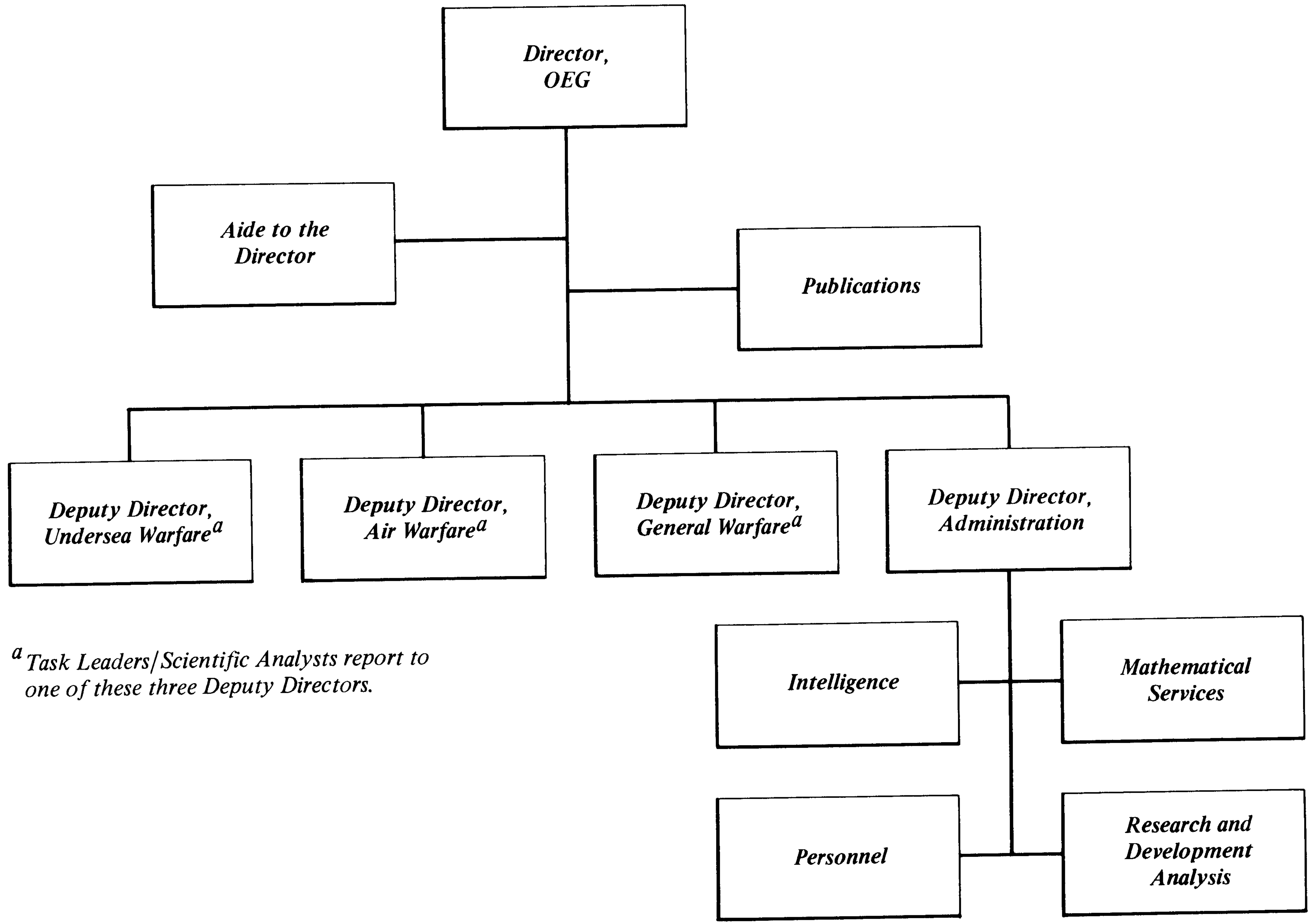
ORG's struggle to make its mark, however, seemed destined to be frustrated, for both major and minor reasons. One of the minor reasons was an abiding difference of opinion between OEG and ONR over how much authority MIT should have in the review and approval of suggested projects, with OEG wanting greater participation by MIT and ONR wanting less. Another minor cause of ORG's difficulties was the eventual requirement to move out of ONR's offices (because of an unusually acute shortage of space) and into a separate building some distance away. With the physical distancing of ORG and ONR came a distancing of purposes. The result was a decline in the flow of information from one to the other and a lost sense of usefulness among ORG's staff. An accumulation of such niggling problems over the next few years helped to short-circuit the good intentions that had inspired ORG's formation.

Then, on 31 December 1956, a meeting was held by the Navy, with Dr. Steinhardt sitting in for OEG, that effectively sounded ORG's death knell. Everyone at the meeting agreed that ORG had evolved into an appendage to OEG rather than into the independent group formerly envisaged by ONR and others. Moreover, ORG's achievements were generally deemed unnoteworthy, to the extent that ONR believed it had benefited insignificantly from the minor studies completed by ORG. In light of the confluence of problems that plagued ORG, it probably came as no surprise when the question of ORG's possible termination was bandied about in the meeting. Over the ensuing weeks, additional meetings settled whatever qualms anyone may have had. By then, all involved—MIT, OEG, and ONR—fully concurred that ORG should expire, which it did on 30 April 1957. A minor proviso by ONR called for the Research and Development Review Section to continue until 31 December, which was when the contract officially ran out.

## The Naval Warfare Analysis Group

In the midst of the goings-on with ORG, OEG underwent two other changes. The first, a fairly minor matter, occurred on 7 December 1954, when the group (up to then designated Op-374) was redesignated Op-03EG. The announcement pointed out that the Deputy CNO for Fleet Operations and Readiness, Vice Admiral Robert P. Briscoe (Op-03)—to whom the group reported—would continue to make OEG's services available to the other divisions of OpNav, the fleets, and Marine Corps, as before. The effective naval responsibility for the group would rest with Op-03B, a rear admiral, and the authority to act as contracting and technical officer would be delegated to Op-03A, a captain. The statement of functions that accompanied the announcement amounted to little more than a slight rewording of previous definitions of OEG's responsibilities to the navy. OEG proper, meanwhile, retained its basic organizational setup (Figure 3-16).

The second, and considerably more important, change for OEG involved the spinning off of another subgroup. In creating ORG, ONR's major aim was to gain direct access to an operations-oriented group that had as its sole reason for being the solution of ONR problems. A secondary aim, as




[a] *Task Leaders/Scientific Analysts report to one of these three Deputy Directors.*

Figure 3-16. Organization of OEG (Mid-1950s) pointed out earlier, was to gear the group's studies to long-term solutions. It was this last aim that spurred the navy as a whole—not just ONR—to begin thinking seriously about establishing an organization capable of tackling the Navy's long-range planning needs.

The idea of such an organization, however, was not entirely new. In fact, for several years, certain circles in the navy had been considering what to do about this apparent lack of strategic planning. Some individuals had even been talking in terms of a "Navy Rand."[13] OEG had already engaged in some work that fell into this area, as provided for in the 1945 task order that included the "analysis of strategic alternatives." But clearly the group's overwhelming responsibility was to help the navy be prepared to fight a war in the immediate or short term. This was what the navy had most wanted and needed, and this was what OEG provided. Furthermore, this was the role that had proved so valuable in two wars fought within the short span of the group's first ten years of existence.

In 1954, the navy approached the subject of strategic planning by first appointing an ad hoc committee to study long-range shipbuilding plans. The committee, which came out with a more sweeping report than had been awaited, recommended that a new "desk" be set up in OpNav for the purpose of dealing with all the navy's requirements for long-term planning. Important, the committee also suggested that the new desk be provided with civilian analytical assistance. Hence, in February 1955, the Chief of Naval Operations, Admiral Robert B. Carney, set up the Long-Range Objectives Group (Op-93), consisting of a small nucleus of experienced senior naval officers headed by Rear Admiral C. D. Griffin.

The new group's purpose was to project analysis as much as ten to fifteen years into the future. In doing so, the group was to examine the following subjects:

- The responsibilities of the navy
- The tasks that must be performed to carry out these responsibilities
- The effect of world technology on the performance of these tasks
- The capabilities required to perform these tasks
- The "optimum" weapons systems and techniques for achieving these capabilities, and their adaptability to and effects on established strategic concepts
- The required direction of weapons development
- The required composition of forces.

To meet the desire to have Op-93 assisted by civilian scientists, it was natural for the navy to turn first to OEG. Although OEG was in a unique position to supply the requisite analytical know-how, there was some understandable hesitation about simply enlarging the group to accommodate this new avenue of analysis:

> While much of the work [the new civilian scientists] will undertake falls within the scope of the charter of the Operations Evaluation Group (OEG), OEG is already fully committed with its present responsibilities. Although OEG's strength might be increased, it would be under strong pressure to devote any such increase to near-term work, with which it is already fully engaged, rather than to consideration of what the Navy should be looking forward to five, ten, or fifteen years from now.[14]

With this in mind, the navy elected to establish at least a quasi-separate group, called the Naval Warfare Analysis Group (NAVWAG). However, circumstances prevented NAVWAG from becoming truly independent of OEG for many years. The reason was that if the Long-Range Objectives Group was to benefit from NAVWAG's assistance, it would have to ensure that NAVWAG was staffed with competent analysts already experienced in military–and, preferably, naval–operations research. The navy therefore proposed that the director of OEG serve simultaneously as the interim director of NAVWAG, in the same way he had been performing that function for ORG. The intent was for Steinhardt's leadership of NAVWAG to be a stopgap measure, until a suitable permanent director could be found. (As it turned out, Steinhardt remained director of NAVWAG for the next four years, whereupon another member of OEG, Douglas L. Brooks, assumed the position.) In addition, the navy planned to arrange for some of OEG's personnel to transfer to NAVWAG, to take advantage of OEG's knowledge of naval problems.

As a result of MIT's successful management of OEG, the navy in October 1955 sent to the institute a description of the proposed new group, asking that it enter into a contract with ONR for NAVWAG's administration. MIT was assured that NAVWAG would remain strictly a civilian organization with a civilian director, and that, like OEG, it would reserve the right to initiate a certain fraction of projects undertaken by it. MIT agreed to the proposal on 8 November. The institute specified, however, that it would prefer to provide its services "by means of an amendment to the present contract covering the work of the Navy's OEG and ORG [contract NOD-6964], rather than by . . . a new separate contract." MIT's response continued that "from our point of view, this advantage stems from the fact that (a) it would make possible a more flexible assignment of scientific personnel, (b) it would facilitate training, and (c) it would simplify administrative problems . . . ."[15] The first two points alluded to the necessary collaboration between NAVWAG and OEG, in terms of NAVWAG's reliance on OEG members both for the partial staffing of the new group and for the training of inexperienced recruits.

These were extremely important provisions, because it meant that OEG and NAVWAG were so closely linked that any distinction between them—in their manning and administration, anyway—was sufficiently blurred to be made insignificant. In sum, NAVWAG became an adjunct of OEG.

Exactly a month later, on 8 December, MIT submitted to ONR a proposal for administering NAVWAG. The agreed-upon contract went into effect on 30 December, in the form of amendments to the MIT/ONR contract for administration of OEG. Owing to the excellent opportunity NAVWAG's presence offered OEG scientists to study strategic issues, OEG was naturally delighted to act, in effect, as its mentor. The most important amendment to the old contract was a delineation of NAVWAG's functions, which followed almost precisely the wording used to describe the functions of the Long-Range Objectives Group. Work actually began under the contract on 1 January 1956. NAVWAG grew modestly over the next several years, as shown in Figure 3-17 (tracing its manpower levels) and Figure 3-18 (tracing its funding levels).

In spite of its smallness, NAVWAG managed to make effective inroads into many of the kinds of long-range problems for which it was created. A major influence on the direction of NAVWAG's studies was the exploding of the Soviets' first thermonuclear device in 1954. Long-held expectations about strategic balance were altered, and the threat of Armageddon loomed large. Suddenly, the United States was obliged to adjust to the military implications arising from the possible use of nuclear weapons by our major potential enemy, the Soviet Union. Evidently, the United States would no longer enjoy its former virtual monopoly on large nuclear weapons and on the aircraft used to deliver them. Even though nuclear parity, as such, was still some distance away, the inevitable narrowing of the gap meant that the United States was becoming increasingly vulnerable to a retaliatory attack.

Because of all this, NAVWAG examined the conditions that were expected over the next decade to invalidate the old policy of absolute deterrence. According to this policy, the United States could use the threat—overt or implied—of a massive nuclear attack against an aggressor's homeland to deter an enemy from even limited aggression. In light of the Soviets' anticipated advances in nuclear warfare, it had to be concluded that their ability to inflict vital and unacceptable damage in return would shortly lead to a stalemated situation, referred to as balanced deterrence. The study considered several issues related to the new technological environment. These included the feasibility of blunting enemy strike (or retaliatory) nuclear forces, the requirements of an effective air defense against enemy bombers, the hardening and dispersal of our own missile sites, and the role of anti-ICBM (intercontinental ballistic missile) batteries

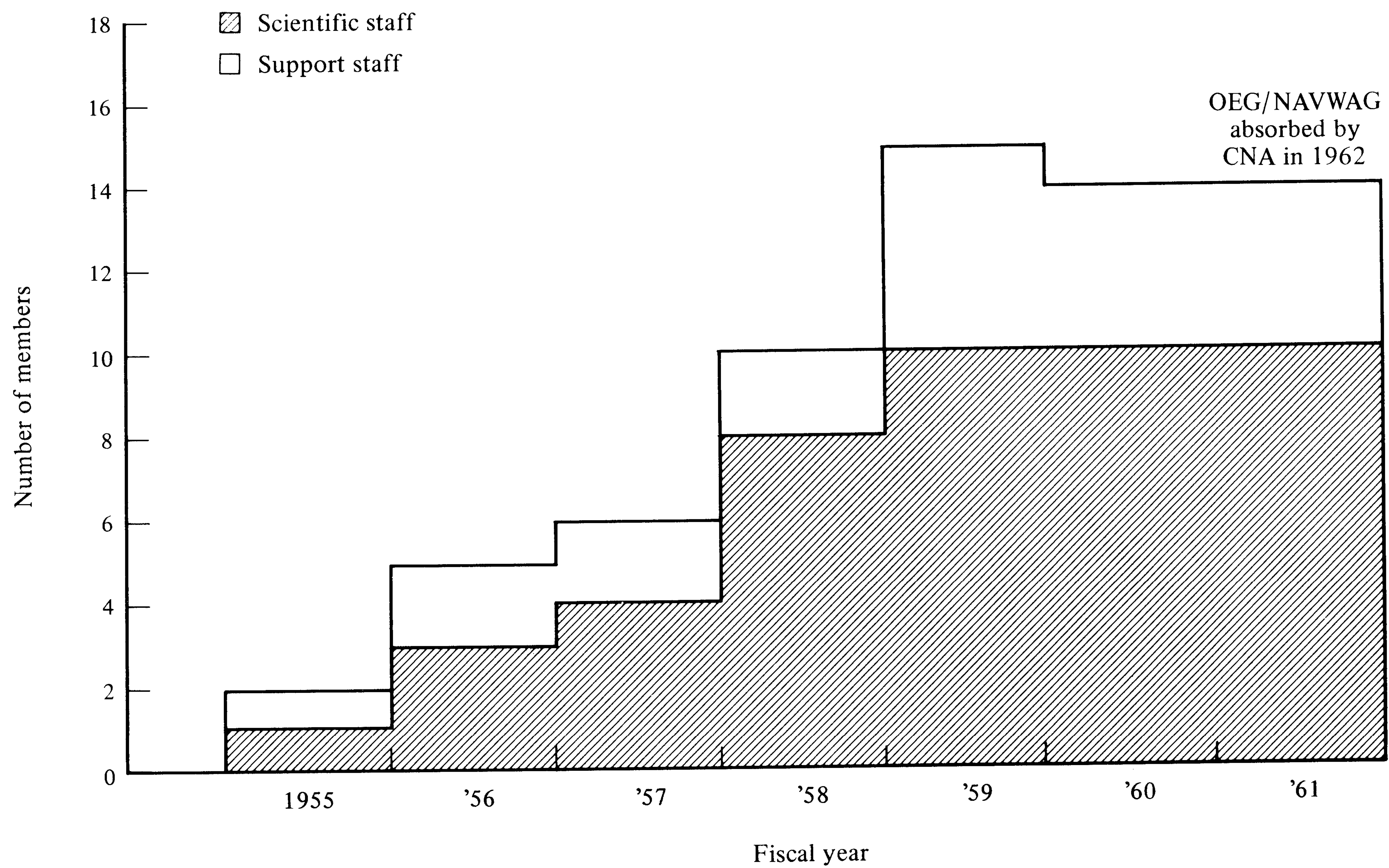



Figure 3-17. Growth of NAVWAG (to 1962)

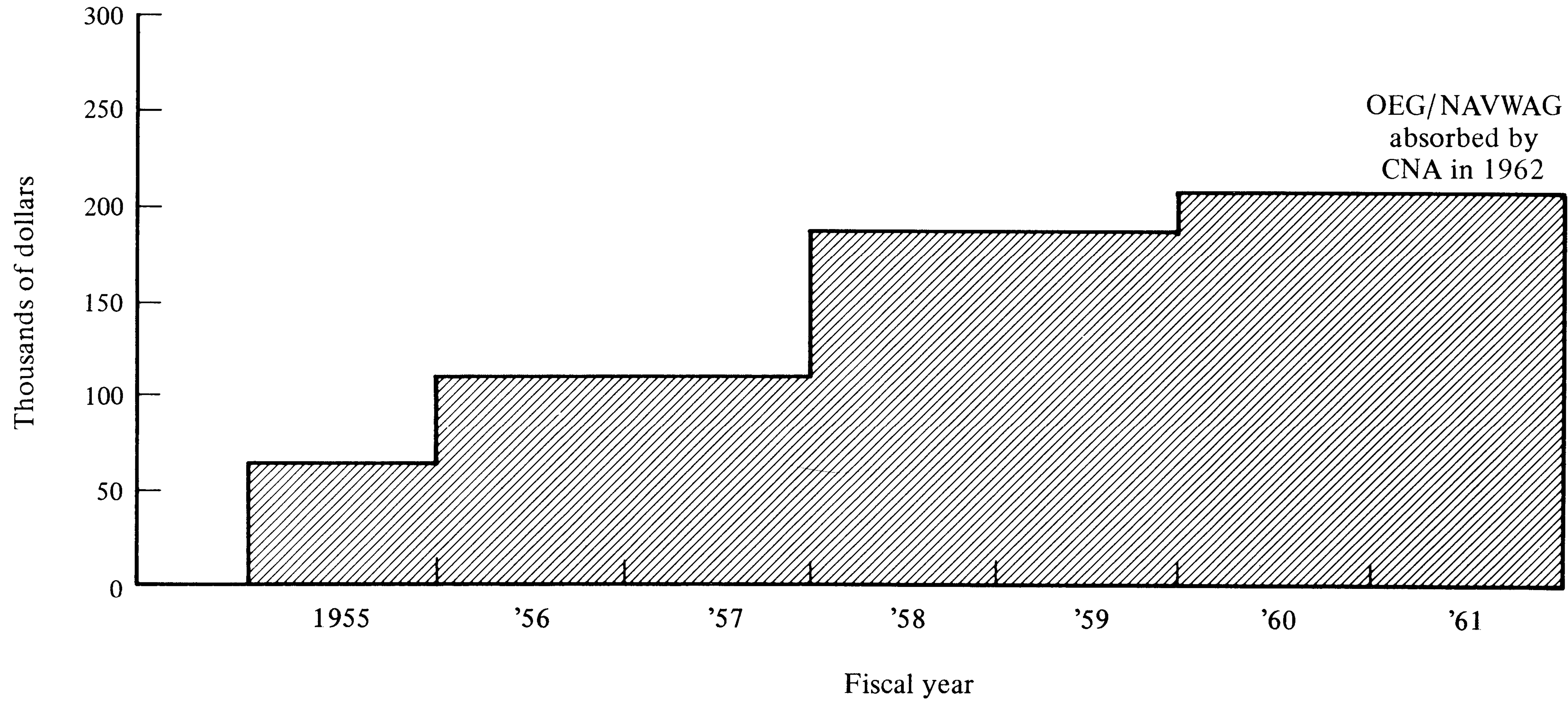



Figure 3-18. Fiscal History of NAVWAG (to 1962)

in protecting missile sites and cities. Recommendations were made concerning the posture the United States should adopt over the next twenty-odd years, with regard to adjusting to the shift in strategic balance and to formulating our military needs on both a nuclear and conventional level.

In determining the long-range objectives of the navy, it was necessary, of course, to examine the many facets of national policy that might affect the navy's options. As Vice Admiral R. E. Libby said in a speech to the National War College on 10 April 1957, "...we cannot solve military problems except in the overall framework of the national problems of which they are a part." NAVWAG therefore began to explore many of these national strategic problems, so that its findings might provide a backdrop for further investigations into issues of more specific interest to the navy.

One such effort by the group focused on fundamental concerns about the power relationships expected to prevail among major nations over the long term. Three basic postulates were advanced as essential ingredients in the formulation of national policy. The first was that there was no absolute insurance against mutual destruction. This implied that the United States should adjust to the status quo and not strive to buy absolute security, for that goal would always prove illusive (not to mention expensive). The second postulate was that neither side could gain *significant* advantage over the other, whether politically or militarily (political and military objectives not always being distinguishable from one another). The consequences of trying to gain such an advantage might be catastrophic, in that an enemy who feels he is cornered might strike out in desperation despite the punishment he would likely have to absorb in return. Third, if either side attempts to win too much from the other, it risks losing everything. That is, all-out wars were no longer practical, although limited wars, fought according to implied agreed-upon rules, would become increasingly possible as a means of advancing national self-interests.

Other conclusions drawn by NAVWAG's study were that a capability for all-out war serves to deter its initiation by an enemy; that the United States should maintain the minimum invulnerable strategic force adequate to deter a rational enemy from starting an all-out war (bearing in mind that too much, like too little, constitutes provocation)[16]; that determination of this force requirement should be based on the "softest" targets, namely, the enemy's population centers; that the United States should develop a "graduated deterrence" capability, whereby different-size nuclear weapons would be available (along with improved conventional weapons) for counteracting limited aggression in kind as well as number; and that vulnerable retaliatory weapons systems should be phased out and replaced by something better because they tend to limit the flexibility of our strategic position and thus add pressure to respond at the first sign of attack or preparation for attack.

With interesting foresight, the study also delved into what effects a large-scale defensive effort might have on the stability of deterrence. The study speculated that attempts to reduce the vulnerability of our soft targets—our cities, people, and industry—would not, in fact, vitiate the enemy's plans to maintain adequate retaliatory forces. Rather, such attempts would simply prompt the enemy into intensifying expansion of his offensive forces until the point of deterrence had again been reached. The result, then, was likely to be a substantial jump in military costs, without having bought invulnerability. Indeed, some of the possible defensive measures—missile installations and fighter bases near cities, or an extensive civil defense (shelter) program—would have been costlier than the additional offensive weapons subsequently put in place by the enemy. Hence, only if a modest expenditure by us could force a large expenditure by the enemy would any such defensive program be justified. This point did not, however, preclude strengthening the defense of our strategic retaliatory forces (as opposed to soft targets), to protect them from a disarming preemptive attack.

Although the subject here is NAVWAG's commitment to strategic studies, it is worthwhile digressing slightly. The reason is that OEG, in its own right (and not just by rotating its people to NAVWAG), made similarly significant contributions to this important area of analysis. One study in particular had a resounding impact on the nation's awareness of whether U.S. deterrent capabilities would be adequate throughout the upcoming decade of the 1960s. First, several assumptions were made regarding the following: the buildup of a nuclear stockpile by the Soviets; the level of Soviet missile technology; the ability of Soviet intelligence to locate (and thus target) our fixed missile sites; the possibility of the Soviets launching a surprise attack; the force levels that must survive such an attack for the United States to retain an effective retaliatory capability; the reliability of systems designed to warn of an attack; and the adequacy of weapons systems available to the United States. The last of these evaluated both singly and together three fixed-base systems—the Titan and Minuteman missiles and an unalerted Strategic Air Command (SAC)—and three mobile systems—the Polaris ballistic missile submarine, an alerted SAC, and naval air. Time trends, as a method of analysis, were of particular importance in gauging the adequacy of our weapons systems vis à vis those of the Soviets.

Completed in 1958, the study concluded that U.S. deterrent forces would be sufficiently weak between 1961 and 1963 that our ability to retaliate to a disarming attack would be in serious jeopardy (Figure 3-19). Word of this prediction entered the political and public arenas, causing a

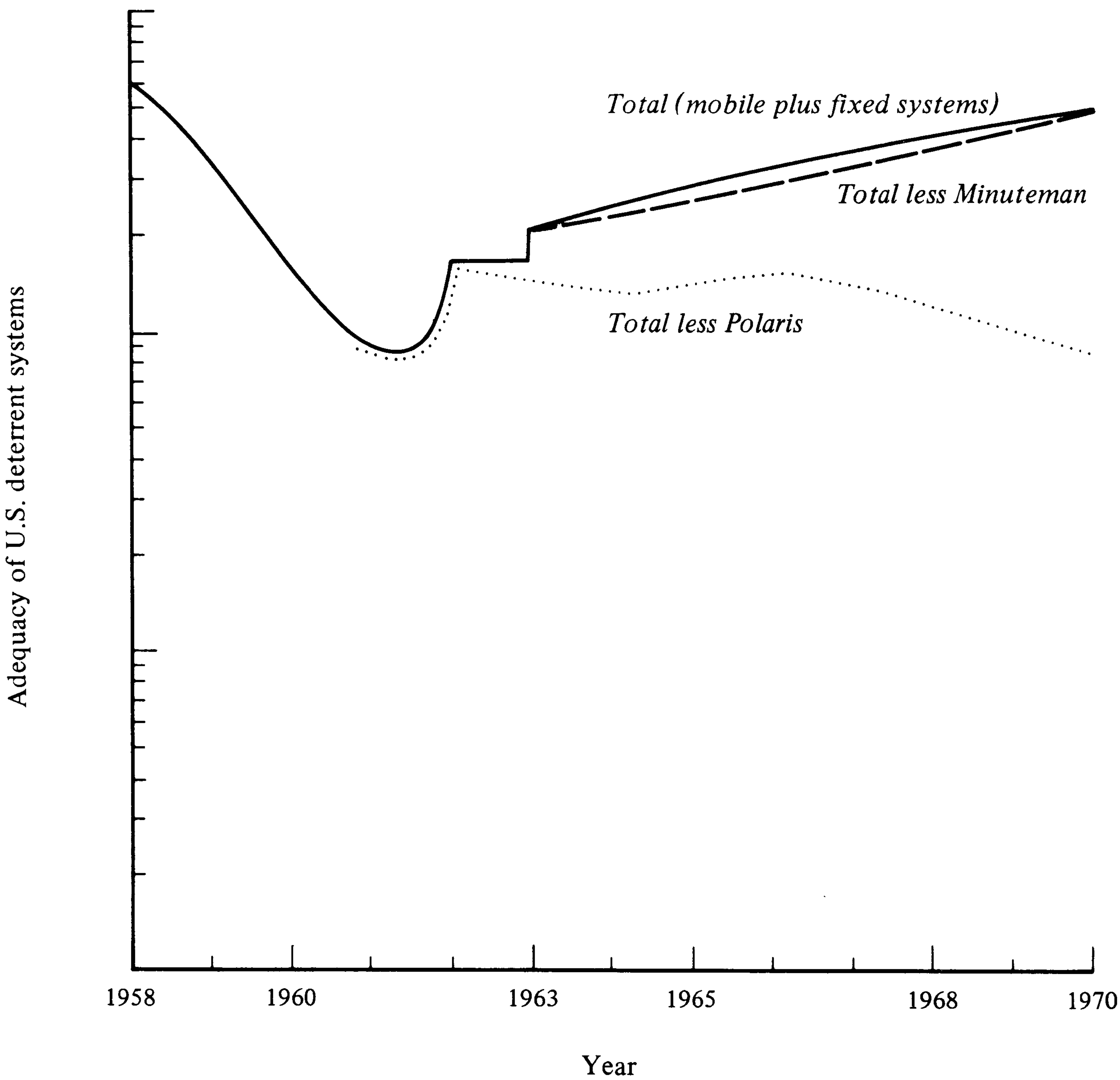



Figure 3-19 Adequacy of U.S. Deterrent Forces

considerable stir. The notion of a "missile gap" suddenly bounded onto center stage. A public debate ensued, enflamed by Nikita Khrushchev's exaggerated claims regarding the production and deployment of Soviet ICBMs. A point easily lost in all this, especially in light of the alarmist rhetoric that prevailed over the next few years, was that the study had in fact proposed stopgap measures to fill the supposed vacuum. These measures included the hardening and dispersal of fixed weapons sites, a program of continuous flights by SAC bombers, the sped-up procurement of available weapons systems (such as mobile cruise missiles), and the increased preparedness of naval air. OEG also recommended that emphasis remain on the development of mobil and concealable forces, rather than on fixed-site forces. Polaris, for example, was spotlighted as meriting accelerated production.

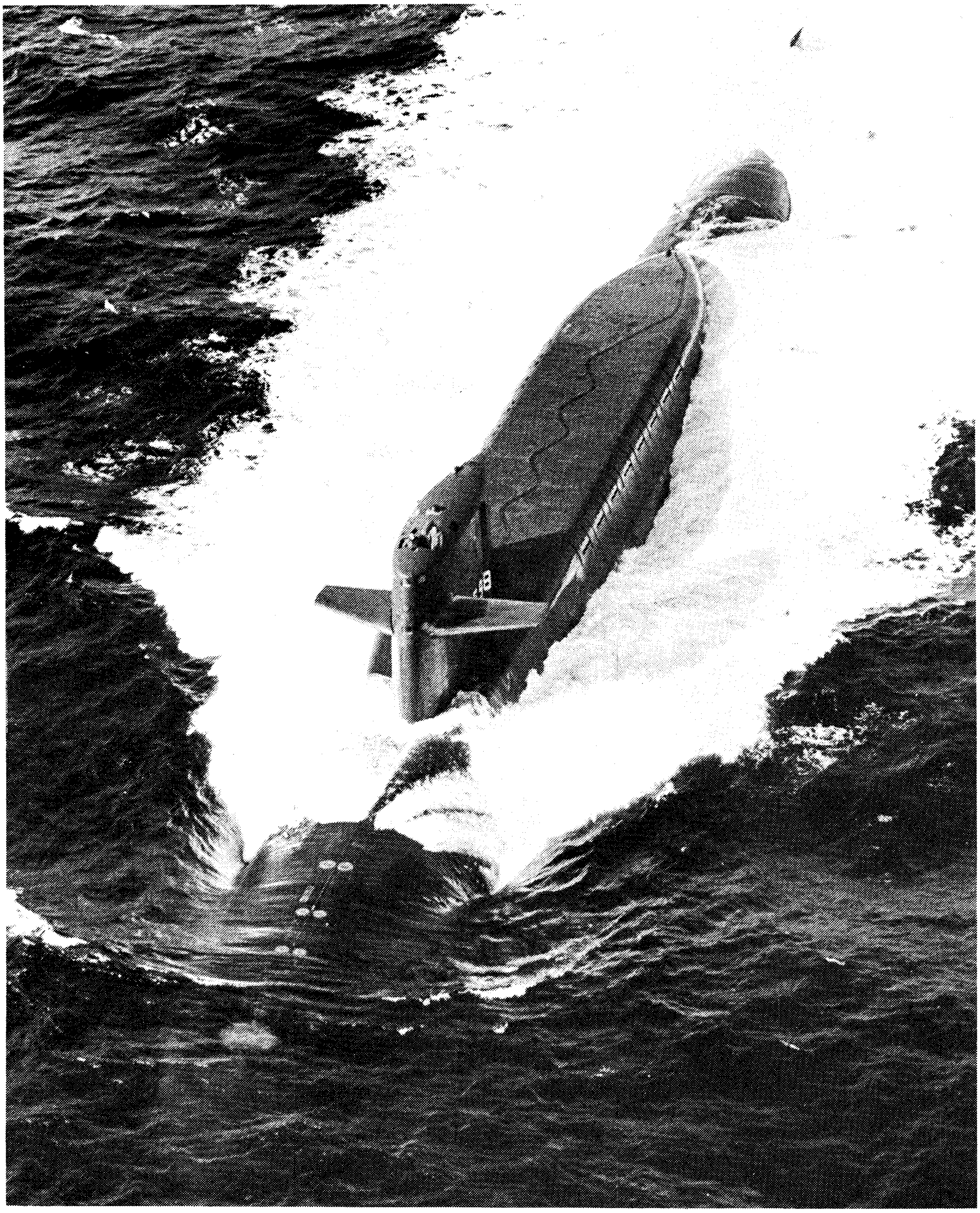
The defense policies of two administrations were greatly influenced by this expectation of a possible low point in U.S. deterrence. Toward the end of President Dwight D. Eisenhower's administration, when the controversy was at its peak, calmer heads nevertheless won out:

> Eisenhower saw the "missile gap" as arising, if at all, in the future and not reaching a peak until 1963, at which time the solid-fueled Polaris and Minuteman missiles were due to become operational in large numbers. Having in the meantime decided to forgo any large U.S. deployment of the relatively unsatisfactory liquid-propellant, first-generation missiles, Eisenhower refused to be panicked into acquiring a substantially larger number of these inferior ICBMs by the threat of a missile gap. Such a gap could emerge, according to Eisenhower's intelligence specialists, only if the Soviets decided to procure and deploy large numbers of their own liquid-fueled, first-generation missiles. Eisenhower was willing to accept a missile gap if the Soviets moved in this direction, believing that a missile gap–if not too pronounced–would *not* be the equivalent of a "deterrence gap." In other words, Eisenhower counted on the overall level of strategic force available to the United States, including its large strategic bomber force, to maintain an adequate deterrent capability during the period in which the Soviets might possess a larger number of operational ICBMs than the United States.[17]

As soon as John F. Kennedy took over the presidency, however, he decided to embark on an extensive program of strengthening American strategic forces. Mirroring much of what OEG's study had recommended three years earlier, he increased the production rate of Polaris submarines by several months, and added ten submarines to the original planned total. He also doubled the capability for producing Minuteman and improved the alert status of SAC's B-52s.

Returning to OEG's adjunct group, NAVWAG, one of the specific strategic weapons systems evaluated by it was the Polaris ballistic missile submarine, which at the time (early 1959) was soon to be deployed with the fleet. The period considered by the study was 1960 to 1970, with emphasis on the last half. Because the ballistic submarine was considered unique in terms of its comparative invulnerability–largely due to its mobility and ease of concealment–the group decided to analyze how Soviet antisubmarine warfare capabilities might fare in a hypothetical attempt to counter it.

First, it was necessary to specify the likely characteristics of Polaris, for both the early and later versions of the submarine. The characteristics that had a special bearing on Polaris's ability to resist antisubmarine efforts included missile range (and thus the areas of the oceans in which the submarine would have to be stationed to reach assigned targets), missile launch rate, submerged vice surface launches, noise emissions, and time at sea. The group then made deliberately unfavorable assumptions, to establish



The navy's first Polaris ballistic missile submarine, the USS *George Washington* (SSBN 598), plows through the ocean. Displacing fifty-four hundred tons and equipped with sixteen missile-launching tubes, the *George Washington* became operational in 1960. (Official U.S. Navy photo.)

the upper limit of the submarine's vulnerability. A number of possible Soviet measures were looked at, both as they existed at the time and as they were expected to be in the future, after the Soviets had had time to respond to the new threat. Because of the opacity of the sea, acoustic techniques of detection and fire control would probably continue to dominate antisubmarine efforts. Particularly large advances were anticipated in this field over the next ten years. Specifically, it was expected that there would be active sonars (for both barrier coverage and area search) capable of assured long-range detection independent of target depth; passive sonars capable of not just detecting but also classifying a target at quite long ranges; and explosive echo-ranging systems.

Also considered was the Soviets' use of radar to spot a fired missile. Once detected by radar, the missile's path could be tracked back to the submarine's location; if the enemy reacted fast enough, he might be able to destroy the submarine before all of its missiles were launched. It was also assumed that infrared detectors would be available to supplement radar. Although the gases of a missile's exhaust provided an excellent radar target immediately after the missile had left the water, such gases persisted only briefly, making it difficult to classify the echoes. Infrared detectors would solve this problem, while offering the added benefit to the enemy of not itself being detectable.

A variety of other technological assumptions were made concerning future Soviet capabilities, as well as estimates of the size and disposition of their antisubmarine forces. The Soviets' choice of tactics against Polaris was also considered, including massive search at the moment hostilities begin, peacetime area surveillance, continuous shadowing, barriers, air-launched missile counterattacks, and isolated peacetime attacks for the purpose of attrition. Even when bleak assumptions were made for the sake of determining the worst-case scenario, the network of ballistic missile submarines appeared minimally vulnerable to a surprise attack. There were a number of ways—including the simple but highly effective measure of increasing Polaris's standoff range—to thwart most of what the Soviets could be expected to do.

## Closing Out the Decade

By the late 1950s, military decision making was becoming burdened with concern over the cost of weapons systems. Now choices over alternative systems had to be made with enormous care. If the wrong choices were made, the United States could waste large portions of its limited defense budget. Moreover, the country might find itself defended inadequately for some time to come because of the long lead times involved in developing sophisticated systems and in changing the course of national defense policy.

To help deal with this situation, the navy, in March 1959, formed the Naval Long-Range Studies Project, based on a recommendation by the Naval Research Advisory Committee. The group consisted initially of about half a dozen naval officers located in Newport, Rhode Island, with Rear Admiral Edwin B. Hooper as its head. As members of the Long-Range Studies Project became immersed in efforts to better understand the navy's requirements a decade or so into the future, they quickly recognized the value of acquiring the assistance of civilian specialists. A contract was thus agreed to, calling for the Institute for Defense Analyses (IDA) to provide such assistance. At the same time, the Long-Range Studies Project changed its name to the Institute of Naval Studies (INS) and moved its offices from Newport to Cambridge, Massachusetts.

Meanwhile, OEG was extending its own horizons, in a way that was to cause the paths of OEG and the newly formed INS to cross. Two things impelled OEG to consider another change to its organization. Foremost was a desire to keep more on top of advances in science, so that the possible consequences of such advances to naval operations might be monitored and the navy kept aware of them. If, furthermore, this information could be used by the navy in its long-range planning, so much the better. The second incentive for change stemmed from Dr. Steinhardt's fear that after scientists had been immersed in naval matters for a while, they tended to evolve into operations researchers first and "scientists" second. He felt quite strongly that it would prove most beneficial if group members could be given the opportunity to retain that one overriding trait—that is, their familiarity with the newest developments in their respective sciences—that made them so valuable to begin with.

To this end, OEG decided to set up yet another adjunct organization, but one more oriented to basic research. Steinhardt summed up his intentions in a 23 June 1959 memorandum to the Deputy CNO for Fleet Operations and Readiness (Op-03) and the director of the Long-Range Objectives Group (Op-93):

> To raise significantly the probability that important help can be offered the Navy in the solution of its most broad problems, it appears essential to me to depart from the wholly integrated task-order type of organization currently in being, and to expend at least some effort toward the creation and maintenance of a research effort organized along more conventional research lines outside the Pentagon. If such a project is undertaken with care, it will leave the present organization of OEG and NAVWAG undisturbed and their role unchanged, except that their usefulness will ultimately be enhanced as a better warehouse of basic methodologies and abilities is developed . . . . [This] separate research organization [would] feed people and ideas into the parent groups, and vice versa.

In November, MIT agreed to a request by the CNO that such an organization be set up within OEG, along the lines proposed by Steinhardt. It was expected to consist of several divisions, each with its own specialty: nuclear propulsion, aeronautics, engineering, missilery, space technology, communications, electronics, economics, navigation, marine architecture, statistics, and so on. The new organization, at first called the Technical

Analysis Group but later renamed the Applied Science Division (ASD), was permitted by the contract to grow over a three-year period to thirty scientists and almost as many support staff, with a budget of $800,000 a year. According to Steinhardt's proposal, the scientists recruited to staff ASD were to "graduate to positions in OEG and NAVWAG" and vice versa.

Although the groundwork was laid, there were two difficult issues left to be settled. The first involved the administrative network linking MIT with OEG, NAVWAG, and the new ASD. Because it had already been decided to locate ASD adjacent to MIT in Cambridge (where INS was situated), strong MIT oversight was suggested. One suggestion—which was rejected—was to place the triumvirate of OEG, NAVWAG, and ASD under the direction of MIT's Naval Architecture Department. The solution that emerged as the most reasonable, however, was simply to assemble a faculty committee, the purpose of which was to provide guidance to ASD in Cambridge and to OEG and NAVWAG in Washington. The director of OEG, who would still head the whole operation, was required to report to the committee.

The second issue left to be settled involved finding a director for ASD who fit the stringent professional requirements insisted on, yet who was also willing to wield less influence and enjoy less control over policies than OEG's director. While it might have been seductive to think otherwise, ASD could not realistically be granted autonomy. It was OEG, after all, that bore the ultimate responsibility for protecting and using wisely the classified and politically sensitive information entrusted to it by the navy on the basis of a special relationship nurtured since World War II. The navy certainly concurred with this reasoning and, furthermore, made it known that it preferred a single and clear-cut chain of command. The issue was finally settled and an able director, Hugh J. Miser, found.

With these last loose ends tied up, ASD began operations in June 1960. The flavor of its work is revealed by a sampling of the subjects taken up by its various teams of specialists. In missilery, for example, there was a study of the effects of new technology (in guidance systems, propellants, and so forth) on the range of future Polaris missiles; in aeronautics, a study of the effects of ship motion, flight-deck geometry, and landing dynamics on the accident rate for carrier-based planes; in nucleonics, a study of the use of nuclear reactors to propel surface ships; in mathematics, a study of Markov processes with continuous outcomes; in economics, a study of past naval budget allocations to aircraft procurement and operating expenses; and in political science, a study of the implications to the navy of arms control. There were others, of course, too numerous to cite. While working on such practical problems, ASD's members managed, also, to pursue their idealistic goal of keeping abreast of advances within their various disciplines. As expected, their proximity to MIT certainly helped.

A year and a half later—when the paths of OEG and INS intersected—ASD's close attachment to OEG ended. At the close of 1961, the navy informed OEG that it wanted ASD to work primarily in support of INS, since ASD and INS were both in Cambridge while OEG was several hundred miles away, in Washington. Although this severing of the connection between OEG and ASD interrupted the latter's usefulness to OEG as a link to academia, the disruption turned out to be short-lived. The reason was that within a few months, INS (and hence ASD) was to be made a component of the new Center for Naval Analyses (CNA), along with OEG and NAVWAG.

Another response to the navy's growing concern about the substantial cost of new systems was the inclusion in OEG of a formal Economics Division. In previous years, the group had occasionally employed the services of individual economists, whenever the need arose. These economists, however, would invariably lose the struggle against the irresistible pull of operations research work that was the real mainstay of the group and thus themselves gradually evolve into operations analysts. In addition, because OEG had hitherto treated economic issues only peripherally, no well-established or particularly talented economist was generally willing to risk obscurity in a sea of physical scientists. Furthermore, the chance of an economist making a place for himself within OEG and forging a distinguished career was slim. As a consequence, many of OEG's operations research scientists would act as economists—though reluctantly—if a study absolutely required it. Naturally, this proved most unsatisfactory, largely because of their lack of familiarity with the methods peculiar to economics. The outcome was that studies in which at least some aspect of the cost of alternative systems had to be taken into account seldom derived cost-effectiveness estimates that were really very reliable. Moreover, no body of costing techniques (or of cost data, in general) that would be directly relevant to OEG's main areas of interest could possibly be developed under these circumstances.

The pressures engendered by the longer-range studies made necessary by the cold war forced the issue to a head. OEG finally decided to establish a formal collection of economists, large enough to attract a highly gifted person to run it and self-sufficient enough to offer its members the opportunity to distinguish themselves as full-fledged economists. Once the decision had been reached, it still took about eighteen months to find someone to form and head the new division. The most difficult hurdle was to persuade prospects that OEG was serious about granting the division sufficient latitude to allow intellectual freedom to flourish. The search ended in September 1961. Stephen Enke, who was already well respected in his field, agreed to serve as a part-time director of OEG's Economics Division and to use his name in the recruitment of other economists. As it turned out, setting up the division proved fortuitous. The general mood at that time was fixed on the idea of budgetary responsibility and accountability among the military services. More important, this was the beginning of the McNamara era, during which Secretary of Defense Robert S. McNamara earned a reputation as a nemesis of waste and high costs.[18]

While all this was going on with ASD and the Economics Division, OEG implemented yet further change. Over the previous few years, it had become apparent that OEG's multiple-team approach to the various warfare areas had led to cumbersome compartmentalization, with each team confined to a too-narrow grouping of problems. This, in turn, caused the several team leaders to devote excessive time and energy to administrative matters rather than to analysis. The situation had also led to overstratification, in terms of real or implied "rank" among group members. Steinhardt felt that the presence of multiple teams, and the ranking that resulted from it, hindered the group's ability to move members around quickly and efficiently in response to shifting analytical requirements. There needed to be complete interchangeability of all individuals, to ensure that the right people were available to work on the right subjects at the right time.

The group was therefore reorganized in early 1960, on the basis of two sections. The first, comprising about two-thirds of the scientists in Washington, was to focus on the short-term problems of the navy—OEG's speciality. The section was split into just three teams, each encompassing a broad warfare area and assigned several subjects for study:

- Undersea warfare
  Submarine strategic deterrence
  Defense of merchant shipping and naval task forces
  Defense of ocean approaches to the United States
  Mine warfare and mine countermeasures
  Harbor defense
  Continental air defense (undersea warfare aspects)

- Air warfare
  Carrier air strikes
  Air support
  Fleet air defense
  Continental air defense
  Surface-to-air missiles

- General warfare
  Nuclear energy
  War gaming
  Communications
  Amphibious operations
  Naval logistics.

It was also planned to establish ad hoc teams to deal with atypical or high-priority projects.

The second section comprised the remaining one-third of the members located in Washington. These ten or so scientists were the most experienced in the group, from whom team leaders were chosen. The section was to examine problems of a broad scope, much as the Operations Research Center had done for the Operations Research Group (ORG) in World War II. The role of field representatives assigned to the various commands and of scientific analysts assigned to the various OpNav desks remained virtually the same.

One final development should be discussed before closing out this era in OEG's history. In earlier years, it had been customary for the group to call on outside consultants to help fill short-term manpower needs or, more typically, to gain access to specialized knowledge. Rarely were more than one or two consultants employed at any one time, and almost all were former group members. Dr. Steinhardt eventually came to the opinion, however, that a formal and quite large body of consultants—perhaps as many as fifty—should be assembled to provide advice on an ongoing basis. These were to be eminent researchers, selected from both universities and industry and representing the spectrum of disciplines. MIT concurred with the idea; hence, in September 1959, the president of MIT, John A. Stratton, wrote to the Chief of Naval Research, expressing support for Steinhardt's proposal.

A permanent OEG Panel of Consultants was formed in early 1960. It comprised more than twice as many members—about 110—as originally contemplated, associated with, among others, Harvard University, the Stanford Research Institute, the Scripps Institute of Oceanography, the National Research Council, Rand Corporation, the National Aeronautics and Space Administration, and the Applied Physics Laboratories. Shirley Quimby, best known for his World War II role in helping to bring operations research across the Atlantic, also participated. MIT provided a large contingent, including Professors Philip Morse and George Wadsworth. OEG "alumni" included George Kimball and Martin Ernst of Arthur D. Little, Inc., John Pellam of the California Institute of Technology, and Robert Rinehart of the Case Institute of Technology, among many others.

The presence of such eminent panel members was expected to accomplish three secondary goals, besides the main objective of providing a source of specialized knowledge for complex naval problems. First, their presence was expected to add to the aura of scientific excellence and objectivity sought by both OEG and the navy. Second, it was believed that these people would help pique the interest of an expanding slice of the scientific community in naval matters. Finally, OEG anticipated improved recruitment by virtue of the influence these people wielded in their respective fields.

OEG made extensive use of its Panel of Consultants until the formation of CNA two years later, when reliance on the panel diminished. One of the more valuable contributions of the consultants was to apply their knowledge of various technical areas in reviewing finished studies and pointing out subtle problems. In addition, subgroups of the panel convened on several occasions to consider specific problem areas. One such subgroup, chaired by Joseph H. Engel[19] and participated in by thirty-five panel members, spent seven weeks in mid-1960 examining naval command, control, and communications systems. Two major conclusions were drawn from its analysis: First, that overall efficiency had been adversely affected by the independent development of each component of the system; second, that information, command, and control requirements of the navy in a general war differed so greatly from such requirements in a limited or cold war that two separate structures in these areas were necessary. The panel's investigation led to suggestions for correcting the defects, by implementing changes to both doctrine and equipment. A follow-up research program was recommended for OEG's Applied Science Division.

Another subgroup met for three days in June 1961. Among the topics discussed were naval requirements and new technological developments; the offensive capabilities of an attack carrier strike force; the aircraft carrier of the future (an early debate over carrier size); the radiological fallout effects on civilians in the aftermath of a general war; deterrence strategies; potential effects of new aeronautical developments (variable-sweep wings, reduced landing speed, and turbofan engines) on naval aviation; and a theory of limited war. Two other convocations deserve mention because of their valuable work. The first was held at the end of October of the same year and centered on future conventional weapons for naval use against land targets: the delivery of weapons by high-speed planes; the ability of pilots to detect and identify land targets visually; the guidance accuracy of surface-to-surface missiles; and such. The second meeting, held in January 1962, considered the threat of hostile spacecraft to naval operations. Among the fields covered were geodesy and geophysics, weather and radar, data processing, and target recognition.

Overall, OEG managed to make maximum use of the panel's many talented scientists, whose work, often incisive, had a tangible influence on OEG's research program. The panel's effectiveness was aided, no doubt, by its being made privy—at OEG's request—to most of the classified material needed to fuel its investigations. But, despite the knowledge gleaned from these convocations of consultants, it also became apparent that there were limitations to this approach to problem solving. No matter how well intentioned its aims, the panel could not be expected to tackle complex, unfamiliar problems within the few days or weeks typically allotted to it and still achieve the same breadth and depth of understanding attainable by a permanent group like OEG.

In sharp contrast to the reflective mood OEG could afford to indulge in in the closing years of the 1940s, change came to define the 1950s. The 25 June 1950 invasion of South Korea by the North produced political fallout that persisted throughout the decade. The war itself tested the flexibility of OEG by forcing a speedy "remobilization" of the group and a radical redirecting of its analysis. The latter involved a quick shift of emphasis from broad, theoretical issues to the immediate wartime needs of the navy. It also involved a shift from traditional notions of naval warfare (formulated largely in the previous war) to quite new notions that arose from having to fight a limited conflict in which naval operations were conducted primarily in support of objectives on the ground. Unaccustomed to this role, the navy needed all the analytical assistance OEG could provide, both on the scene and at home.

The ripple effect of the conflict, however, went well beyond the war itself. The cold war got much hotter as East and West railed against each other. Once the Soviets had exploded their first thermonuclear device, raising the specter of a nuclear holocaust, the United States had to revise its thinking concerning many critical issues, such as the adequacy of its retaliatory capabilities and the feasibility of an all-out war. As circumstances changed—that is, as consequences of a war loomed frighteningly, and as the cost of military preparedness increased at a staggering rate—the United States needed reliable input into its long-range decision making more than ever.

The navy, for its part, faced both technical and policy questions involving long-term commitments to force requirements. These pressures on the navy soon worked their way through to OEG, prompting the group to think in terms of a much bigger participation in long-range planning. But it was necessary, in the meantime, to prevent this new obligation from intruding into the important yet narrower operational concerns that were the mainstay of the central group. Hence, OEG founded spinoff groups whose charters specified that their reason for being was long-term, or strategic, thinking. By no means, however, did OEG completely distance itself from these kinds of subjects, as evidenced by its "missile gap" study. The work done by OEG and its most successful subgroup, NAVWAG, went to the heart of the challenges faced by the navy during this period. Creation of an Economics Division, furthermore, demonstrated OEG's flexibility in the face of budgetary considerations that had become woven into the fabric of military decision making.

The turbulence that characterized the 1950s and the first year or two of the 1960s helped OEG to grow in two ways. First, the group demonstrated during the Korean War that it could quickly marshal its resources to respond to an emergency—an easily overlooked quality of an operations research group. Moreover, the group demonstrated that it was intellectually flexible enough to broaden the spectrum of its analytical abilities to encompass strategic problems exacerbated by a sudden change in the military balance between the two superpowers and by increasingly contentious Kremlin policies.

Whereas the diverse needs of the navy were what inspired OEG's branching out in the first place, it was the resultant sense of diffuse organization that prompted talk of increased consolidation. The navy's perception of being served by a somewhat splintered advisory body was heightened by new Defense Department initiatives pressing for added accountability from the services in deciding on force levels. In sum, cost-effectiveness had become the watchword of the day. The effect of all this on OEG was profound.

# 4

# OEG and the New Center for Naval Analyses

## Establishment of CNA

Until the 1960s, budgetary constraints and defense needs were often reconciled without the benefit of cost-effectiveness analyses. It was not so much a studious attempt to avoid considering cost along with effectiveness, as a case of benign neglect. Alain C. Enthoven, deputy assistant secretary of defense for systems analysis, described the Eisenhower administration's approach to defense management as follows:

> It had several important defects, perhaps the most important of which was the almost complete separation between planning and decision making on weapon systems and forces, on the one hand, and budgeting on the other .... Generally speaking, costs were not introduced systematically, either to test the feasibility of the whole program or for purposes of evaluating the efficiency of the allocation.[1]

The swearing in of Robert S. McNamara on 21 January 1961 as secretary of defense marked the beginning of a new philosophy of defense management. As Secretary McNamara later reflected: " . . . my instructions from both President [John F.] Kennedy and President [Lyndon B.] Johnson were simple: to determine and provide what we needed to safeguard our security without arbitrary budget limits, *but to do so as economically as possible*" [emphasis added].[2]

Within this framework, McNamara designed a new method—his planning-programming-budgeting system—to help him wade through the thicket of competing claims made by the three services. The new method helped to unify the many considerations that had a bearing on the Defense Department's decisions regarding national security. It took account of alternative weapons systems, force requirements, and strategic issues (both political and military), then related the cost of these to the budget—all to reach sound decisions on a balanced and affordable military structure. According to Charles J. Hitch, assistant secretary of defense (comptroller) and main architect of the planning-programming-budgeting system, this was a "dynamic process," subject to change as a result of new assumptions, information, and alternatives.

McNamara recognized that this heavy responsibility of balancing programs and costs could no longer be done on the basis of intuition or past experience. The seemingly desirable choices and the complexity of the subject were too great for such a haphazard approach. But the new planning system "would be a shell without substance . . . were it not backed by the full range of analytic support which operations research . . . can bring to bear on national security problems."[3] As explained by Hitch: "Our objective, therefore, has been to build an integrated and mutually supporting structure of systems analysis throughout the Defense establishment [both an in-house and outside capability] with the broadest kind of exchange of information and techniques at and between various levels. This arrangement provides the checks and balances so essential to minimizing parochial viewpoints and organizational bias."[4]

The infrastructure was already in place for providing the analytical support needed to back up McNamara's new planning system. OEG, of course, was a major element of the infrastructure, as were the air force's Rand Corporation, the army's Research Analysis Corporation (RAC), and the Defense Department's Institute for Defense Analyses (IDA).

This new emphasis on cost as well as on effectiveness, plus McNamara's general regard for operations analysis as the linchpin in any well-conceived defense program, prompted the navy to begin evaluating its own analytical support. It seemed to the navy that its support was far too diffuse. In Washington, for example, the navy had OEG, along with its adjunct group, NAVWAG, and its Economics Division; and in Cambridge, Massachusetts, were the Institute of Naval Studies (INS) and the Applied Science Division (ASD). The secretary of the navy, Fred Korth, therefore asked the Naval Research Advisory Committee for advice on this matter. The committee's recommendation was no surprise: the navy should make every effort to pull together these disparate advisory groups and place them under one management.

The urge to tidy up the tie lines among these research activities had been felt by OEG long before the committee's recommendation to the navy. In September 1960, Dr. Steinhardt, OEG's director, sent a memorandum to the Vice CNO, the Deputy CNO for Fleet Operations and Readiness (Op-03), and the Director of the Long-Range Objectives Group (Op-93), proposing changes to OEG's own organization. The aim, above all else, was to simplify the nomenclature of the components of OEG, to reflect more clearly the relationship between OEG, NAVWAG, and ASD (the latter, at the time, had not yet been reassigned to assist INS). The solution proposed was to use "Operations Evaluation Group (OEG)" only when referring to the overall management—embodied, in effect, by just one person, Steinhardt. The scientific staff that made up the old OEG would then constitute the new Operations Evaluation Division (OED), under the directorship of Joseph H. Engel (Figure 4-1). The second component of OEG would be the Naval Warfare Analysis Division (NAVWAD), consisting of the same scientists as NAVWAG and with the same mission, but with a division rather than group status. Douglas L. Brooks was to be NAVWAD's director. The third and last component would be ASD, headed by Hugh J. Miser. (The Economics Division would not become the fourth component for another year.)

According to the proposal, Dr. Steinhardt, as director of OEG, would be accountable to an MIT faculty committee for the management and coordination of all three divisions.[5] Op-93, however, expressed the opinion that "...the self-designation of this common director as Director OEG and the common superior to all three 'divisional directors' places him, in

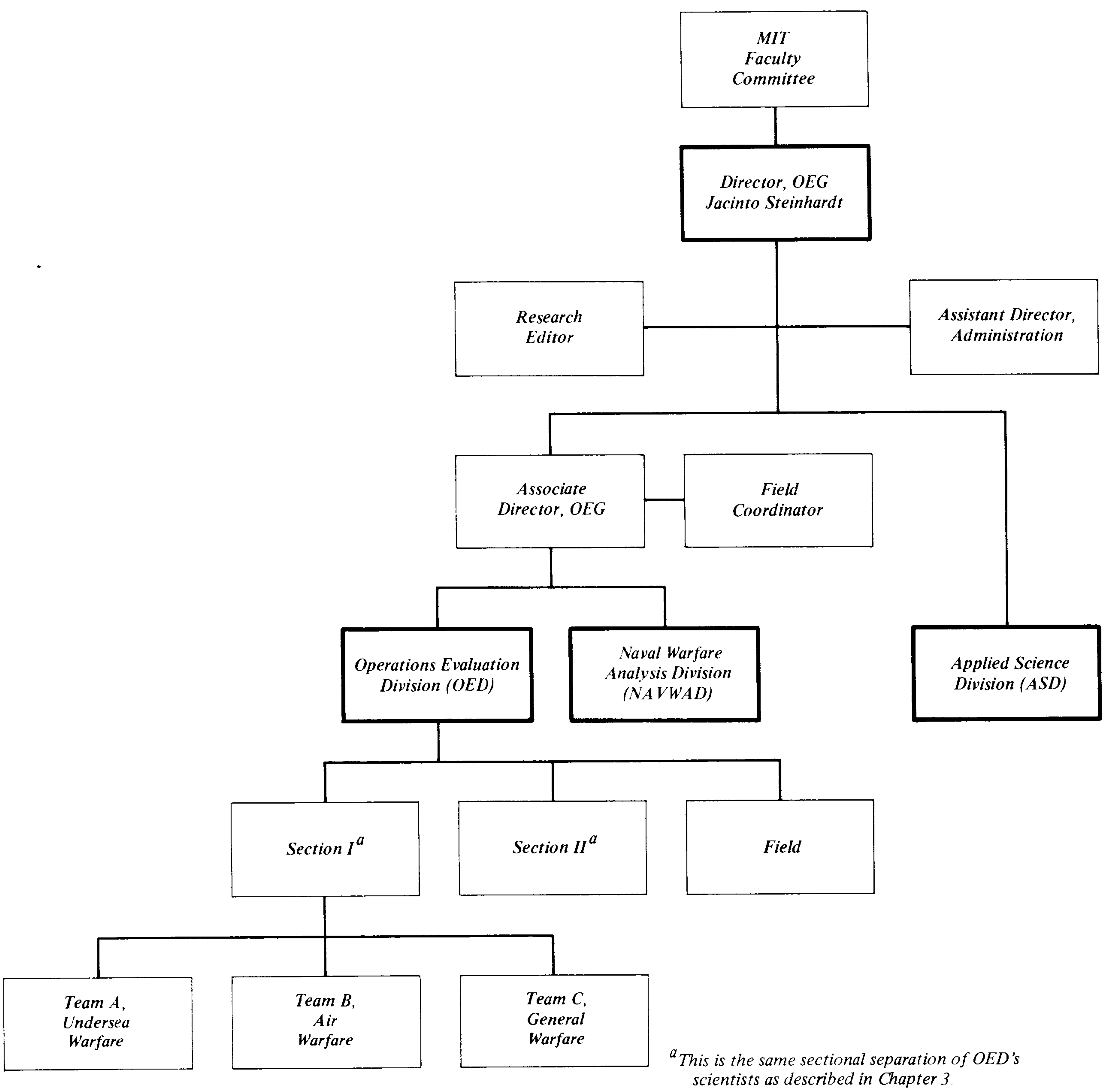



Figure 4-1. Reorganization of OEG into Divisional Structure

effect, at the organizational level of Vice CNO." This, he concluded, would be unacceptable. An additional concern was that the proposed arrangement would cause the OEG director's main line of attachment to shift from the navy to MIT, and that he would henceforth be less accessible to the navy.

However, a key qualification in Steinhardt's September 1960 memorandum—a statement that should have made the entire imbroglio unnecessary—apparently got lost in his detailed account of the proposed reorganization. He stated, quite explicitly, that "it is not intended that the names of OEG and NAVWAG be changed within the Navy context." That is, the new divisional structure was just for ease of administration, use of which would be confined to OEG and MIT. Outside of OEG-MIT circles, and most especially as far as the navy was concerned, the long-established nomenclature of OEG and NAVWAG—and not OED and NAVWAD—would remain in effect. Indeed, publications describing OEG at the time either did not mention the divisional structure at all or only alluded to it in some parenthetical way. So, it was within these fairly severe limitations that the reorganization was eventually implemented.

The main point is that OEG's attempt to clean up the nomenclature was really a move to do something about the awkward relationship that existed among the various groups then doing work for the navy. But OEG, alone, could go only so far, especially since INS remained apart from OEG and thus could be integrated only through navy action. A move to bring this about began in earnest in May 1961, when the president of the Institute for Defense Analyses (IDA), Garrison Norton, proposed to the navy that an organization be formed to assume the responsibilities as prime contractor for the administration of OEG, NAVWAG, ASD, and INS. (You may recall from the last chapter that IDA already held the contract for INS.) The proposal, in fact, was a synthesis of ideas contributed by several individuals, including the assistant secretary of the navy for research and development, James H. Wakelin, and the president and vice president of MIT. Two months later, in July, Rear Admiral Hooper, director of INS, fueled the drive for change by similarly recommending to the Vice CNO that a single contractor be found in order to coordinate the navy's study effort.[6]

Shortly thereafter, exploratory talks got under way between the navy and the Smithsonian Institution, Johns Hopkins University's Applied Physics Laboratory (APL), the University of Chicago, the army's newly established Research Analysis Corporation (RAC), and the Franklin Institute of Philadelphia. As described by the MIT President's report of 1962, MIT wholeheartedly "joined with the Navy in examining the possibility of consolidating its operations research efforts, including Naval plans and policy"; however, the institute declined an invitation to assume the management of the proposed new enterprise, feeling that to do otherwise would mean going too far beyond the institute's "proper province." IDA took itself out of contention, too, despite its evident suitability.

Negotiations with the Smithsonian Institution proceeded smoothly for about three months, with opening inquiries conducted by the Chief of Naval Research, Rear Admiral L. D. Coates. In October 1961, it looked as if only a few final details needed to be ironed out, as the director of the Long-Range Objectives Group (Op-93), Rear Admiral Thomas H. Moorer, met with the secretary of the Smithsonian Institution. Selection of the institution looked particularly attractive at that time because of President Kennedy's recent establishment of the Bell Committee. The committee was to investigate what had been characterized as the "extensive" use of contracts with private institutions to provide for the operation and management of research and development programs, and for analytical studies and advisory services. In light of this investigation, the composition of the Smithsonian Institution's Board of Regents—consisting of members of both houses of Congress, Vice President Lyndon B. Johnson, Chief Justice Earl Warren, and some prominent businessmen—was expected to forestall adverse criticism. But whatever gains had been made during the negotiations quickly unraveled when the Chief Justice became the lone dissenter in an otherwise enthusiastic and unanimous endorsement of the proposal by the other regents. Consideration of the Smithsonian Institution thus ceased.

Early in the course of these negotiations, Steinhardt had voiced his preference for APL over the Smithsonian. Moreover, in a 10 August memorandum to Assistant Secretary of the Navy Wakelin, Steinhardt argued for the continued separation of OEG/NAVWAG from INS. Influenced by Steinhardt's reasoning, APL indicated its disinterest in an overall management role but did express interest in the management of just OEG/NAVWAG. The latter, however, was simply no longer an option.

Hence, in November 1961, with several of the early prospects out of the running, Assistant Secretary Wakelin asked the Chief of Naval Research to take over the search for a suitable sponsor to administer the proposed new organization. From this point on, OpNav's participation in the search became minimal. Wakelin, meanwhile, remained actively involved in the quest for someone to direct the new organization, believing that the success of such an enterprise would depend on the person selected to run it. Over the next couple of months, Wakelin interviewed and rejected several candidates. Finally, in January 1962, he and Rear Admiral Moorer (Op-93) agreed that Frank B. Bothwell—since 1958, director of the University of Chicago's Laboratory of Applied Sciences—was eminently qualified to head the new organization, and negotiations toward his employment immediately got under way.

In the meantime, Rear Admiral Coates had pared down the list of possible management organizations, until only the Franklin Institute seemed both suitable and available. A December 1961 visit by Wakelin to Wynn L. LePage, president of Franklin, helped allay some of the misgivings the Franklin Institute had about managing the navy's operations analysis functions. Serious negotiations were begun shortly thereafter, involving Francis L. Jackson for the Franklin Institute, and Rear Admiral Coates and Wakelin's office for the navy. Final agreement on the remaining details for Franklin's participation was reached in a meeting between Coates and LePage in late February 1962, and a contract (Nonr-3732(00)) was signed on 21 March. The contract, for the amount of $2.4 million, was backdated to 2 January 1962, to cover expenses incurred by Franklin during the negotiations with the navy and during its preliminary search for a chief scientist to head the organization. Franklin was not expected to assume its management role, however, until 1 July.

The Franklin Institute was founded in Philadelphia in 1824 for the purpose—to quote the original charter—of "promoting the mechanic arts." Bearing the name of Benjamin Franklin, the institute was formed as a scientific and educational society, whose members conducted scientific research either at their own expense or through the financial goodwill of supporters who wished to further the progress of industry. From the institute's founding until 1924, these members undertook many scientific investigations, a large fraction of which were self-initiated.

For an entire century, the Franklin Institute's reliance on volunteerism among member scientists remained virtually unchanged. Then, in 1918, a prominent industrialist by the name of Henry W. Bartol willed one million dollars to the institute, to help establish a laboratory "for the conduct of researches in the physical sciences and for the investigation of problems of a scientific nature arising in the industries." The bequest enabled the institute to fulfill a long-held desire to form a permanent staff of researchers, through creation, in 1924, of the Bartol Research Foundation. At the time Franklin accepted the navy contract, the foundation's staff, headquartered on the campus of Swarthmore College, was involved almost entirely in pure research, conducting studies in nuclear physics, cosmic radiation, astrophysics, and other such fields.

With the outbreak of World War II, the urgent need in the country for military research meant that the Franklin Institute had to realign its priorities. Members were soon engaged in work prompted by requests from the Army Ordnance Corps (AOC) and the Office of Scientific Research and Development (OSRD)—with whom, you may recall, ASWORG/ORG was associated. Its quickly expanded, largely hardware-oriented staff helped to improve weapons and other military equipment, such as airborne fire control and artillery design. Then, as the war wound down, the institute moved to convert this newly developed research capability into a permanent laboratory. Using the wartime group as a nucleus, the institute established, in 1946, the Franklin Institute Research Laboratories, or FIRL.

FIRL continued its war work in chemistry, physics, and electrical and mechanical engineering. But other areas of research were added in the 1950s as newly hired specialists brought with them an understanding of, for example, solid state physics and metallurgy. During that same decade, the laboratories' interests broadened to encompass operations analysis, in addition to many other disciplines, such as nuclear and aerospace engineering.

With the signing of the contract on 21 March 1962, the Franklin Institute—thereby agreeing to manage a consortium of the navy's analytical advisory groups—added yet another dimension to its already diverse responsibilities. The contract, in conjunction with a directive from the secretary of the navy,[7] officially established the Center for Naval Analyses (CNA)[8] as "an overall agency charged with the management and support of the [navy's] major study groups." This meant that the Franklin Institute would assume the responsibilities of the two main former contractors, to wit, MIT (holder of the contract for OEG and NAVWAG) and IDA (holder of the contract for INS). As outlined by the navy secretary's directive, "the basic function of CNA will be to manage and to direct the conduct of studies . . . of problems in naval warfare and manpower in the broadest sense. The studies and analyses on operational and logistical aspects of naval warfare, present and future, shall include but not be limited" to the following areas:

(1) Current fleet combat readiness
(2) Naval application of new technological developments
(3) Development and procurement programs
(4) Long-range requirements for equipment, materiel, personnel, and supporting services
(5) Long-range aspects of strategic planning, and the effects of changes in science and technology.

The director of the Long-Range Objectives Group (Op-93) was designated the scientific officer for CNA, to whom CNA's chief scientist was to report with respect to planning, coordination, and analyses (Figure 4-2).

Also described by the directive were the groups absorbed by the new CNA. OEG and NAVWAG were to continue providing the same kind of analytical support as they had always done. The description of OEG's role, for instance, was identical to that in its 1945 charter. Also, the director of OEG was to continue being responsive primarily to the Deputy CNO for Fleet Operations and Readiness (Op-03), even though CNA as a whole was placed under Op-93. NAVWAG's role was likewise almost identical to its original charter, with two exceptions: first, the group was to limit its projections to the mid-range, that is, to within the coming decade; second,

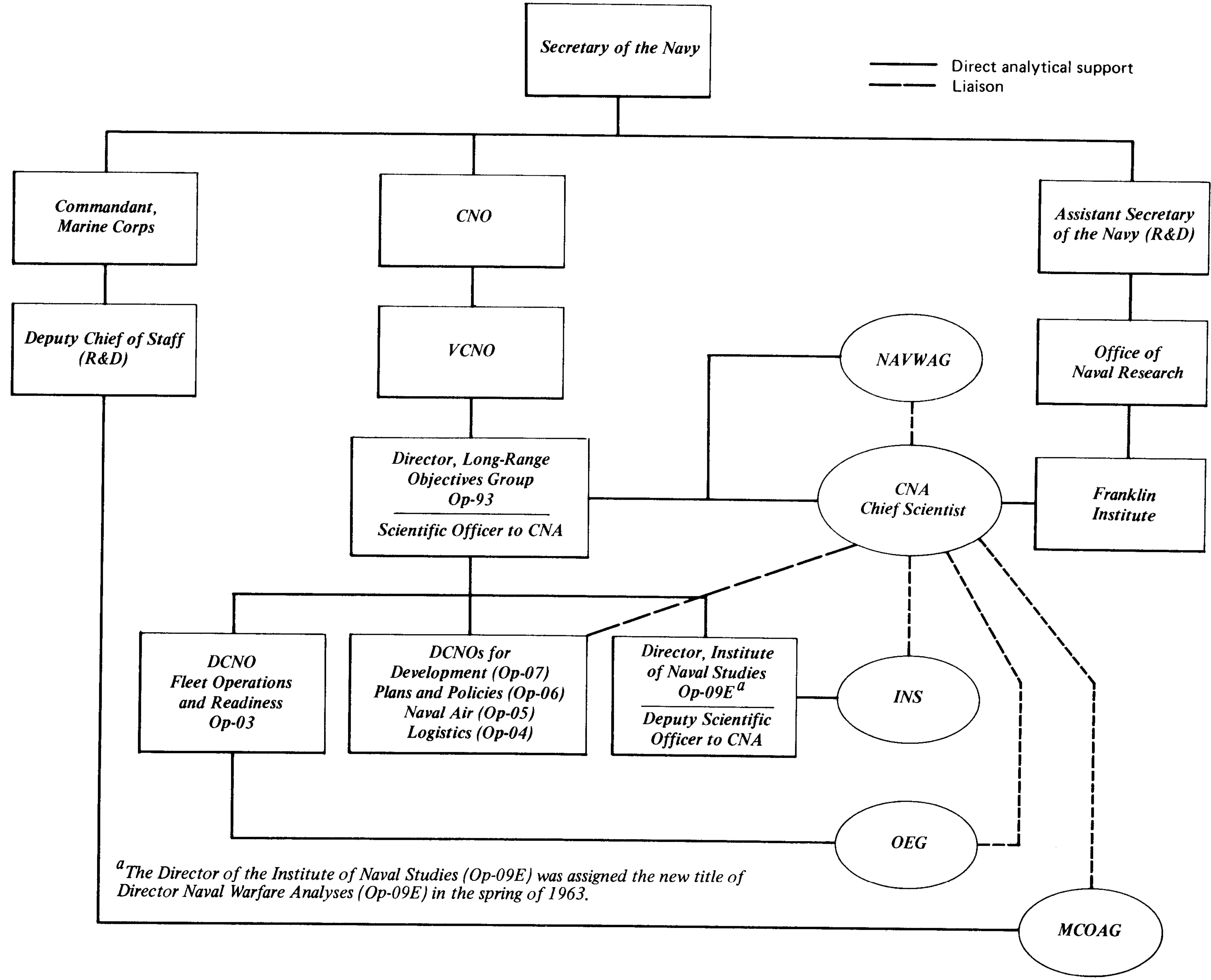



Figure 4-2. CNA Tie Lines to the Navy and Marine Corps

it was to conduct cost-effectiveness studies, primarily of alternative force mixes. Furthermore, NAVWAG was to stay as a component of OEG, at least for the time being, rather than split off as a separate group. Additionally, an entirely new component of OEG was formed, called the Marine Corps Operations Analysis Group (MCOAG). MCOAG was to consist initially of analysts from OEG—a total of four during 1962—who were already providing services for the commandant of the Marine Corps. OEG's Applied Science Division (ASD), which in late 1961 had been directed by the navy to support INS, was officially severed from OEG and made a formal part of INS.

INS became the other main group, besides OEG, making up the new CNA. Its studies were to address long-range problems in the following general areas:

(1) National security and national objectives of the navy
(2) The nature of warfare and future threats to U.S. naval seapower
(3) The international environment and situations involving the possible use of naval forces
(4) The implications and effects of advances in science and technology on seapower
(5) Resources and other economic factors affecting the navy
(6) Forecasts of likely enemy capabilities and the use of these capabilities in naval warfare
(7) Naval functions, postures, and capabilities to support future requirements
(8) The means of attaining required naval capabilities.

In other words, INS's role remained largely unaltered, too.

The director of research for INS, a CNA-appointed civilian scientist, reported the group's study results to the director of INS (Op-09E), a rear admiral. Because of the confusion caused by the similarity of these two titles, CNA's director of research for INS was changed in May 1963 to simply director of INS (to conform with OEG's arrangement), and the former title of director of INS (Op-09E) was changed to director of naval warfare analyses (Op-09E). Also, even though the rationale for establishing CNA was to consolidate the management of the navy's study groups, INS was not immediately united with OEG in Washington; rather, it stayed divided between Cambridge and the Naval War College in Newport, Rhode Island, for another four years.

### A Period of Turbulence

While the navy and Franklin Institute were negotiating the contract for the administration of CNA—and during the first few months that the contract was actually in effect—related events were to prove disruptive to just about everyone involved. One such event began with an exchange of letters from mid-February to early March 1962, between officials at Franklin and the assistant secretary of the navy for research and development, James H. Wakelin. The letters from Franklin explored the possibility of the institute hiring a person who had been a special assistant to Wakelin since July 1961, if a Navy-Franklin contract were consummated. The problem this posed, however, was that the assistant had allegedly played a role—to how great an extent was certainly unclear at the time—in representing the navy during the negotiations with Franklin for management of CNA.

So, in response to the Franklin Institute's inquiries, Wakelin had the Judge Advocate General (JAG) and the General Council investigate the conflict-of-interest implications of such a move. Their ruling suggested that the hiring of the special assistant would not violate the letter of the conflict-of-interest laws, as then written. These laws, however, had not been significantly modified since the Civil War. Indeed, five of the statutes on the books had been enacted before 1873. Moreover, these statutes did not really address this type of situation; rather, they had grown out of army procurement improprieties, and mostly sought to prevent a government official from directing government business to a company in which he had a financial stake. Still, since the initial ruling—though by no means amounting to the navy's imprimatur on the matter—indicated a lack of any illegality in the proposed move, the former assistant to Wakelin was hired by the Franklin Institute on 19 March 1962, "to assist with the administrative and liaison task with CNA."

Immediately thereafter, Wakelin informed the institute—on the advice of the director of defense research and engineering (DDR&E)—that the hiring was, nevertheless, a possible violation of the spirit of the law and would certainly be a violation of the letter of a proposed amendment to the law. Even though a legislative logjam in Congress promised to delay passage of the proposed amendment, the Franklin Institute, wishing to avoid questions of impropriety, rescinded the employment of Wakelin's special assistant on 31 March. The latter, in a similar gesture, returned some advance pay and expense money.

Almost five months later, on 17 August 1962, the special assistant to Wakelin again resigned, to serve initially as a consultant to Franklin. Then, on 1 September, he became a full-time employee of Franklin as a technical representative and as assistant to the director of the institute, in which capacity he was to head the Washington office of the Franklin Institute Laboratories. No more than ten days had passed, however, before the press looked into the incident. On 10 September, Baltimore's *The Sun* noted: "A former high Navy official has set up shop here [Washington, D.C.] to represent a defense contractor with whom this same official negotiated a big contract, for the Navy, only last spring." The article added: "The Navy's legal department has ruled that this sudden switch of loyalties does not violate the present conflict-of-interest laws . . . . But when the proposed job-switch became known last spring, the Navy [on 3 April] insisted that [the special assistant] would not take the private job." However, Wakelin, from whose office this assurance had been made, said he was unaware of his assistant's subsequent employment with Franklin until *The Sun* queried him about it the evening before the story was released.

Disturbed by the questions arising from these events, Secretary of the Navy Fred Korth ordered a probe—on 10 September, the very same day the newspaper report appeared. In his statement, Secretary Korth noted that "Wakelin [had] stated to the officers of the institute and [the special assistant] that while the Navy did not regard the proposed employment as in violation of existing law, it would, nevertheless, be contrary to the policies of the Defense Department." The next day, the Franklin Institute acknowledged that discussions with navy officials had gotten under way. On 17 September, the former assistant was given a leave-of-absence with pay. Two days later, Senator John C. Stennis (D-Miss.), chairman of the Senate Preparedness Investigating Subcommittee, announced that his subcommittee's staff would make a full inquiry into the matter. The course of the subcommittee's inquiry was expected to hinge, however, on the findings of the navy's investigation, a report of which was handed to Senator Stennis in early October.

Secretary Korth's report to Stennis pointed out that although Wakelin's special assistant had indeed acted for the navy in negotiations with the Franklin Institute during a period when Franklin was seriously considering employing him, no conflict-of-interest laws had actually been violated. However, the navy's investigators concluded that the special assistant's "negotiations with the Franklin Institute leading to his present employment did violate Paragraph IV of Department of Defense Directive 5500.7, which disqualifies Department of Defense personnel from representing the department in dealings of any kind with any business entity with which they have arranged or are negotiating for subsequent employment."

Coincidentally, later that month, on 24 October, President Kennedy signed a law that both tightened and broadened the scope of existing conflict-of-interest statutes. The major provision—and the one that would have had a bearing on this episode—permanently barred former full- or part-time federal employees from representing private interests before federal agencies on matters in which they participated "personally and substantially" before leaving government service. The law also disqualified former employees for one year from handling private business before an agency in matters for which they had higher responsibility but no personal involvement.

Finally, as to the contract for Franklin's management of CNA, the navy report declared that "the provisions included in this contract are appropriate, that the financial arrangements with the Franklin Institute are fair and reasonable, and this is sound procurement." Senator Stennis added that as further assurance, he had been advised by Korth that the administration of the contract would be kept "under close scrutiny to ensure that its continuation is at all times in the best interests of the Government."

For all practical purposes, the episode ended on 14 November, when the Franklin Institute announced that the special assistant had resigned on 2 November. As explained by Franklin: "This step was taken in the mutual realization that [his] value to the Institute had been impaired by the adverse publicity which he received when he joined the staff of the Franklin Institute Laboratories." Senator Stennis's subcommittee subsequently chose not to hold public hearings in the case, apparently satisfied with the thoroughness of the navy's report on the incident, the additional evidence gathered by the subcommittee's own investigators, and the favorable results of a General Accounting Office (GAO) review of the contract.

One other factor that contributed to a clearing of the air was a 29 October 1962 letter from Secretary Korth to Senator Stennis, detailing major management-level changes he had implemented in the Franklin-CNA relationship. The reasons for the changes, however, went beyond the controversy just described. In fact, the changes stemmed from basic philosophical differences between the navy and the Franklin Institute regarding how CNA's study program should be run. Fortunately, these differences of opinion only minimally affected the operations of OEG and NAVWAG—these groups had historical momentum on their side, which tended to insulate them to a large degree. INS, however, fared less well.

The situation began earlier that year, shortly after Frank B. Bothwell had been named chief scientist of CNA, at the urging of Wakelin and Rear Admiral Moorer (Op-93). The director of the Franklin Institute Laboratories (FIL)—the division of Franklin to which CNA was attached—began to disagree with Bothwell over the conduct of CNA's research program. The issue essentially came down to this: Was CNA an integral part of the navy establishment, and just happened to be managed by the Franklin Institute? Or, was CNA an integral part of Franklin, and just happened to be advising the navy? The question, in other words, was one of influence and of degrees of loyalty. The result was a jockeying for control that worsened as the summer wore on.

Then, on 24 August, the Franklin Institute acted to strengthen the line of authority between it and CNA management. The institute laid out for Bothwell six requirements: to hold monthly staff meetings in Washington for representatives of Franklin; to forward a copy of all scientific reports to FIL; to obtain the approval of FIL's director on hiring personnel or on granting pay increases in salary brackets above a specified level; to obtain the approval of FIL's director before granting academic leave to CNA staff members; to report to FIL's director on all visits by Bothwell and the directors of OEG/NAVWAG and INS to outside civilian agencies; and, finally, to report to FIL's director on visits to CNA by personnel from civilian agencies.

Because of the seemingly irreconcilable differences at the topmost levels of CNA and Franklin, and the maneuvering for control over the research program, the Vice CNO, Admiral Claude V. Ricketts, suggested to Wakelin on 20 September 1962 that CNA be removed from the Franklin Institute Laboratories. He also suggested that CNA's chief scientist, Frank Bothwell, be given virtual autonomy. Wakelin concurred with Ricketts's suggestions—he, too, viewed the present situation as untenable—but recommended that any changes in the CNA-Franklin relationship await the outcome of an investigation by Secretary of the Navy Fred Korth.

Because INS was the component of CNA most affected by these goings-on, its members took the initiative in trying to bring about a solution. On 25 September, INS submitted a series of suggestions to Rear Admiral Edward E. Colestock, special assistant to the president of the Naval War College, proposing how the problem might be handled. Colestock immediately transmitted to Rear Admiral Moorer his views on deficiencies in the contractual arrangements with Franklin. Then, at Colestock's request, Bothwell's administrative assistant, Warren E. Thompson, set forth in a memorandum the steps required to form a new nonprofit organization to manage CNA. A month later, on 21 October, the assistant director of INS laid out for Admiral Ricketts the opinions of CNA's senior staff concerning the causes of the tension that prevailed in their relationship with FIL.

In the meantime, some fifteen of the twenty-six scientists making up INS's Applied Science Division (ASD) chose to resign. ASD's staff had been told in early June of their impending transfer to the management of the Franklin Institute and had been informed they would have until 6 September to decide on leaving or staying. However, according to a 22 August report to the navy from ASD's director, Hugh J. Miser, Franklin had agreed by mid-summer to continue only three of the twenty-eight projects actively being worked on by ASD. In the view of most of the scientists, the slow pace with which the institute was reviewing the projects boded ill for their prospects, so they elected to leave—some right away, others a little later. Unfortunately, many of those who resigned were among ASD's most experienced people.

Although OEG remained largely on the sidelines during this turbulent period, group members were understandably disturbed. On 21 September, OEG's director felt obliged, for the sake of morale, to issue a memorandum to his staff clarifying events:

> We [Frank Bothwell and Director, OEG] informed Mr. Wakelin of the concern felt by many of the OEG staff as a result of this publicity [in *The Sun, The Philadelphia Inquirer,* and elsewhere], and emphasized the importance to the staff of a management arrangement that would preclude the recurrence of any future actions by the management [the Franklin Institute] which might reflect unfavorably on OEG. Mr. Wakelin has assured Dr. Bothwell and me that the requisite corrective action can and will be taken. The investigation ordered by Secretary Korth of the press allegations will be thorough and unbiased. We thus have sincere affirmation by the highest levels in the Navy Department that CNA and its OEG component will be accorded a meaningful and efficient management. Quite probably the Secretary's investigation will result in changes in the administration that will permit CNA to continue to discharge its mission effectively and efficiently for the Navy. Furthermore, it will be made publicly clear that CNA itself was in no way partner to any of the alleged questionable actions reported by the press.

These "changes in the administration" of CNA were indeed forthcoming, which returns us to the 29 October 1962 letter from Secretary Korth to Senator Stennis. In the letter, Korth explained two management-level changes designed to heal the wounds. The first, which had to do with CNA's line of attachment to Franklin, resulted from a meeting on 22 and 23 October between Secretary Korth, Assistant Secretary Wakelin, Admirals Ricketts and J. B. Colwell (Colwell had relieved Moorer as Op-93 a month before), and the president of the Franklin Institute, Dr. Wynn L. LePage. In that meeting, LePage agreed to assume the management of CNA and to take on the title of CNA director. LePage was to appoint a deputy–bearing the title of CNA executive director[9] –to help handle administrative matters. The appointment was designed, in part, to free Bothwell from such matters, so that he could concentrate on overseeing the analyses under way at CNA. The Franklin Institute Laboratories (FIL) had thus been removed from the CNA picture. The Executive Committee of the Board of Managers of Franklin approved the unusual arrangement on 24 October, and a public announcement was made on the 30th. Even on its own merits, the strained relationship between FIL and CNA warranted some such intervention by the navy. But even more significantly, there were international problems, such as the revelations about Soviet offensive missiles in Cuba, that demanded the navy's and CNA's undivided attention. The problems were potentially so serious the navy could not afford continued unsettlement at CNA, its main analytical arm.

The second change implemented by Korth was creation of a CNA Policy Council. Formally set up on 13 December,[10] the Policy Council consisted of eight members from the navy, Marine Corps, and Franklin Institute.[11] Its purpose was to "review, on a continuing basis, such matters as CNA study programs, budget, operating procedures, etc., and to provide policy guidance to CNA in these areas." The navy, by its greater representation on the council and by its holding of the council's chairmanship, settled any doubt as to the navy's (as opposed to the institute's) prerogatives in deciding on the proper course for CNA's research program.

These two changes—the appointment of LePage as CNA director and creation of a CNA Policy Council—subsequently contributed to an easing of both the acrimony and confusion that had characterized the opening months of the new contract. As summed up by Admiral Colwell in a report to Op-090, after the new arrangements had been in effect for a year: "At present, the Navy-CNA situation appears to be proceeding in a satisfactory manner. Dr. LePage and Dr. Bothwell appear to be functioning in an atmosphere of mutual trust and the agreements made . . . in October 1962 are being honored." He added that "certain officials of the Franklin Institute have expressed the opinion that the . . . present atmosphere [is one] of amity."

### Twentieth Anniversary Conference on Operations Research

Since 1942, when OEG came into being, the nation had fought two wars, the Soviets had become a serious military threat, and a nuclear standoff had made the East-West ideological struggle precarious. As the world situation changed, OEG's role changed, too. Hence, to commemorate OEG's twenty years of support to the navy, the Office of Naval Research (ONR) decided to sponsor an international conference on operations research, to be held in Washington on the 14th through 16th of May 1962.

Although the conference was planned primarily to honor OEG's anniversary—Secretary of Defense McNamara, for instance, had sent Dr. Steinhardt a congratulatory message—it had two other important purposes. One was to survey the past accomplishments, present activities, and future plans of military operations research groups in the United States and abroad. The second purpose was to hear and discuss papers on the following: new techniques, unsolved problems, and new fields of application in operations research; educational opportunities in the field; and current ideas regarding the organization and direction of military operations research groups. These broad topics were taken up in the course of six half-day sessions, during which representatives from government, industry, and the academic world—from home and abroad—took part.

The first session, chaired by Rear Admiral Thomas H. Moorer, director of the Long-Range Objectives Group (Op-93), centered on operations research for the U.S. Navy. An overview of OEG's World War II beginnings was provided by Admiral Jerauld Wright, who as Op-34 (Strike Warfare), had in 1947 advocated enlarging the then-new peacetime group (see Chapter 2). To complete the historical picture, OEG's associate director, Joseph H. Engel, described how the group had evolved in the years since World War II.

Then, the "user's" view of naval operations research was presented. First, Rear Admiral C. E. Weakley, Assistant CNO for Development, offered a personal account of the early benefits of operations research. One example he gave dated back to 1943, when Steinhardt, then a member of ASWORG assigned to the staff of Commander Fourth Fleet in Recife, Brazil, devised search plans for protecting convoys and for preventing German blockade runners from transiting the South Atlantic. Weakley noted that at the time he was engaged in convoy escort work and thus had an opportunity to learn firsthand of the effectiveness of operations research methods.

The second user's view was given by Rear Admiral L. D. Coates, Chief of Naval Research. Coates's talk centered on the formation of ONR's Naval Analysis Group, which had proved to be the answer to ONR's desire for an in-house analytical capability. (The Operations Research Group, set up in June 1953 for the same purpose, had failed to gel into what ONR and OEG had envisioned.) A major portion of the group's work was concerned with the implications of new technology on naval systems and research planning, with an eye on long-range developments. Specifically, ONR's Naval Analysis Group had five functions: one, to conduct studies of advanced naval systems; two, to assess the possible uses of scientific and technological advances in future naval systems; three, to apply both operations and systems analysis techniques in guiding ONR's research planning; four, to conduct basic research into the development of new methodologies; and, five, to promote, via contracts with outside organizations, the development of new technology that could be used to improve naval systems.

The assistant secretary of defense and deputy director for defense research and engineering, John H. Rubel, led the second session, on the general use of military operations research in the United States. In this session, talks were given by representatives from DoD's Weapons Systems Evaluation Group (WSEG), the army's Research Analysis Corporation (RAC), and the air force's Operations Analysis Office and Rand Corporation. Mostly the speakers outlined the history of these OEG counterparts, as well as the kinds of analysis engaged in by them.

Session three dealt with military operations research abroad. In this session, the director of Britain's Operational Science and Research, Eric Holmberg, described the operations research work being carried out by the Admiralty, the War Office, and the Air Ministry. His main observation was that despite the early contributions by the British to the formalizing of operations research, especially by such scientists as Professor P. M. S.

Blackett, clearly most of the theoretical work by this time had shifted across the Atlantic to the United States. Holmberg explained that the reason, quite simply, was one of resources. Britain's commitment to operations research was much smaller, even in relative terms, than that of the United States. British staffs were too small to devote time to the development or refinement of methods of analysis; instead, they had to respond to the press of day-to-day needs.

The topic of military operations research abroad concluded with Professor Bernard O. Koopman providing a more sanguine examination of the status of operations research in the NATO alliance. He discussed briefly NATO's SHAPE Air Defense Technical Center (SADTC) at The Hague and the antisubmarine warfare group under the Supreme Allied Commander, Atlantic (SACLANT), at La Spezia, Italy. Also, Koopman sketched out the various programs being implemented by NATO's Advisory Panel on Operational Research, on which Professor Philip Morse was serving as chairman. These programs were aimed at promoting the use of operations research among alliance members, through education, special lectures, and visits by experienced practitioners.

The next two sessions, containing a potpourri of subjects, could not be titled by any main theme. Rather, they bore the rather nondescript titles of "Special Topics I" and "Special Topics II." The first of these was chaired by the vice president of MIT, Major General James McCormack, USAF (Ret.). The second was chaired by Frank E. Bothwell, at the time still director of the University of Chicago's Laboratory of Applied Sciences but soon to be CNA's chief scientist.

One of the speakers during this series of special topics was Charles J. Hitch, assistant secretary of defense (comptroller) and, as described earlier, a key contributor to Secretary McNamara's program of cost accountability. Hitch used the opportunity of the conference to expound on the reasons—and hopes—for the Defense Department's new financial management system, and to explain its reliance on good and plentiful analysis. By way of background, he depicted how DoD's dual roles of financial management and military planning had traditionally been handled in virtual isolation from one another. Consequently, each role had been subject to what in many respects were incompatible methods of handling. They were on, according to Hitch, "completely different wave lengths." For instance, budgeting was handled in terms of "functional categories"—procurement, military personnel, operation and maintenance, and so forth—and projected only one year ahead. In contrast, planning was handled in terms of military forces and major weapons systems, projected five to ten years ahead. As explained further by Hitch:

> The "functional" arrangement of the budget, while still necessary for the management of certain classes of Defense activities, does not

> focus on the key decision-making area that is of principal concern to top management in the Defense Department, namely, the sound choice of major weapon systems in relation to military tasks and missions. It does not produce the data in the form needed to relate directly the cost of weapon systems to their military effectiveness; and because its time horizon is generally limited to only one year, it does not disclose the full time-phased costs of proposed programs.[12]

It was necessary, therefore, to restructure DoD's financial management system on the basis of six goals: to link military planning and budgeting; to group forces and weapons systems according to their main missions; to tie costs directly to the forces and weapons systems, so that the implications of choices may be accurately predicted; to project forces, programs, and costs over a five-year period, so that future as well as present implications of choices may be understood; to break down costs into the three categories of research and development, procurement, and annual operating[13]; and, finally, to develop a means for translating programs into budget categories and vice versa. The result of this effort was the planning-programming-budgeting system. According to Hitch, Secretary McNamara's new management approach "facilitated the application of operations research or systems analysis to defense problems." In fact, he added, "the history of the past year demonstrates that operations research has, to a substantial degree, taken advantage of the opportunities." As a parting endorsement, the assistant secretary promised that the Office of the Secretary of Defense would "do everything possible to increase your [OEG's] opportunities for effective contribution in the future."

Alain C. Enthoven, who as director of systems analysis in Hitch's office was also closely associated with the planning-programming-budgeting system, talked on a different subject that had a bearing on OEG's NAVWAG. The subject was the use of operations analysis at the national policy level as opposed to its more traditional and familiar role.

At the national level, defense policy had to take account of much more than just how to "optimize" the effectiveness of particular operations or how to "maximize" the achievement of an objective for a given cost—traditional analysis questions. Rather, matters such as the mix and size of our nuclear and conventional forces were the domain of the president, Congress, the secretary of defense, and the Joint Chiefs of Staff, who made their decisions on the basis of their best judgment, in light of many uncertainties involving values that an analyst could not realistically hope to quantify in his supporting studies. This did not suggest, however, that the analyst's job in support of decision makers at the national policy level was in any way insignificant. On the contrary, Enthoven stressed that "only in rare and exceptional cases is it possible to do a sensible job of formulating national defense policy without careful consideration of the relevant numbers." One recalls a quotation that appeared in the Introduction, which described operations research as a "scientific method of providing executive departments with a quantitative basis for decisions . . . ."[14]

Another of the special topics in this session had to do with the slow acceptance of operations research at universities, as a discipline warranting a separate curriculum. From the beginning, operations research had generally been done by multidisciplinary teams. None of the early practitioners was formally educated in the new field; rather, they were mathematicians, statisticians, physicists, chemists, engineers, actuaries, and so forth. Then, in the early 1950s—after OEG had already been in existence for a decade—some formal courses in operations research were offered at a few universities. Even so, there was considerable debate whether the total body of knowledge that came under the heading of operations research was substantive enough to merit a doctoral program. Some educators, confused about the purpose of operations research, were unwilling to concede that the field should be separated from the several disciplines from which many of its methodologies had been derived.

Finally, MIT and Johns Hopkins University granted their first doctor's degrees in operations research in 1955, and the Case Institute of Technology followed in 1957. (By the time of OEG's twentieth anniversary conference, these three schools had granted thirty-one doctor's degrees and seventy-six master's degrees in the field.) By 1959, thirty universities had added the subject to their educational program—although still not enough to meet the growing demand for operations researchers by industry as well as by the military. Of these thirty institutions, only twenty-four offered curricula leading to degrees: nineteen schools offered a doctor's degree, five offered a master's degree.

Moreover, by far most of these programs, rather than being supported by their own faculties, had been integrated into applied mathematics and statistics departments, engineering (particularly industrial engineering) departments, or business administration departments. Hence, although students rarely had the option of pursuing a major study in operations research, they were at least able to write their theses in the subject. MIT was a notable exception, having long since formed its Operations Research Center. Despite the general lack of a separate curriculum, the fact remains that operations research had finally breached the ranks of the nation's universities. In time, enough students would be exposed to operations research to become educators themselves or practitioners ready to join organizations like OEG.

The remaining talks in the special-topics sessions dealt with the application of economic analysis to policy making and the role of high-speed computers in military operations research. Both of these were given by representatives from Rand Corporation: William H. Meckling, who joined CNA shortly thereafter, and Norman C. Dalkey.

The sixth and last session, chaired by Ralph E. Gibson, director of Johns Hopkins University's Applied Physics Laboratory, was entitled "The Third Decade." In this session, Stephen Enke, who headed OEG's Economics Division, discussed the appropriate application of economic criteria to the study of military systems and what other criteria should override considerations of cost. In cautioning against a possible doctrinaire attitude toward the new drive for cost-effectiveness studies, Enke observed that "the current danger is that important military factors will be neglected because of undue stress on cost comparisons and economic efficiency." He added, "The moral . . . is that the economic criterion can be applied only in conjunction with intelligence estimates and military judgment."

Also as part of this session, OEG's director, Dr. Steinhardt, summed up where the group had been and where he thought it was heading. He began by providing a historical anthology of the group's successes and a summary of the areas–for example, tactical analysis and weapons evaluation–in which the group had been the most active. He also provided a list of features that he felt had enabled the group not merely to survive but also to remain an effective advisor to the navy. These features included integration of the group into the operating forces of the navy by means of an extensive field program, multiple tie lines up and down the entire naval hierarchy, and objectivity and realism in its analyses.

More important, Steinhardt took a moment to reflect on the "promise of the future." One timely point, given the then-recent formation of CNA, concerned how the charters of OEG/NAVWAG and INS should differ in order for the navy to derive the most benefit from the new arrangement. "I would like to propose," he concluded, "that the principal distinction between work done in OEG/NAVWAG and INS within the new CNA be that INS principally address itself to making broad, long-range studies within the field of responsibility of the Navy as a whole, rather than in direct support of the current decision-making processes at the level of Chief of Naval Operations or fleet commander [the latter being OEG's sphere of influence]." Steinhardt expected several advantages to a move in this direction. First, it would enable CNA to put to good use the kinds of talent already in INS. Related to this point, it would serve to attract high-caliber analysts interested in the challenge posed by a broad and far-reaching charter. In addition, such a staff could, from time to time, provide important support to studies being undertaken in OEG and NAVWAG, in which, for example, reliable estimates of technical feasibility, development time, and cost were needed. Finally, the arrangement would allow INS to break new ground in navy planning and to avoid duplicating the work of others.

Another look to the future was ventured by Herbert K. Weiss of the Aerospace Corporation. Weiss discussed supposedly foreseeable changes in the tasks and techniques of operations research and the kinds of organizations that would tackle these challenges. Also, Frank Bothwell made some brief remarks about his pending position as CNA's first chief scientist. The session ended with a panel discussion that included the founder of ASWORG/OEG, Philip M. Morse; the director of ASD, Hugh J. Miser; the president of IDA (the former contractor for administration of INS), Garrison Norton; and representatives from the air force's Operations Analysis Office and Rand and the army's Research Analysis Corporation.

The three days of formal talks were broken up by an anniversary dinner, given on the evening of 15 May at the Shoreham Hotel. Speakers included Secretary Korth, Assistant Secretary Wakelin, Vice Admiral Griffin (Deputy CNO for Fleet Operations and Readiness), and others. Martin L. Ernst—formerly an OEG associate director, but at the time of the conference employed by Arthur D. Little, Inc.—acted as toastmaster.

As he had at OEG's Decennial Conference on Operations Research, Professor Morse gave the principal address during the dinner. He discussed how the scientist in the United States had become thoroughly integrated into the defense establishment, causing scientific and military terms to become commingled. Observed Morse, "Officers talk like physicists, and acousticians argue tactics." He pointed to this fact to explain one of the reasons for his subsequent efforts to spread the practice of operations research among NATO allies. Referring to the prominence of the scientific method in U.S. military circles, Morse said:

> It really is confusing for the military staffs of our NATO allies, who aren't used to this interpenetration of scientific and military thinking. The countries which do not have military operations research groups find it increasingly difficult to coordinate their plans with ours . . . . Top officials from other NATO countries have had little or no experience in working with operations research teams, and top scientists from these countries have had no experience in working on military problems. We run into a real communication barrier at the national level.

To help improve this situation, Morse and others, including fellow OEG alumni, were working through the NATO Advisory Panel on Operations Research to promote the use of operations analysis abroad.

The tone of the messages offered during those three days in May 1962 indicated that the world of operations research in general—and of OEG, in particular—had made great strides since the last time such noted representatives from science, government, industry, and academia had assembled to commemorate a major milestone in the group's history. From fertile beginnings had grown a complex community of operations and systems analysts, whose influence had spread throughout and beyond the military sphere. OEG recognized, moreover, that as a component of the newly formed CNA, its advisory role on behalf of the navy would prove as essential in the coming years as it had in the last twenty.

### The Subsumed OEG

It was pointed out earlier that OEG's responsibilities and commitments—and its charter—remained essentially unchanged by its being absorbed by CNA. OEG's lines of attachment to the navy were similarly left undisturbed. That is to say, the group continued to report the results of its study program to the Deputy CNO for Fleet Operations and Readiness (Op-03) and continued to maintain its tie lines to executive agencies throughout the Office of the Chief of Naval Operations (OpNav), including the assignment of scientific analysts to many of OpNav's warfare branches (Figure 4-3). The system of sending members to the field was left in force, too, with OEG representatives reporting to nineteen commands, including fleet commanders (Figure 4-4).

One significant change, however, was the loss of Dr. Steinhardt as director of OEG, who left in the latter part of August 1962 to fill the post of science advisor to the president of Georgetown University. The legacy left by Steinhardt's sixteen-year stay as the group's head was substantial. He played a critical role, for example, in ensuring that the peacetime group was able to establish a firm footing in the years immediately following World War II, when there was still uncertainty as to the group's continued acceptance by the navy. Additionally, his unflagging pursuit of a scientifically excellent group paid off, as he refused to dilute the quality of his staff for the sake of bigness, and he encouraged scientists already in the organization to stay abreast of advances in their fields. He always promoted provocative thinking among his analysts, so that difficult issues would be faced head-on, even at the risk of having to present unwelcome conclusions. Steinhardt also demonstrated an uncanny shrewdness in guiding the group through uncharted waters, forming spinoff groups like ORG, NAVWAG, ASD, and the Economics Division in response to changing navy expectations. Finally, under Steinhardt's leadership, OEG continued to contribute to the development of the basic science of operations research and, by way of its "alumni," to place its imprint far and wide.

OEG's directorship subsequently passed to Dr. Joseph H. Engel. Engel's first association with the group dated back to 1949, shortly after earning his doctorate in mathematics from the University of Wisconsin. Since then, he had spent a year assigned as a field representative to the Seventh Fleet in the Pacific and a year with the Sixth Fleet in the Mediterranean. He had

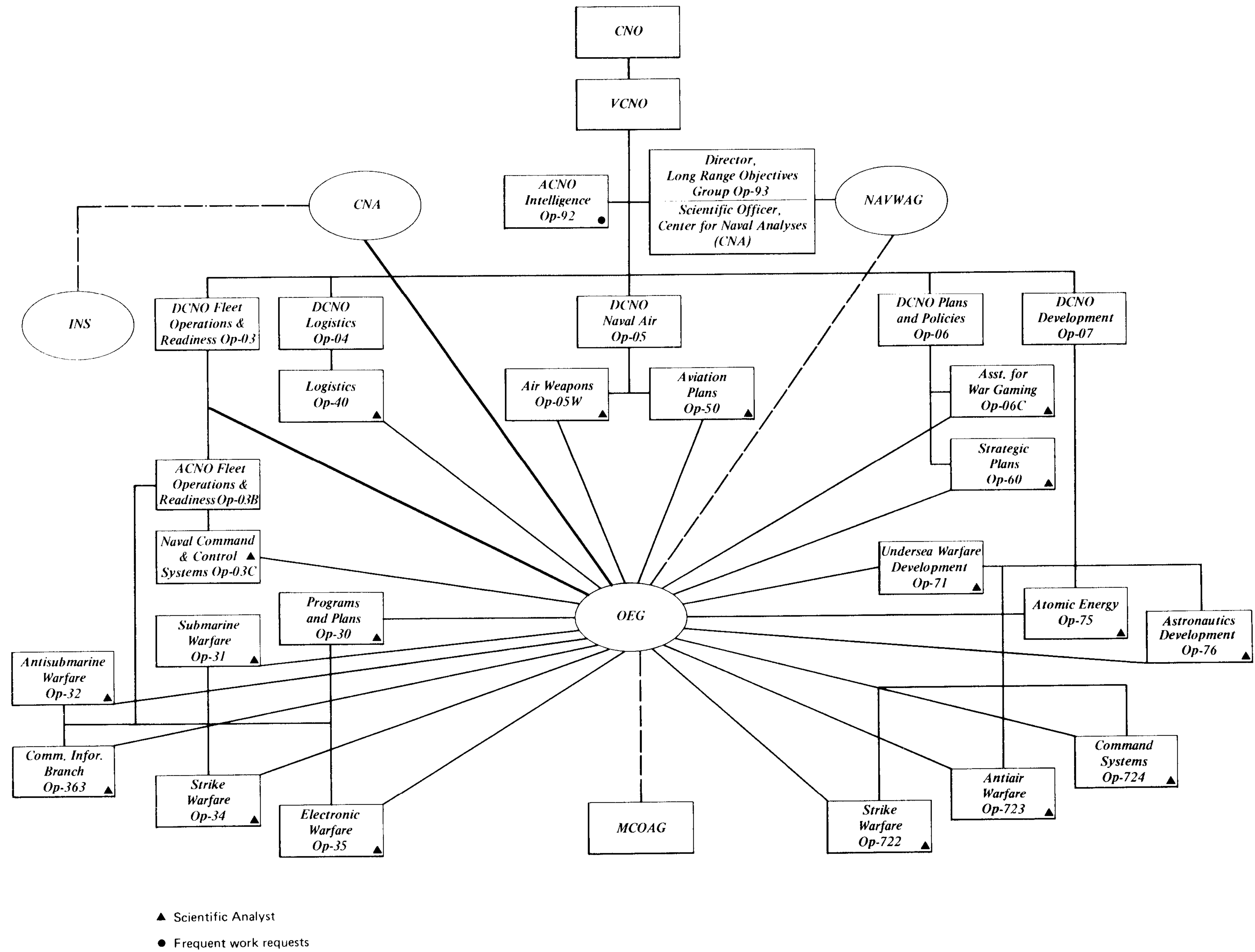



Figure 4-3. OEG Tie Lines to CNO for 1962

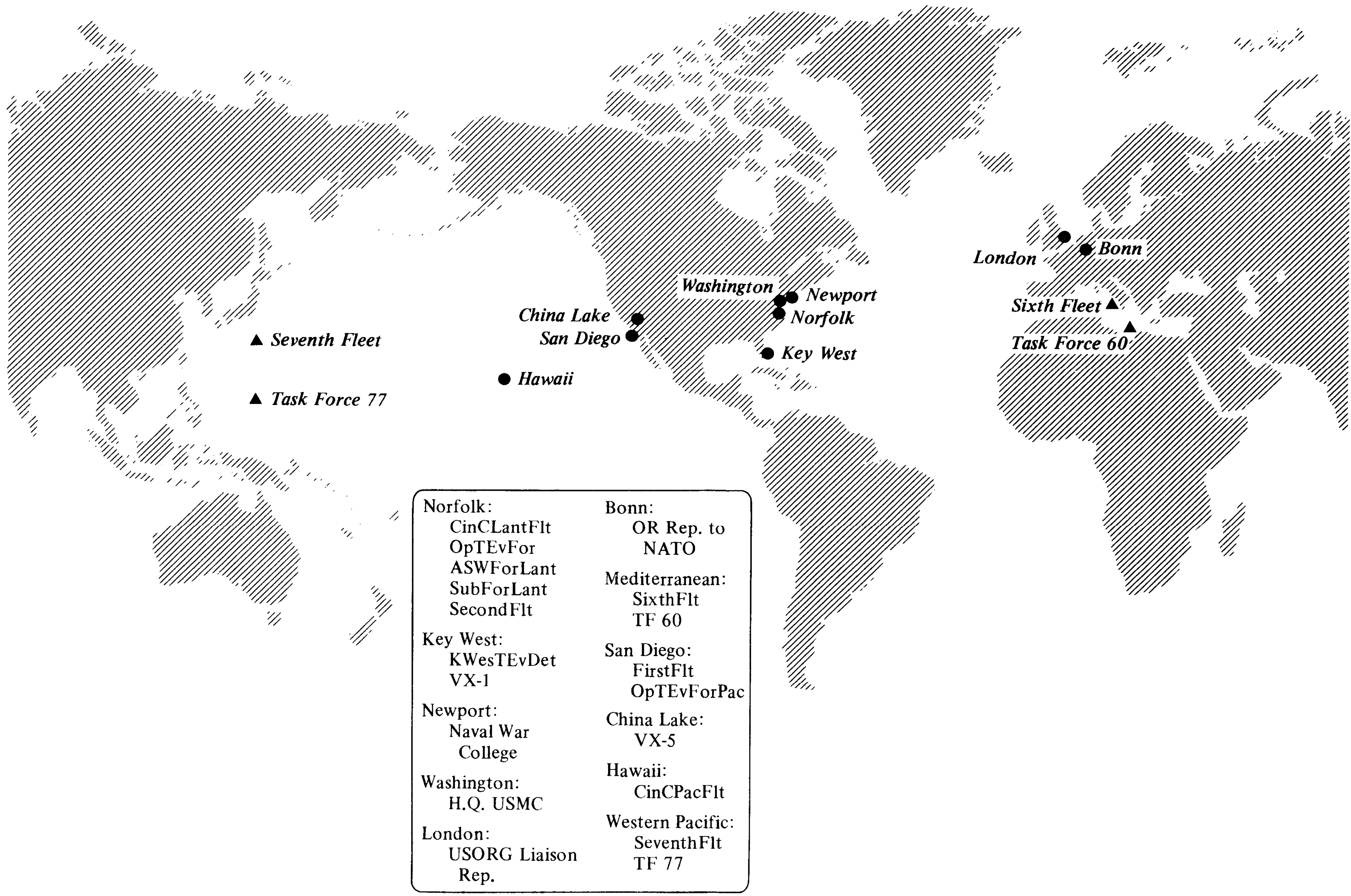



Figure 4-4. OEG Field Assignments for 1962

been appointed a deputy director of the group in 1957, and then director of the Operations Evaluation Division in 1960. In January 1961, Engel was made OEG associate director, filling a top post that had been left vacant for two years, since Martin Ernst had vacated it. In this position, Engel was to relieve Steinhardt of some of the pressure of running the group. Principally, he was to help coordinate the group's activities, to ensure a coherent and responsive program. This involved, among other things, participating in the formulation of work conducted by each of OEG's components and maintaining contacts with the navy. All in all, then, Dr. Engel had been thoroughly steeped in most aspects of OEG's operations by the time, in September 1962, he became the new director.

Over the several weeks before actually taking over the directorship, Engel had been working with Steinhardt to implement a few minor organizational changes. OEG's lot since being absorbed by CNA had remained remarkably unaffected by it all; yet, the group clearly could not ignore that it was now functioning in a larger context, with a sister group, INS. "We are a homogeneous group of colleagues," Engel observed at the time, "with a single goal of providing the best possible advice to the Navy with the facilities available." Hence, some changes were necessary, to guarantee the group's continued effectiveness.

OEG was made to consist of four components (Figure 4-5). The first, the Operations Evaluation Division (OED), was headed by Howard W. Kreiner, who had taken over that position soon after Engel had relinquished it. OED was the largest of the components, consisting of two scientific sections that were themselves split into teams responsible for one or two major themes of investigation: undersea warfare, antiair warfare, electronic countermeasures, and so on. OED also had responsibility over the field program, except for those members assigned to assist the Marine Corps. The remaining three components of OEG were the Economics Division, headed by William H. Meckling, who had come over from the Rand Corporation to replace the departing Stephen Enke; NAVWAG, headed by Sidney K. Shear, a long-time OEG associate; and the Marine Corps Operations Analysis Group (MCOAG), headed by Russell C. Coile, whose name first surfaced in connection with the running of ORG's research program in the mid-1950s. In line with a desire to preserve a general sense of continuity, however, the Economics Division, NAVWAG, and MCOAG were not slated for any change of charter.

OEG, meanwhile, expected to add many more scientists to its roster. In fact, funds had already been arranged to permit the addition of ten analysts—over and above recruitments to replace analysts lost by attrition—for fiscal 1963. These were to be distributed among all of OEG's components. Also, some INS members were expected to transfer to OEG. The anticipated enlargement of the group's manpower pool helped to allay

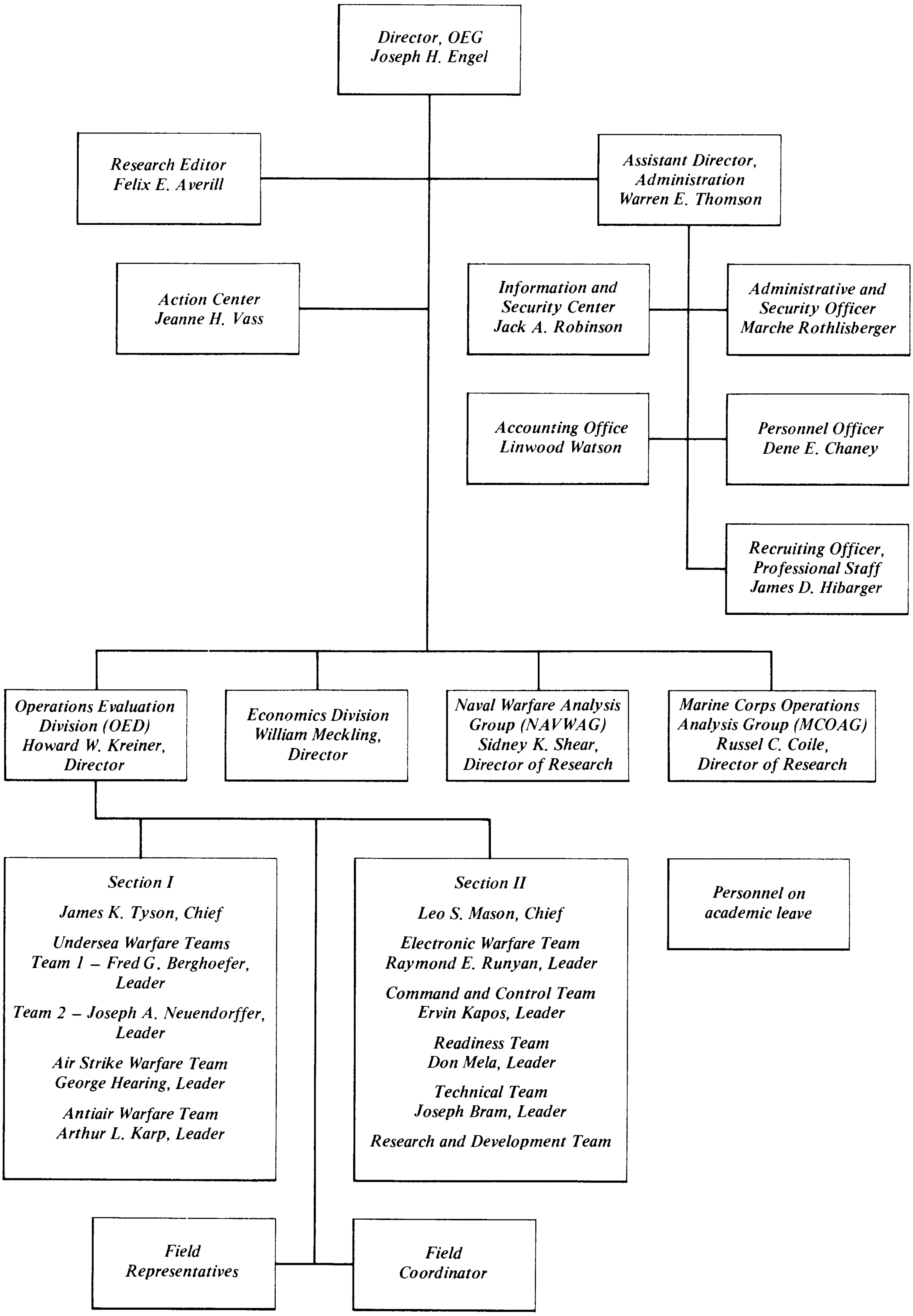



Figure 4-5. Organization of OEG on Becoming a Component of the New CNA

some of the concern that had built up about the manageability of a large field program. The enlargement not only headed off the need to cut back the field program, but actually enabled Engel to respond positively to several requests from both the navy and Marine Corps to add field representatives to existing billets or to newly opened ones.

Insofar as OEG's relationship with INS was concerned, not all details had yet been worked out. Even by the end of 1962, procedures for coordinating the roles of these two sister groups had yet to be settled on. The most serious questions at that point, however, centered around INS rather than OEG, for the latter's role was already well rooted. Specifically, INS's charter was similar to NAVWAG's in terms of long-range planning, yet obviously the two groups should not cover the same ground. Also, though INS was expected to provide OEG with technical support, how this was to be arranged was unclear. Most important, INS needed good leadership to provide it with a sense of direction. One thing *was* clear, however, which was that OEG's accumulated experience—twenty years' worth—qualified it to take on the role of senior partner, at least until INS could better establish itself. Indeed, CNA's new chief scientist, Frank Bothwell, intended to rely heavily on OEG for assistance in defining an appropriate research program for INS.

The kind of analysis that INS did settle into—that is, helping the navy to establish the long-range requirements of its operating forces—is perhaps best illustrated by an early study that assessed possible U.S. naval contributions to the deterrence or control of limited conflicts. Study projections covered the period from 1966 to 1980, with emphasis on the last five years. To understand possible future scenarios, INS first examined the characteristics and geographical distribution of past conflicts, from the end of World War II to the early 1960s. Factors considered in this preliminary phase of the study included the effect of various parameters, such as force ratios and weapon capabilities, on the outcome of these conflicts.

The study then weighed the prospects for limited conflicts in each region of the world. From political analyses and an appraisal of strategic alternatives available to the involved states, a list of potential conflicts was deduced. These conflicts ranged in intensity from coups d'etat and civil disorders at one end of the scale, to civil wars and limited wars at the other end. An assessment was then made of the degree of U.S. interest and likely involvement in each conflict, in light of overall political and strategic considerations. Various environments were postulated, taking into account the relationship between the United States and the Soviet Union, the Sino-Soviet schism, the strength of Communist powers in general, the policing role of the great powers, the influence of economic considerations on U.S. motivation, and so forth. Once these projected conflicts had been described as quantitatively as possible, INS attempted to determine the levels, mixes, and deployment of U.S. naval forces necessary to deter or end such conflicts.

It was toward such issues, then, that INS tended to gravitate and by which it came to distinguish itself. On the other hand, OEG's domain—the immediate and short-term needs of the navy—posed problems that were more manifestly manageable, less prone to the uncertainties of geopolitics, and, some would say, more assured of preparing the navy for actual contingencies.

**Crises in Cuba and the Dominican Republic**

One way in which OEG had traditionally supported the navy was by analyzing recent real-world operations. The Cuban missile crisis of October 1962, and the role played by the navy during that period, provided OEG with one of the more interesting episodes for examination.

The roots of the missile crisis reach deep into the cold war policies of both the United States and Soviet Union. Briefly, the Soviets envied how the United States had succeeded, until the late 1950s, in parlaying its strategic superiority to advance its own interests around the world while impeding Soviet initiatives. That is, the threat of massive retaliation had been invoked by the United States not just to deter the Soviets from starting a war but also to frustrate Soviet foreign policy goals. Having learned the lesson of the preceding years, Kremlin leaders decided to try to change if not the hard realities of the U.S.-Soviet strategic imbalance, then at least the perception of it. The successful testing of a Soviet ICBM in August 1957 and the orbiting of Sputnik in the fall had enormous psychological impact in the United States, setting the stage for Khrushchev's gambit. Soon afterwards, Khrushchev began issuing overblown numbers concerning Soviet ICBM deployments, in an effort to intimidate the West into giving the Soviets increased latitude around the world.

The benefits to the Kremlin of engaging in such a ruse were dubious at best, despite fears stirred up in the West by the resultant debate over a supposed "missile gap" that favored the Soviets. Slowly, though, evidence was pieced together—from U-2 reconnaissance flights and satellites—that by late 1961 totally discredited Khrushchev's claims of strategic superiority. The fact was that the Soviets had not deployed many ICBMs at all, having decided that its first-generation missile was inadequate and that development of an improved missile was required before large-scale deployment could take place.

President Kennedy subsequently used the evidence to reveal that Soviet assertions about their strategic capabilities were a deception. In doing so, he took away from the Soviets the foreign policy leverage they were beginning to enjoy, for even the rhetorical excesses of Khrushchev failed to deflect attention away from the concrete evidence the American administration held in hand. But it was this very denuding of the Soviets that prompted Khrushchev to seek a quick remedy that would help restore his country's ability to act authoritatively wherever and whenever it wished. Hence, the decision was made by Moscow that at least a temporary solution to the United States's reestablished strategic edge—that is, until the Soviet ICBM force could be enlarged to the point of *true* parity or superiority—was to deploy medium- and intermediate-range ballistic missiles and IL-28 bombers in Cuba, in striking distance of most of the continental United States. The implications could not have been more serious, for the deployment, according to President Kennedy, "would have politically changed the balance of power."

The Soviets proceeded to ship the missiles as quickly and surreptitiously as possible in the hope of handing the United States a fait accompli. U.S. intelligence, however, discovered the missiles on 14 October, just before the first batch were to become operational. Kennedy seized the initiative and insisted that both the missiles and bombers be withdrawn. He believed that although the Soviets may have been willing to incur great risks by deploying the weapons in the first place, they would nevertheless retreat once the risks became overwhelming. After three weeks of brinkmanship, U.S. pressure on the Soviets paid off: the missiles were removed during the second week of November, and the bombers were to be withdrawn over a thirty-day period.

President Kennedy's assumption that Khrushchev was capable of acting rationally if faced with a no-win situation—contrary to the Soviet leader's general reputation in the West as an impulsive maverick—provided the basis for the U.S. Navy's role as the crisis unfolded. The Cuban missile crisis, in fact, led to the largest naval operations since the Korean War, a full decade earlier. The operations around Cuba involved three major activities: the blockade of Cuba, and accompanying surveillance operations; the prosecution of Soviet submarine contacts; and the concentration of units in the area of the Florida Strait for a possible attack against Cuba. The object of one OEG study was to determine the effectiveness of the most important of these activities—the navy's surface surveillance in support of its quarantine of Cuba.

The blockade, proclaimed on 22 October, was implemented on the basis of plans hurriedly developed by the navy, with close participation by OEG. As initially conceived, the blockade was not intended to be complete but, rather, to induce Soviet ships carrying arms or other prohibited materials to Cuba to stop and return home. The operation later evolved into an attempt to locate *all* ships in the approaches to Cuba and to track ships of special interest. U.S. surveillance ships (mostly destroyers and cruisers) were first concentrated along a barrier, dubbed the Walnut Line, about five hundred miles from Cuba, so as to remain beyond the range of the Cuban air force

(Figure 4-6). Another reason for initially maintaining the barrier so far from Cuba was to ensure that President Kennedy and his advisors would have as much time as possible to react to events.

The need to establish the line five hundred miles from Cuba, however, caused two problems. First, since the intercepting ships acted on information supplied by planes, aircraft searches had to be conducted even farther from Cuba than the five hundred miles. Second, the line had to be more than three times as long as one that ran, for example, from Florida to the Bahamas to Hispaniola. The length of the line therefore made it necessary to increase the size of the force, while still losing some degree of efficiency. So, on 30 October, just six days after the first barrier had been put in place, the quarantine line was moved closer to Cuba, forming the so-called Chestnut Line. At this time, blockade ships also began to patrol the passages in the area, such as the Florida Strait and Windward Passage.

Air coverage, provided mostly by patrol aircraft (VP) with help from carrier-based planes, was concentrated in three zones. The first ran north and south from Puerto Rico to Bermuda, and to the east and west of Bermuda. A second zone ran from Puerto Rico to Jacksonville, along the Bahamas and off the Florida coast; flights from Guantanamo to the Bahamas helped to strengthen this coverage. The third area was just outside Cuban waters, covered by planes from Key West and Guantanamo. In addition to these three formal zones, flights from Lajes in the Azores patrolled selected regions in the mid-Atlantic. Also, many planes were sent out to observe Soviet ships of special interest–ships that had been detected earlier or revealed by intelligence sources–in an attempt to determine their intentions. About two-thirds of the VP effort was devoted to ocean surveillance and special search and tracking flights, and about one-third was devoted to antisubmarine patrols, including the escort of surface ships.

Once OEG had measured the magnitude of the surveillance effort, in terms of aircraft flight hours and ship-days in the quarantine area, it could then assess the operation's overall effectiveness. The measure of effectiveness was taken as completeness of coverage, measured by the fraction of ships entering the surveillance area that were identified. To accomplish the mission, naval units had to examine all shipping in the areas of interest. The quality of information obtained on ships entering the surveillance area, however, differed markedly. Complete identification, including origin and destination, was not always possible. For the purpose of the study, then, identification was considered as "positive" if the name and type of ship were obtained. (Usually, the ship's registry was gotten with the name.)

Aircraft, it was found, made nearly two-thirds of all the positive identifications; land-based patrol aircraft alone (that is, excluding carrier-based planes) made a little over half of all positive identifications. Carrier aircraft spent nearly as many flying hours on surveillance as did patrol aircraft, but

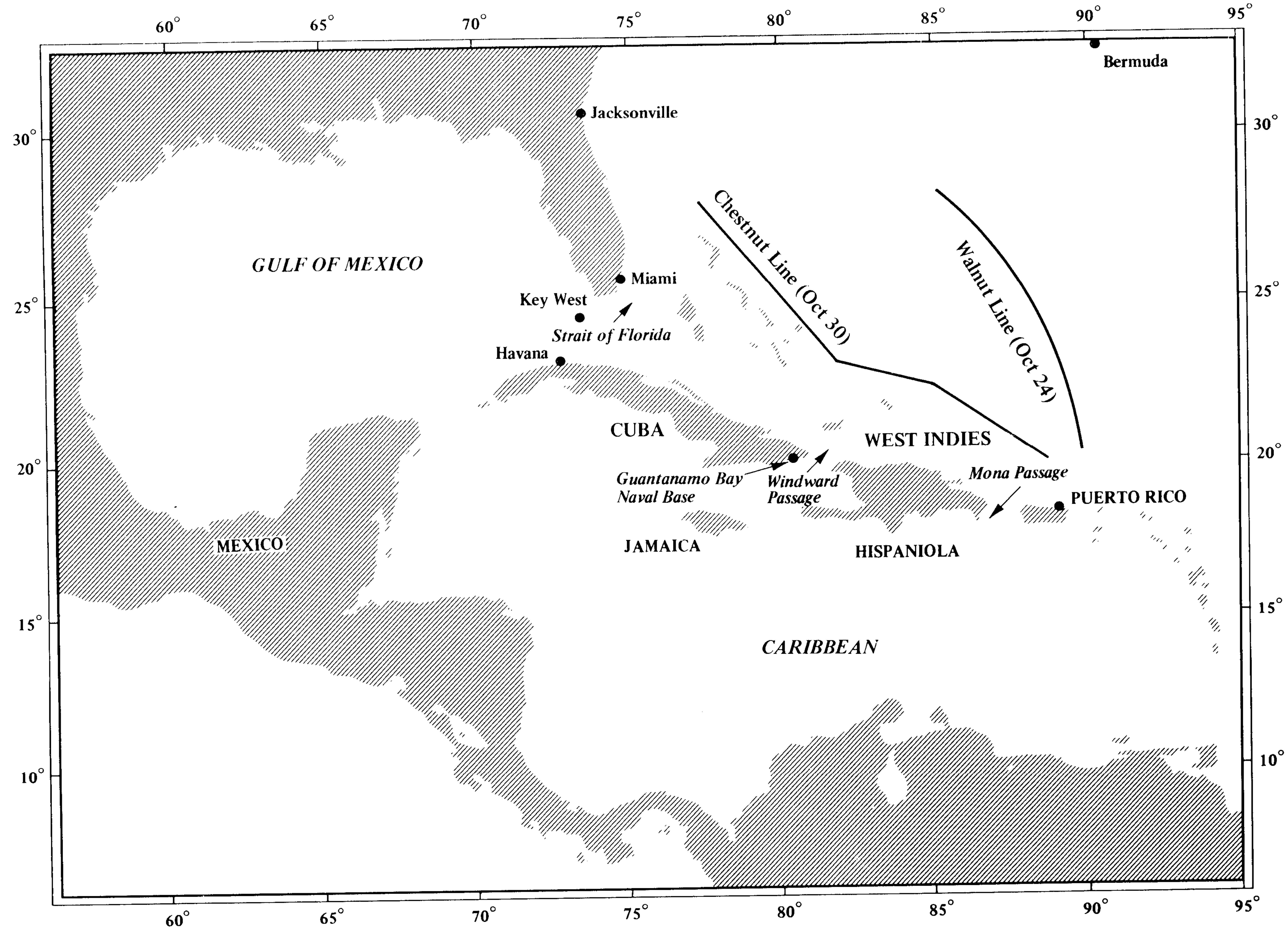
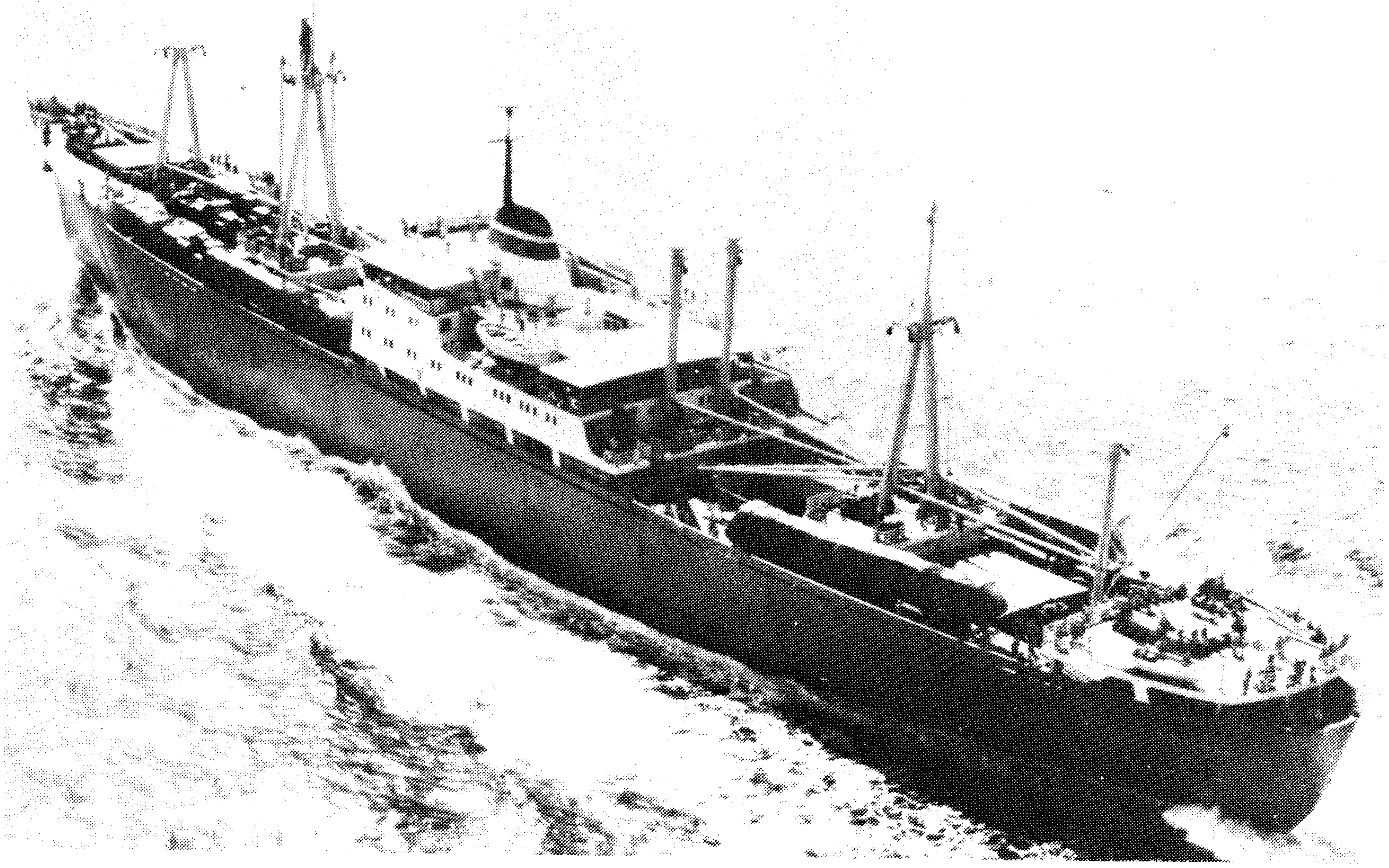



Figure 4-6. Main Disposition of Surveillance Ships along Barrier Lines during Cuban Missile Crisis



The Soviet ship *Divinogorsk* with four missile transporters, each with a canvas-covered missile lashed to its deck. (Official U.S. Navy photo.)

their effort was concentrated in limited sectors and occurred intermittently. Land-based patrol planes, destroyers, and cruisers, which together accounted for the bulk of the full-time surveillance force, chalked up nearly all (five-sixths) of the positive identifications. As expected, ships made the most identifications in restricted waters, such as in the Florida Strait and Windward Passage. The number of contacts was influenced by the opportunities, which depended on shipping densities, and the search effort expended, as measured by ship-days, flying hours, or length of barrier patrolled.

OEG found that overall, 86 percent of the merchant ships on trips between Europe and the Gulf of Mexico-Caribbean area (based on Lloyd's Voyage Supplement) were identified by surveillance forces. The group then broke down the data into four major samples, on the basis of the origin and destination of each trip and whether the ships were inbound to or outbound from their destination ports. One sample, for instance, covered ships steaming to Caribbean and Gulf ports from Northern Europe; another sample consisted of ships heading in the opposite direction (that is, ships outbound from their destination ports). About nine out of every ten ships in both of these two important categories were identified. A third sample covered transits from Southern Europe and the Mediterranean area to Caribbean and Gulf ports, while yet another sample considered ships embarked on the return trip. In these two categories, surveillance forces identified about eight out of every ten ships making the run.

These results indicate that coverage was effective, especially when it is realized that the proportions of ships identified were lower rather than upper estimates of effectiveness. One reason for the lower estimates was that some of the identifications and sightings, it was discovered later, were either not reported at all or reported but not received for analysis. Specifically, data were not obtained for 35 of 261 surveillance flights, which meant that identifications achieved on those flights could not be factored in. In addition, some ships' names were transmitted with errors, often because of the difficulty caused by the Cyrillic letters on Soviet ships. Some names were so garbled, in fact, that later analysis could not correctly reconstruct them. The ultimate compliment to the overall effectiveness of the navy's quarantine, however—and one that surpassed the significance of mere numbers—was its success in preventing the Soviet Union from gaining a strategic advantage. OEG's study, in turn, helped to preserve an accurate and detailed record of this critical episode. The work also had the very practical purpose of contributing to an understanding of future force requirements, in the event the navy had to plan for another such large-scale surveillance operation.

Cuba, however, was not the only flashpoint requiring a quick naval response. Over the course of the weekend of 24 and 25 April 1965, leftist rebels in the Dominican Republic took control of the Presidential Palace and most of Santo Domingo in an attempt to oust the conservative civilian government that had ruled since the overthrow of Juan Bosch. Fearing a second Cuba, President Johnson began to take steps for an evacuation of American citizens and for possible U.S. military intervention. The Caribbean Amphibious Task Force, with fifteen hundred marines, positioned itself near Santo Domingo, and the 82nd Airborne Division at Fort Bragg was put on alert.

The evacuation began on 27 April. Marine communications teams flew in from USS *Boxer* to set up radio communications at the American embassy and at San Isidro Air Force Base. On 29 April, a Joint Task Force was activated: while two battalions of the 82nd Airborne moved from their landing point of San Isidro in order to enter the city, the marines established an international safety zone around the American embassy. During the second week of the crisis, the marines and paratroopers linked up, splitting the rebel-held territory in two and allowing direct surface communication between the two main bodies of U.S. troops. Fighting began to diminish and mediation efforts got under way through the Organization of American States (OAS), leading to a ceasefire on 6 May. The next day, the Joint Task Force was dissolved and Lieutenant General Bruce Palmer, U.S. Army, commander of the land forces, was designated U.S. Commander in the Dominican Republic (USComDomRep).

As part of a continuing effort to assess the efficiency of communications in various real-world situations, OEG undertook an analysis of messages received and sent by the joint headquarters of the Commander in Chief, Atlantic (CinCLant), and the Commander in Chief, Atlantic Fleet (CinCLantFlt), during the Dominican Republic crisis.[15] Although the command structure was highly mercurial, there were three main phases, corresponding to the onset of the crisis, the activation of the Joint Task Force, and the establishment of Palmer as USComDomRep. Each phase was so marked by numerous major and minor shifts in command relationships, however, that it would be of questionable value to sketch out the command structure here. Suffice it to say that communications links were abundant.

OEG's objective in examining almost four thousand of the messages sent to and from the various naval commands involved in the crisis was threefold. The first was to compile a historical record of the events. This meant analyzing messages entering and leaving the CinCLant/CinCLantFlt Operations Control Center. The kinds of things looked at were the number of messages sent and received, their contents, to whom they were distributed, whether there were delays, their level of classification, and the priority placed on them. Such information was expected to provide the data base required for deriving reasonable models of command organization and fleet communications that would enhance the United States's ability to predict command and control requirements in future crises. The second goal was to use the findings to determine the requirements for a worldwide network of computer-based military command and control systems. Finally, the group wished to establish a basis for defining realistic ways of standardizing command and control and reporting systems, to ensure their mutual compatibility. The functional compatibility of these systems could best be realized by first knowing who typically talked to whom in real operations, and what kinds of information—plans, intelligence, logistics, and so forth—were generally conveyed.

## Early Analysis of the Vietnam War

The relatively brief, albeit intense, episodes involving the likes of Cuba and the Dominican Republic accounted for only a fraction of OEG's commitments. It was also during this period that the group started to devote a large portion of its effort to the escalating war in Vietnam. This was certainly not unexpected, given the increasingly sensitive circumstances the U.S. Navy found itself in at that time. The Tonkin Gulf crisis of August 1964 presaged just how deeply involved the navy was to become. On 31 July, the USS *Maddox,* a World War II-vintage destroyer, embarked on a so-called De Soto patrol in the Tonkin Gulf. The general aim of these patrols was to show American resolve to back South Vietnam and to gather electronic intelligence. The patrolling ships often ventured within the twelve-mile limit claimed by North Vietnam, but not within the three-mile limit recognized by the United States.

The specific mission of the *Maddox* was to try to pick up evidence of Hanoi's continuing infiltration of people and supplies into the South. On 2 August, however, three North Vietnamese patrol boats—believing, erroneously, that U.S. vessels had been taking part in South Vietnamese naval strikes against installations along the North Vietnamese coast—engaged the *Maddox* with torpedoes and machine gun fire. The *Maddox* managed to avoid the torpedoes and began firing back with its battery of 5-inch guns. Backup was supplied by F-8E Crusaders launched from the alerted carrier USS *Ticonderoga* stationed nearby. All three of the patrol boats were hit, with one set ablaze and the other two forced to head for home. The *Maddox,* virtually unscathed, proceeded to open waters, whereupon the Commander in Chief of the Pacific Fleet (under the president's direction) quickly ordered it back into the Gulf, along with the USS *C. Turner Joy,* to underscore its right to operate freely on the high seas. Though President Johnson decided to treat this attack against the *Maddox* as a possible mistake, a second such incident occurred two days later, on 4 August, involving both the *Maddox* and *C. Turner Joy.* President Johnson reacted swiftly, approving retaliatory air strikes against North Vietnam and pushing through Congress the Tonkin Gulf Resolution that gave him considerable latitude in running the war.

Those few days in August 1964 took on, of course, historic proportions. Behind all this history making, however, lay the groundwork necessary to conduct the day-to-day operations of the war. OEG was a key element of that ground laying. For example, in the same year as the Tonkin Gulf incident, OEG examined the navy's ability to interdict transportation in North Vietnam. The study was made both to aid planners involved in deriving contingency plans for Southeast Asia and to present an example of the minimum amount of analytical planning required for preparing an effective interdiction campaign. An attack on North Vietnam's transportation network might entail any or all of three goals: to delay Chinese forces entering the fight; to sever all Sino-Soviet supply routes to North Vietnam; or to cut links between the Hanoi-Haiphong complex and South Vietnam, Laos, or some other part of North Vietnam that was to be the site of an amphibious operation. OEG considered campaigns designed to accomplish each of these goals. The three carriers normally deployed in the Western Pacific were regarded as particularly important because, if the Chinese did launch a surprise attack, these carriers could begin air strikes well before any major effort by land-based planes could get under way.

Because all land transportation routes from China into Laos, Eastern Thailand, Cambodia, and South Vietnam passed through North Vietnam—except for a few trails of very limited capacity—the North's transportation system had considerable strategic significance. Key to this transportation system were four highways and two rail lines connecting China with Hanoi, and two highways and one rail line linking Haiphong with Hanoi (Figure 4-7). Supplementing these routes were the extensive waterways of the

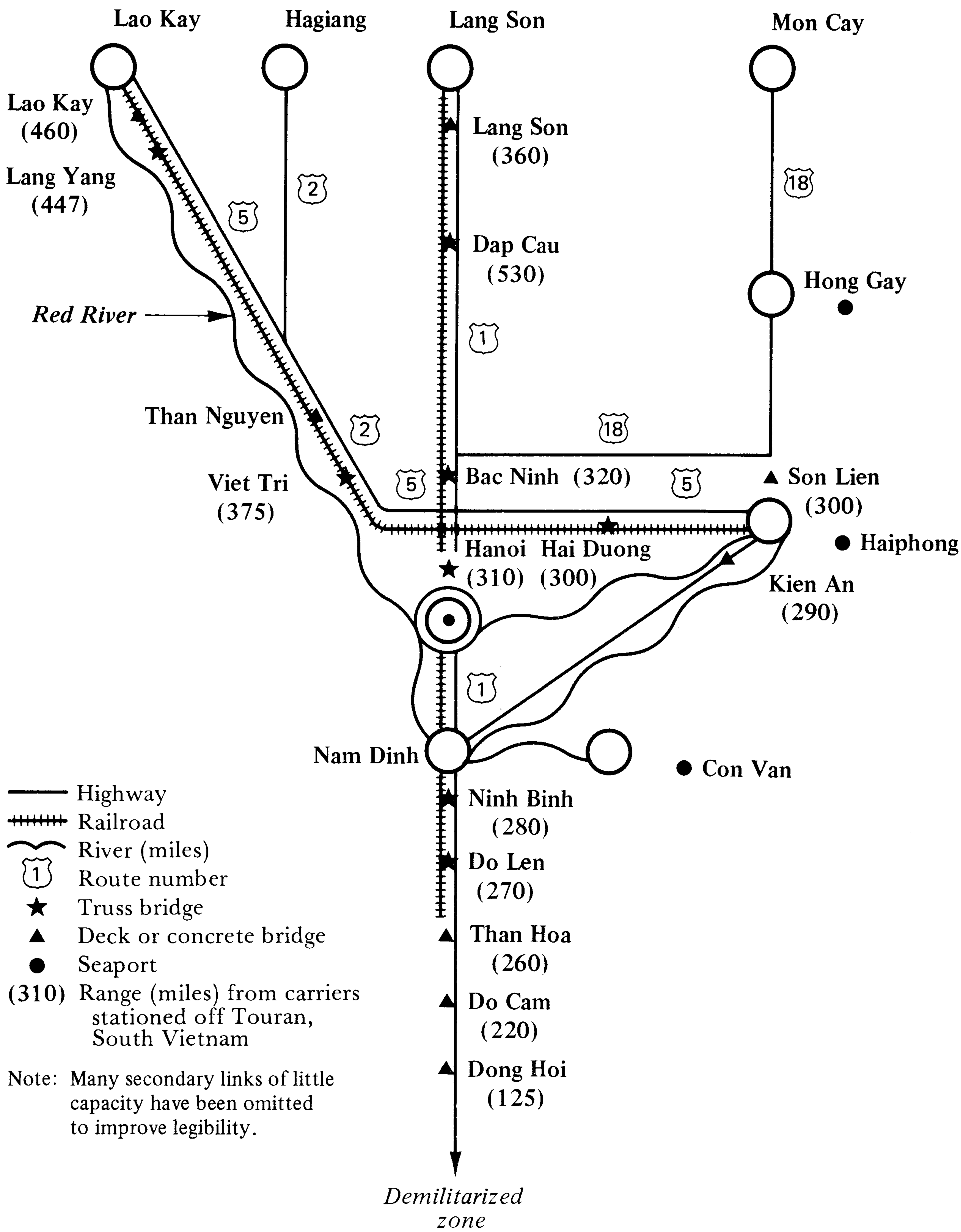



Figure 4-7. North Vietnamese Transportation Network (Schematic Representation)


A U.S. Navy A4 Skyhawk, part of Attack Squadron 23 aboard the USS *Midway*, drops a bomb on a Viet Cong stronghold in South Vietnam. (Official U.S. Navy photo.)

deltas of the Red River and the Sang Thai Binh, and a myriad of interconnecting canals. In addition, the upper Red River provided limited transportation between the Chinese border and Hanoi. Nearly all traffic from the Chinese border or from North Vietnamese seaports funneled through Hanoi or Nam Dinh on its way south and west. Finally, all transportation south of Nam Dinh was restricted to one road and rail link, reducing to just a single road beyond Than Hoa.

The capacity of the highway links was worked out, based on their characteristics: surface, width, gradient, maximum bridge load, and so forth. Daily tonnages were derived for two-way vehicular movement for both the dry and wet seasons. In computing these tonnages, short bottlenecks were deliberately excluded from consideration, on the expectation that such stretches of roadway could be readily improved or simply circumvented, as was done in Korea. A similar technique was used to figure the capacity of the rail links. The capacity of the river links, however, was estimated from the characteristics and number of river craft available to the North Vietnamese. The characteristics of North Vietnamese junks—that is, their length, beam, draft, and tonnage—did not differ materially from those in the South. Because of their shallow draft, junks could reach Hanoi or Nam Dinh even at low water. So, given an estimate of the number of junks available, plus the turnaround time for junks traveling between Haiphong, Hanoi, and Nam Dinh, it was then possible to calculate the maximum capacity. Not all available junks, of course, were expected to be used for transportation; some, for instance, were certainly retained for fishing, especially by those living in the delta regions. On the other hand, the study did not take into account the few low-draft steamers, barges, and tugs available, nor the many sampans. The final estimate of capacity was left conservative so that once the effects of interdiction were investigated, it would be possible to gauge the upper limit of the effectiveness of a particular campaign.

Next, it was necessary to determine the strike capabilities of a carrier, of the type stationed off Tourane (later renamed Da Nang). The number of sorties that were possible depended, among other things, on the time it took to prepare for a strike and the rate at which planes were lost per sortie. Since weather drastically affected strike capabilities, the results were given for both dry and wet seasons. Also, the probability of destroying various types of targets was worked out for different ordnance carried by the attacking planes.

With all these background data in hand, OEG then turned its attention to the interdiction effort itself. Interdiction comprised two levels. The first involved a period of intense effort, during which enemy air and ground defenses were neutralized and the transportation network was disrupted as much and as quickly as possible. The second level involved a period of sustained effort, during which the gains achieved in the initial phase were preserved by defeating enemy attempts to repair or bypass the cuts. Because of the inevitable lag between completion of repairs and reattack of the target, interdiction could never be complete. The success achieved during this phase depended on the level and quality of reconnaissance and the ability to direct a strike quickly against a repaired target.

The group first looked at the ten road and rail bridges north of Hanoi as likely targets (Figure 4-7). Three criteria made these bridges suitable for strikes: they were important in the flow of supplies from seaports and the Chinese border into North Vietnam; they were long enough to lend themselves to air attacks; and, finally, once cut, they could not be conveniently bypassed. The number of sorties required was then calculated for each bridge, as was the number of carriers for completing the entire operation, again for both the dry and wet seasons. The results considered only what it would take to interdict the flow of traffic along these routes and not what additional effort would be necessary to neutralize enemy air defenses or to suppress flak.

Experience in Korea had shown that the enemy could quickly repair destroyed bridges. Repeated attacks were therefore required to counter repair attempts. A "steady state" would prevail, then, when the rate of target destruction equaled the rate of target repair. The chief factors having a bearing on the level of steady state were the average time in which the enemy repaired damaged bridges, the delay between bridge repair and reattack, and the number of daily sorties available for reattack. The level of steady state actually achieved affected the amount of traffic that got through, expressed as residual tonnage. The residual tonnage reaching Hanoi under various combinations of attack delay and repair time was then estimated. Most strikingly, it was shown that the traffic (residual tonnage) was increased by a factor of three or more if reattack of repaired bridges was delayed by as little as one day, thereby seriously impairing the effectiveness of the interdiction campaign. Of interest, too, was that some of the residual tonnages during the wet season exceeded those for the dry season, because the effects of poor weather on our air strikes overshadowed the effects of poor weather on the movement of enemy vehicles.

Although inland water traffic played a substantial role in getting supplies to Hanoi from the coast, it was difficult to assess the potential effect of an interdiction effort. One reason for this was the ease with which junks could be built—materials were readily available, and cost and time were minimal—permitting the enemy to maintain a good supply of them despite attacks. In addition, there was some question as to whether the gun then being used on attack aircraft was appropriate for sinking such simple wood structures as junks. Moreover, the kill probability of general-purpose bombs and napalm against junks appeared too low even to consider their use. It was also evident that the results of an interdiction effort against water traffic would not be felt for perhaps months. Despite these caveats, the group was able to estimate how many days it would take to reduce enemy junks to just a quarter of their original number, through the commitment of all planes not required for land interdiction.

A still more favorable situation would be obtained if naval air strikes were concentrated in the region south of Hanoi. There were a couple of reasons for that fact. First, the road and rail network narrowed to a single link, with a capacity decreasing to about twelve hundred tons a day south of Than Hoa. Although, in theory, only one point along this link needed to be cut to ensure interdiction, in actuality several points needed to be cut to prevent the enemy from concentrating his defensive and repair facilities

An enemy supply train, about thirty miles north of Vinh on the North Vietnam coastal railway, burns after being struck by planes from the attack carrier USS *Midway*. (Official U.S. Navy photo.)

and auxiliary transport in one location. Even so, there was still excess strike capability that could be directed toward objectives other than interdiction, such as neutralization of enemy defenses and reconstruction facilities and harassment of attempts to bypass the cuts.

A second reason for the more favorable situation south of Hanoi was that, with only four ports of consequence below Ninh Binh, the coastline offered little protection to enemy seagoing traffic. Also, inland waterways south of Nihn Binh were nonexistent. Finally, the closer range of targets from the carriers off Tourane improved strike opportunities considerably. One last observation was that if air attacks were coupled with South Vietnamese attacks near the demilitarized zone or with a threat of amphibious landings in the southern panhandle of North Vietnam, then even fewer of the supplies would ever make it through to enemy troops.

But, no matter how effectively these air strikes could interdict traffic coming southward through North Vietnam, all would have been for naught if South Vietnam's coastline could not be sealed off, too. Evidence that the Viet Cong were trying in a major way to move people and supplies along the coast soon came to light. On 16 February 1965, a camouflaged 100-ton steel-hull ship was discovered in the shallow water of Vung Ro Bay, South Vietnam, by a helicopter on a medical rescue mission. Air strikes subsequently sank the ship, resulting in the capture of a large quantity of arms removed from the ship itself and from nearby caches. Up to that time, South Vietnam's Coastal Force and Sea Force had been using some two hundred small craft to patrol the country's coastal waters. After the 16 February incident, however, U.S. naval forces were assigned to augment the effort in a campaign that became known as operation Market Time.

OEG's field representative to Commander Seventh Fleet took part in that fleet's preparations for Market Time. Other group members did analysis of Market Time for Commander Task Force 71. Later, in September 1965, the Commander in Chief of the Pacific Fleet sent a study group to Saigon, to help the staff of Task Force 115 do an analysis of force requirements for Market Time. This group included an OEG scientist, John H. Fry, who helped to estimate force requirements for patrols. All in all, the participation of OEG field analysts in planning Market Time and in observing operations at sea provided the navy with considerable insight into Market Time's utility. Back in Washington, meanwhile, other OEG scientists were conducting studies of Market Time for the Office of the Chief of Naval Operations.

After the inception of Market Time, there was no firm evidence of further infiltration by steel ships for more than a year, when one was detected and sunk by Market Time forces on 10 May 1966, and another was captured on 20 June. There was plenty of evidence, however, that wood junks were busily transporting small numbers of Viet Cong and limited quantities of arms, supplies, and documents from one point to another along the South Vietnamese coast. By early 1966, Market Time forces were reporting the capture of about five junks per week.

Originally, the primary mission of Market Time sea and air patrols had been to prevent the Viet Cong from using the sea to transport arms from sources outside South Vietnam. Within a few months, however, this mission was expanded to prevent seaborne transshipments of contraband from one location to another *within* South Vietnam. To counter this, Market Time forces generally operated out to about forty miles from shore, extending from the 17th parallel all the way around to Cambodian waters. The barrier consisted of three rings, as shown in Figure 4-8: U.S. naval forces were responsible for the outer ring, while South Vietnam's Sea Force and

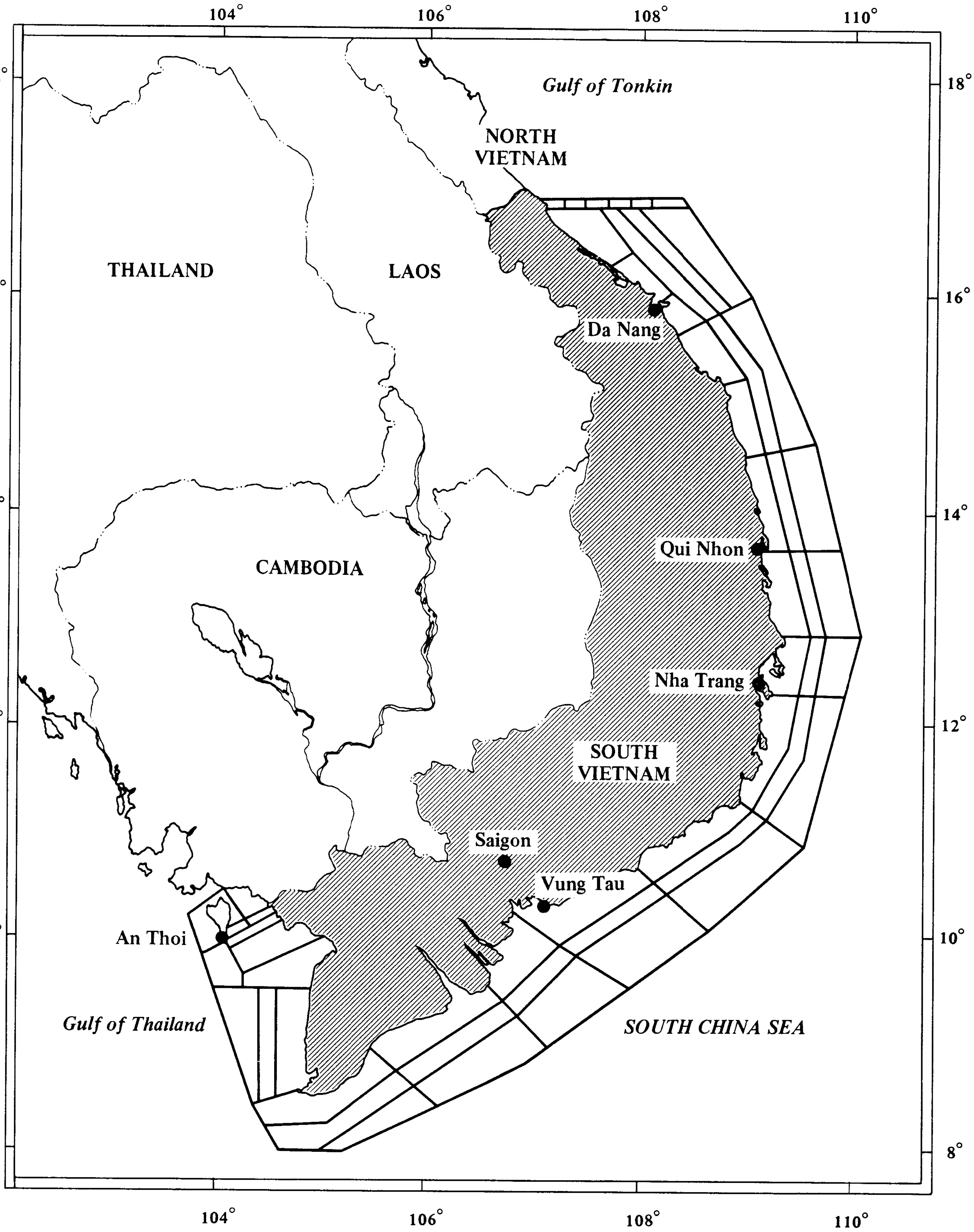
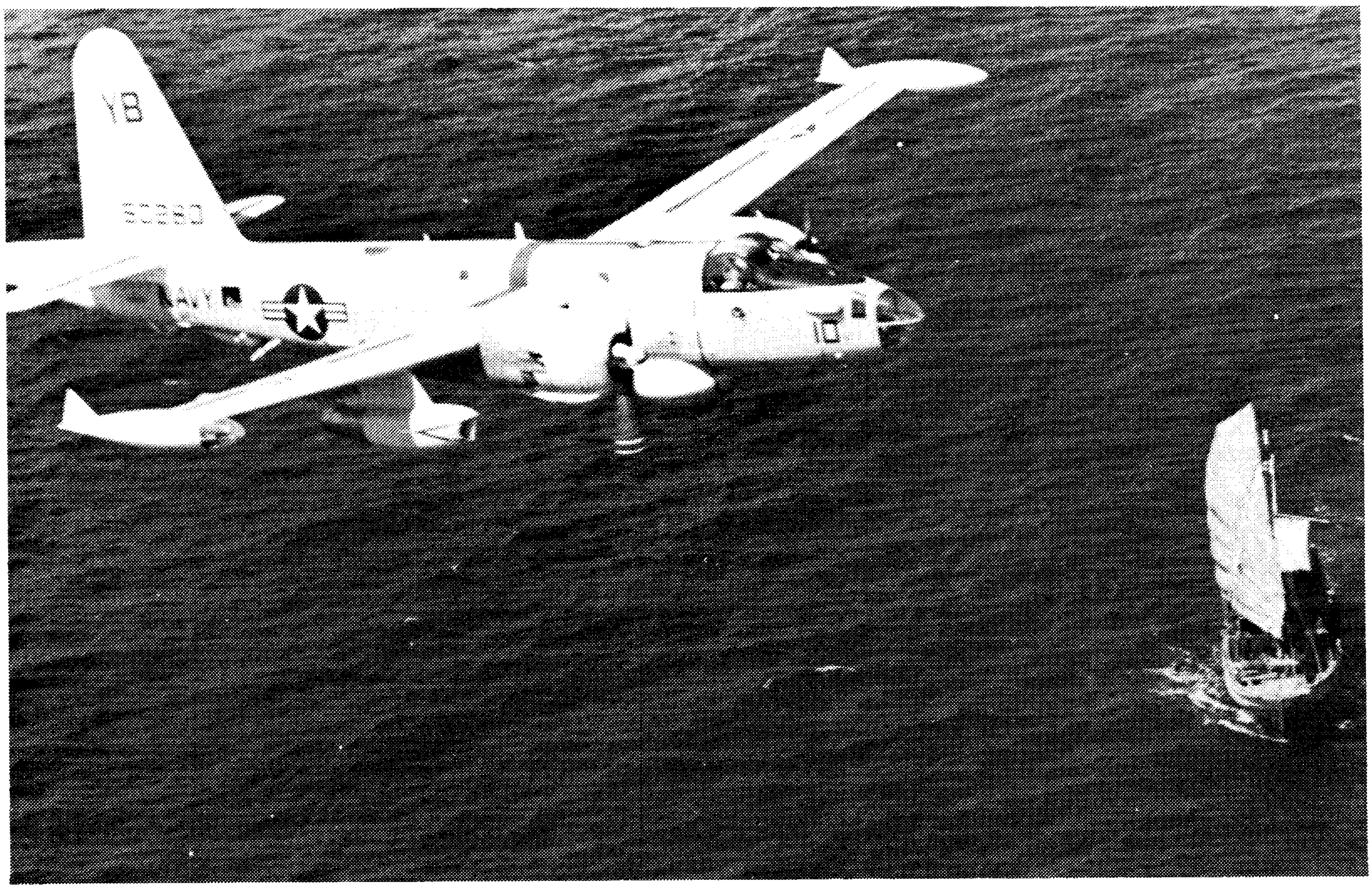



Figure 4-8. Market Time Patrol Zones

Coastal Force patrolled the middle and inner rings, respectively. Junks that were ostensibly engaged in trade or fishing were either inspected from the patrol boats or boarded and searched. Although available forces could board only a few of all the junks at sea at any time, they did succeed in discovering small amounts of contraband as a result of searches. Additionally, many Viet Cong craft revealed themselves by firing on or trying to run from approaching patrol boats. The surface operation was backed by patrol planes, whose primary mission was to report ships or junks engaged




A U.S. Navy Neptune checks out a Vietnamese junk while on Market Time patrol south of Vung Tau. (Official U.S. Navy photo.)

in suspicious behavior, such as off-loading supplies at sea or running at high speed toward shore.

Besides having helped to plan these operations, OEG attempted to assess Market Time's effectiveness in terms of the limitations imposed on Viet Cong activity. A wide variety of considerations were examined, such as the probability of vessels—steel ships or junks—infiltrating the patrol barrier and making it to shore undetected. It was then possible to calculate, up to a particular level of confidence, the number of vessels that succeeded in avoiding detection, which was shown to be quite small for both junks and the more conspicuous steel ships of over 100-ton cargo capacity. The findings enabled the group to propose improvements to Market Time, including the design of barriers suitable for spotting enemy infiltrators among the many innocent craft.

### Other Analysis in the Mid-1960s

Notwithstanding these calls to advise the navy in times of crisis or war, OEG's principal reason for being remained largely unaltered. The group's staple still consisted of analyses of requirements, fleet operational readiness, weapons selection and usage, and naval tactical warfare and amphibious assault. Requirements studies were concerned with determining the operational needs of aircraft, ships, detection systems, and command and control systems. Present and near-future fleet capabilities and logistical requirements were evaluated, to ascertain operational readiness. Weapons-related studies considered the selection, delivery, loading, and stockpiling of conventional and nuclear weapons, and problems of air and naval fire support of assault forces. OEG also investigated the navy's requirements in tactical deception and electronic warfare, including tactics for antiair warfare, antisubmarine warfare, and surface naval warfare.

As an example of a capabilities study, OEG did an analysis of how well a hunter-killer group, operating in the vicinity of a carrier task force, could protect the carrier against submarines. The measure of effectiveness was assumed to be the additional survival time given an attack carrier in a task force accompanied by a hunter-killer group, compared with an unaccompanied carrier task force opposed by the same threat. Fleet exercises were examined to find out the effect of increased defense against submarines on the survivability of carrier strike groups in their launch ranges. OEG looked at twenty-one encounters, in which all but one enemy submarine were powered conventionally. Whenever submarines opposed the carrier task force, friendly antisubmarine forces were also around. Patrol planes were usually used when no hunter-killer group was present, but were not always used when hunter-killer forces happened to be close by. Hence, a comparison of submarine successes against the attack carrier in exercises with and without a hunter-killer group were expected to give a conservative estimate of the kind of defense such a group provided against submarines.

Submarine density was generally heavy in the exercises, which was probably realistic. Under U.S. peacetime operating procedures at the time, it was possible for the enemy to know the location of our attack carriers to within one hundred miles or so. Therefore, a high-density submarine attack could be mounted in the areas where the attack carriers were to launch their strikes. The primary finding of OEG's investigation was that the addition of a hunter-killer group did significantly increase the carrier's survival time, but that the benefits of the hunter-killer group's presence might not be felt immediately. If, for example, the task force and hunter-killer group arrived in a new area at the same time, full protection may be lacking for several hours, because the hunter-killer group would not have had time to perform an early sweep of the area. With proper coordination, however, the presence of a hunter-killer group was found to increase the expected lifetime of a carrier in the launch area by a factor of about three.

In addition to the undersea threat to surface ships, there was also a threat from the air. Hence, in the field of electronic warfare, OEG studied the use of projectiles loaded with chaff (material, such as strips of foil, ejected into the air for reflecting radar waves) in protecting a fleet against air attacks. The scenario of greatest concern in the use of chaff involved the defense of a naval task group against enemy land-based planes searching for it, and the launch of enemy air-to-surface missiles at long ranges. Neither the particular caliber of chaff projectile being studied nor tactics for its employment had yet been fully developed. OEG's role, therefore, was to derive several experimental tactics that would provide operational training in the use of chaff, as well as furnish further data for assessing and modifying fleet chaff doctrine. From the investigation it was concluded that the chaff projectile could probably weaken the enemy's search effort and induce errors in the homing circuits of the enemy's missiles, such that a small margin of safety could be gained for the targeted ship.

An analysis also was done of fleet logistic readiness for a limited war. The group considered ammunition and petroleum requirements and the adequacy of stock and replenishment shipping to meet those requirements. It studied the major problems of replenishing ships under way and of prepositioning ammunition and petroleum stores in the Mediterranean and Western Pacific. The computations were based on existing plans, forces, and estimated expenditure rates. In addition to determining requirements for the first three months of a limited war, the analysis also considered how requirements for prepositioned ammunition and petroleum for a war extending beyond three months would be affected by a concerted anti-shipping campaign by enemy submarines in the Atlantic and Pacific oceans.

OEG demonstrated that the number of ammunition ships then in the Mediterranean could not satisfy gun ammunition requirements for a major amphibious landing. The Sixth Fleet, it was found, could not rely on the one nearest base to meet its needs—even for air support operations alone—when fleet support was distributed among the several available Mediterranean bases. The group therefore recommended that the number of ammunition ships in the Sixth Fleet be increased by four. It also recommended that the navy consider specially loading one of these ships with gun ammunition, for use in rearming gunfire support ships during major amphibious operations.

In contrast to the situation with ammunition, the prepositioned petroleum reserves in the Mediterranean were found to be more than adequate to meet the requirements for a three-month supply. However, the number of oilers in the Eastern Mediterranean could not support a limited war in that region. Hence, OEG suggested that two additional oilers be deployed in case of a conflict in the Middle or Near East. As far as the Western Pacific was concerned, the number of oilers assigned there was sufficient to support three carrier strike groups and the same number of hunter-killer groups, provided Subic Bay remained available as a supply base. If Subic Bay became unavailable, only two of each group type could be sustained.

In sum, then, OEG's research program consisted of three primary areas of investigation: analyses of present capabilities, from which recommendations were derived to improve doctrine, tactics, and operational procedures; studies of future capabilities for long-term planning; and investigations of the technical aspects of strategic planning. The studies cited above are simply examples of the kinds of problems that engaged the group during this time.

**Organizational Reshuffling within CNA**

The years immediately following the establishment of CNA were marked by many changes. The first of these involved the separating of NAVWAG from OEG in August 1963, and a concomitant enlarging of NAVWAG's mission in order to emphasize cost-effectiveness analyses.[16] Within less than a year, then, CNA had grown from two to three coequal operating groups: OEG (including MCOAG), NAVWAG, and INS.

All three operating groups were in turn supported by the newly formed Research Group. In contrast with most of the projects of the operating groups, the Research Group's program consisted of broader-based studies. Such studies included development of basic methodology, evaluation of the engineering and scientific characteristics of different types of equipment, and parametric research. The latter, parametric research, enabled analysts to obtain results in advance for a variety of conditions likely to be encountered by a particular system. For example, a detection device might be studied to determine its expected range against each of a number of alternative combinations of target characteristics, including type, range, and velocity. Some of the study areas to which the Research Group directed its attention included: a theory of the distribution of search and reconnaissance; basic analytical techniques, such as the application of game theory; weapons and their effects; the hydrodynamics of various types of ships; the aerodynamics of planes, helicopters, missiles, and space vehicles; economic principles useful in selecting from among alternative military systems; and political and economic trends and international developments. To a lesser degree, the Research Group also assisted in the review of work performed by the operating groups, checking, among other things, for scientific validity.

In the same month that NAVWAG became independent of OEG, Wynn L. LePage, director of CNA and president of Franklin, decided to assign the members of OEG, NAVWAG, and INS to one of four new research divisions within the Office of the Chief Scientist, Frank Bothwell. One of the divisions was to specialize in operations research and mathematics, a second in the physical and engineering sciences, another in economics, and the last in strategic studies. The assignment to a division, however, in no way altered the basic association members had with their respective operating groups. Rather, the aim was simply to tie together in matrix fashion all those scientists in CNA who shared common backgrounds and interests, regardless of whether a scientist happened to be a member of OEG, NAVWAG, or INS.

The year 1965 proved even more restless than 1963. It all began in February of that year, when MCOAG was detached from OEG and made an independent group within CNA, as had happened with NAVWAG two years earlier. (This meant that for the first time in about twelve years, OEG was no longer responsible for a subordinate research group.) According to its charter, MCOAG's analyses for the Marine Corps were to address the following subject areas:

(1) Cost-effectiveness of alternative mixes of weapons, systems, and forces
(2) Landing force operations, involving the gathering, processing, and interpreting of data, and the study of action and exercise reports
(3) Operational performance of new equipment and the effectiveness of new organizations, tactics, and logistical techniques
(4) Research and development plans
(5) Tasks for carrying out the responsibilities of the Marine Corps of the future, and the "effect of the state of technology on the nature of equipment for the performance of these tasks, the capabilities required to perform these tasks, and the optimum weapons systems and techniques for achieving these capabilities and their adaptability to, and effects on, established Marine Corps policies."[17]

The director of MCOAG was located in Marine Corps Headquarters, reporting administratively to CNA but operationally to the Deputy Chief of Staff for Research, Development, and Studies (RD&S). The portion of MCOAG at Marine Corps Headquarters was augmented by Marine Corps officers who received direction from MCOAG's director. The portion of MCOAG at Marine Corps Schools in Quantico, Virginia, was assigned to provide analytical support to the Coordinator of Marine Corps Landing Force Development Activities. Some of MCOAG's scientists were assigned to Fleet Marine Force staffs, in response to requests for such assistance. If an office within Marine Corps Headquarters wanted analysis done, the request had to be channeled through the Deputy Chief of Staff (RD&S). The latter reviewed the appropriateness of such requests, assigned priorities, and controlled the distribution of study results. Requests originating from offices outside Headquarters—for either temporary or permanent attachment of MCOAG scientists to meet analytical needs on a short-term or ongoing basis—had to be submitted to the commandant of the Marine Corps for approval and handling.

A few months later, in the spring and early summer of 1965, CNA underwent several other changes. The first had a bearing on CNA's top management. Specifically, Dr. LePage decided to bow out of his CNA directorship and to relinquish the title and responsibilities to Bothwell. This meant that the roles of chief scientist—Bothwell's position for the preceding three years—and of CNA director were merged for the first time. In explaining his motives for this consolidation of duties, LePage noted: "I have always conceived of CNA as an organization of scientists run by scientists. The designation of Dr. Bothwell as Director and Chief Scientist gives full effect to that concept. It also accords complete recognition from the standpoint of organizational structure to the fact that the success of CNA depends on the quality of [its] scientific output." To help Bothwell manage his expanded responsibilities, Edwin A. Speakman was appointed assistant director. Creating the post of assistant director meant, however, the de facto elimination of the executive directorship held by Charles M. Mottley since early 1963.

Another extensive round of changes that occurred that summer centered on a new approach to the conduct of studies by CNA. A major reason for the changes was several study requirements put forth by Op-91 in his capacity as executive secretary of the CNA Policy Council. These requirements included a growing need for valid operational data, improved cost-effectiveness analyses, increased analytical support of operational commanders, and continuity of effort in strategic analyses. In addition, there was concern about the fragmentation of CNA's work and the possible duplication of expertise resulting from the fact that OEG concentrated on the short term, NAVWAG on the mid-term, and INS on the long term. Although there was no desire to disrupt this time-frame orientation of CNA's operating groups—it was, after all, a long-honored scheme that had basically worked well—a few shortcomings did need to be corrected. Hence, Bothwell made some changes designed to satisfy the Policy Council's several requirements, as well as CNA's own awareness of deficiencies.

One cause of this reorganizaton effort was the urgency felt by Bothwell to obtain assistance in two areas of responsibility—program planning and review—for which his office was accountable. Because of the pressure to deliver study results to the navy as fast as possible, it was often the case that not enough time was left for Bothwell's office to do the kind of in-depth quality review ideally called for. At the same time, the pressure to complete already-active studies in a timely fashion meant that plans for future research programs were inclined to be neglected. Bothwell therefore decided to attach to his office two new positions. One of these was the director of program planning, to which Sherwood C. Frey was appointed. Frey's function was to maintain up-to-date plans for all of CNA's current and potential studies. The other position bore the title of assistant chief scientist for program review, to be filled by OEG's director, Dr. Engel. As such, Engel was to review the quality of all studies, from inception to completion.

The vacancy left in the OEG directorship slot by the transfer of Engel was filled by James K. Tyson, a physicist with a doctorate from MIT.

Tyson's association with the group dated back to May 1942, when he became the tenth scientist to join the then-nascent ASWORG, OEG's World War II predecessor. Leaving the group shortly after the close of the war, he subsequently worked with the Armor Research Foundation at the Illinois Institute of Technology and with the army's Operations Research Office, affiliated with Johns Hopkins University. He also held the Chair of Physical Sciences at the Naval War College. Since rejoining OEG in July 1959, Tyson had served as a section chief (refer back to Figure 4-5) and, from August 1963, as director of the Operations Research and Mathematical Sciences Division within Bothwell's office. Then, in September 1964, he was appointed director of NAVWAG, where he remained until being named Engel's replacement in July 1965.

Another effect on OEG of Bothwell's reorganization effort was considerable added emphasis on data collection and interpretation. "Without the support of real checkpoints [that is, valid operational data] on our theoretical calculations," Bothwell observed in justifying his proposals, "the major issues facing the Navy—whether procurement or development decisions, tactical or strategic alternatives—remain unresolved or at best are shrouded in uncertainty. . . . CNA is keenly aware that its ability to produce better analyses on subjects requested by the Navy depends significantly on an improvement in the data base." Bothwell therefore decided to establish within OEG an Operational Data Acquisition Division, which was later renamed the Test and Exercise Division (Figure 4-9), with support from an Operational Data Base Section.

Additionally, the team structure of OEG, organized according to warfare areas, was to be strengthened. The purpose was to permit NAVWAG's studies to benefit, too, from the special understanding these teams (or "sections," as they were now called) had of each warfare area. It seemed to make more sense simply to enhance OEG's warfare teams—which were then expected to respond to NAVWAG's needs, as well as to OEG's—than to duplicate the team structure within NAVWAG itself. So, the second major component of OEG became the Warfare Models Division (Figure 4-9). The main service provided NAVWAG by the warfare teams that made up this division of OEG came in the form of combat models designed to relate the effectiveness of combat systems to the systems' own characteristics and to the characteristics of the enemy threat.

As had always been the case, the field program, whereby analysts were sent to naval commands, and the scientific analyst program, whereby members were assigned to warfare desks within OpNav, remained key elements of OEG's program. As Bothwell was enacting these changes, some eighteen analysts were already in the field, assisting the staffs of the Commanders in Chief of the Atlantic and Pacific Fleets, and the Commanders of the Second, Sixth, and Seventh Fleets, among others.

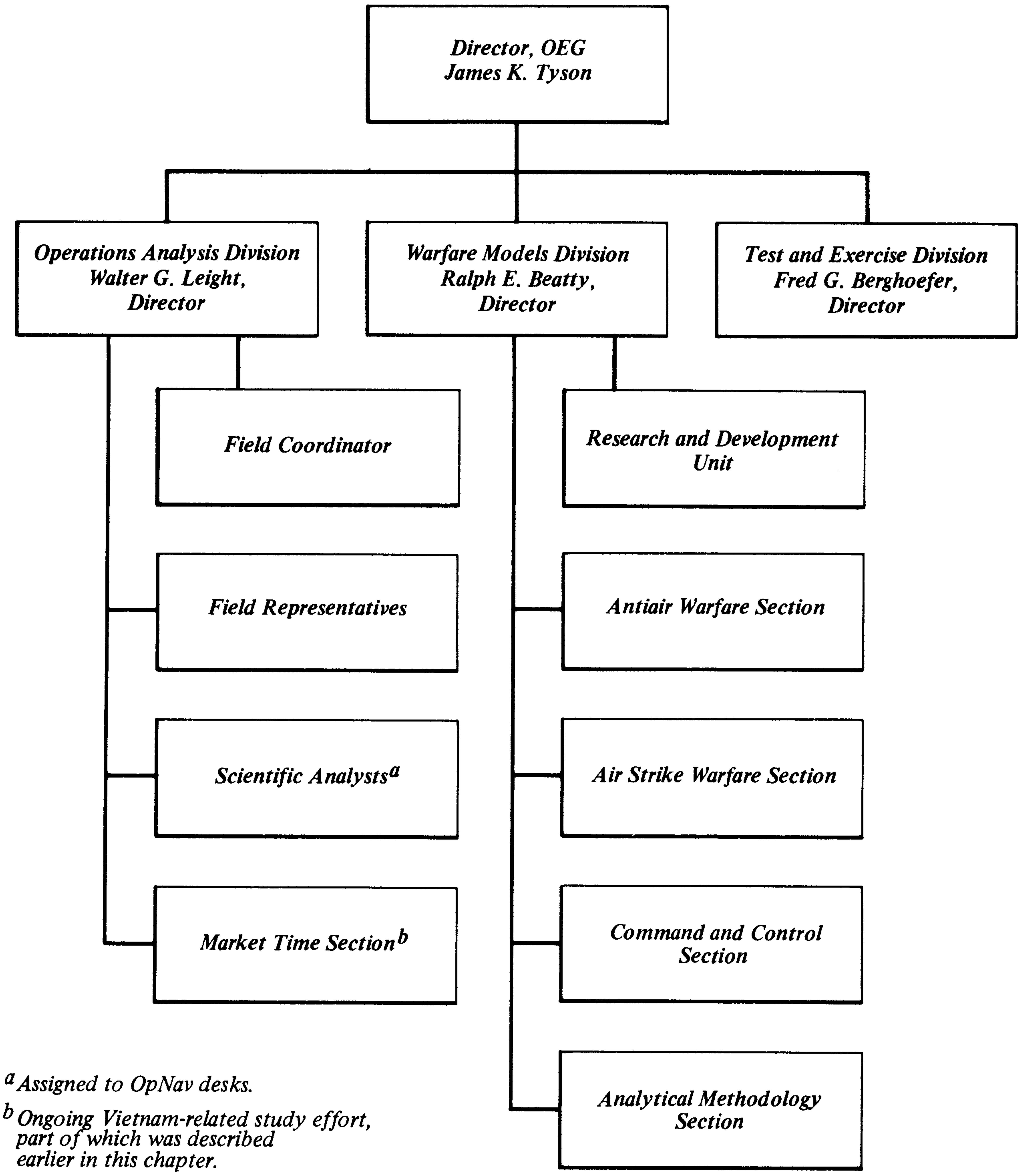



Figure 4-9. Organization of OEG (Mid-1960s)

Another nine analysts divided their time among sixteen warfare desks within the CNO's office: Submarine Warfare (Op-31), Fleet Operations (Op-33), Strike Warfare (Op-34), Electronic Warfare Systems (Op-352), Air Weapons System Plans (Op-05W), Strategic Plans (Op-60), and Communications (Op-94), to name just a few. The pressure to enlarge these activities, though always present, could no longer be deflected, largely because of the recent sharp increase in the navy's involvement in the war in Southeast Asia. Another reason to enlarge the field program was to help satisfy a need for additional combat data on which OEG/Washington relied. Bothwell decided, therefore, to have the expanded field and scientific analyst programs make up the third major component of OEG, the Operations Analysis Division (Figure 4-9).

The sweeping changes unfurled during the summer of 1965 did not end there, however. In addition to a need for the development of combat models, which had become the preserve of OEG's new Warfare Models Division, there was also a need for the development of engineering models, whose purpose was to relate system characteristics and effectiveness to cost. These models were often referred to as "rubber designs," that is, mathematical formulas in which various elements could be altered or "stretched" in order to learn how engineering changes might affect the final product. These types of models, resulting from studies of equipment cost and performance, were especially useful in determining trade-offs among competing systems and were thus vital to the preparation of development programs. The strong interest of the Department of Defense in having the navy stress cost as well as the operational effectiveness of alternative engineering designs imposed a further demand on CNA to use such models. Though CNA had, in fact, already produced some engineering models (for aircraft carriers and various types of escorts), this work clearly needed to be expanded to include many other systems, such as aircraft, weapons, and sensors. Inasmuch as this work was largely of an engineering nature—as opposed to the conventional operations research work that was at the heart of OEG's combat models—Bothwell proposed establishing a new operating group within CNA, called the Systems Evaluation Group (SEG).

Headed by Donald H. Witcher, SEG consisted of three divisions. The Cost Analysis Division was expected to develop and apply models that would help the group better understand the costs involved in systems of different physical and operating characteristics. The Technical Analysis Division was similarly expected to develop models and methodologies, but for gaining insight into the relationship between performance and a system's physical characteristics. Finally, SEG's Technical Analysis Division was given the task of obtaining the most recent engineering data, by developing close ties with industry and the navy's material bureaus and laboratories. This role called for considerable coordination with the other two divisions of SEG, since the data were mostly for their use in attempts at modeling. From time to time, SEG was also assigned special projects on an ad hoc basis that did not precisely fit the main work of the group. For example, it examined ways of lowering the number of naval aircraft in the supply pipeline relative to the number of planes actually out in the fleet, and it examined the performance of an improved shore bombardment ship capable of providing deep and effective fire support of amphibious assault forces.

Also during this period, a major addition to the already numerous roles of the Office of the Chief of Naval Operations had a bearing on who in the navy served as CNA's main point of contact. As part of an extensive reshuffling of naval administration that took place in 1966, the CNO, Admiral David L. McDonald, decided that the practice of operations research and systems analysis in the navy had mushroomed to the point that a central office was needed to tie these activities together. This coordinating office was named the Systems Analysis Division (Op-96), with Rear Admiral Elmo R. Zumwalt chosen in the fall to be its first director. Zumwalt, in turn, was to operate under the Director of Navy Program Planning (Op-090).

The new office had four main functions. The first was to provide the CNO with his own analytical capability, with emphasis on weighing the relative merits of alternative force levels, weapons systems, personnel levels, and so on. Under Zumwalt, the division established, for example, the basic characteristics for a class of destroyers, called Spruances, intended to replace the aging ships then beginning to burden the American fleet. It also conducted a study of surface-to-surface missiles that led directly to the development of the Harpoon antiship cruise missile. A second function of the division involved coordinating the CNO study program with other navy study efforts. Third, the division was responsible for preparing the annual budget estimates for the CNO, which included appropriations for CNA.

The fourth function—and one especially important to CNA—was to review the progress and results of studies done for the navy. (Op-96, in fact, had been designated deputy scientific officer to CNA, under Op-090.) Five of the six groups that made up Op-96 contributed to one aspect or another of this review process.[18] The General-Purpose Warfare Group (Op-962) had an oversight role with respect to studies pertaining to surface, subsurface, antisubmarine, and tactical air warfare. The Strategic Warfare Group (Op-963) monitored studies dealing with strategic warfare, as well as chemical, biological, and radiological warfare. Logistics, personnel, and communications, command, and control came under the purview of the Warfare Support Group (Op-964). Last, the Military and Political Intelligence Appraisal Group (Op-965) focused on studies of naval intelligence and surveillance systems, among other related issues. These four groups within Op-96 based their judgments of study progress on feedback from CNO project officers who were assigned to each study. The Studies Management Group (Op-966) served as a conduit for this feedback, so that the information could be directed to the right people in the right form. These project officers, in turn, provided a means for Op-96 to pass along guidance to CNA on its studies. By 1968, the division had more than twenty officers taking part in CNA's research program.

The same year that saw creation of the Systems Analysis Division (Op-96) also saw the relocation of INS from Cambridge to Washington. Because of its geographic separation from the rest of CNA, INS had been enjoying considerable autonomy. Bothwell and others believed, however, that close control over the direction and quality of INS's work could be achieved only if there was increased day-to-day oversight. Although not all of INS's people chose to stay with the group, the move to Washington nevertheless went into effect. Hence, for the first time since 1962, when OEG and INS were first brought under one management, all of CNA's operating groups—OEG, INS, NAVWAG, SEG, and MCOAG—were now under the same roof.

The one last change to be mentioned here occurred a few months later, in January 1967. Edwin A. Speakman, who just a year and a half earlier had been appointed assistant director of CNA, was elevated by LePage to the dual position of vice president of the Franklin Institute and director of CNA. In this capacity, Speakman was to serve as the operating head of CNA, with complete responsibility for its overall management, including the allocation of resources and the performance of work by OEG and the other groups. He was also to act as the principal channel of communication between Franklin, CNA, and the navy. Importantly, however, scientific matters were to be delegated to the technical director and chief scientist, which was Bothwell's new full title following Speakman's promotion. According to LePage, Bothwell was expected to be able to devote himself "more effectively to the analytical problems that needed his guidance and daily counsel," now that he had been disencumbered from administrative affairs.

## The Navy's Selection of a New CNA Sponsor

This last spate of changes typified those first five years following the establishment of CNA in 1962. However, for OEG—perhaps because of its twenty-odd-year tradition—this period proved less turbulent than it did for the rest of CNA. Indeed, OEG played a stabilizing role. To begin with, its relinquishing of NAVWAG and MCOAG had the positive effect of enabling the group to concentrate on the types of analytical issues that were called for by its original charter. At the same time, the final breaking away of these spin-off groups proved a boon to CNA for it provided the center with two additional operating groups whose areas of specialization complemented those of OEG and INS. OEG, in effect, had infused the new-begotten CNA with a large corps of talented and experienced scientists—whether through OEG proper, or through NAVWAG and MCOAG—who provided CNA with a solid foundation on which to build.

Yet, the navy continued to express dissatisfaction with the Franklin Institute's management of CNA's contract. According to Wakelin's replacement as assistant secretary of the navy, Robert A. Frosch, there were several "running difficulties" that the navy was anxious to clear up. One major difficulty had to do with concern over the timeliness, quality, and realism of studies by CNA under Franklin.[19] Dissatisfaction was also voiced over the many changes Franklin had initiated in the management of CNA over the last four and a half years. In fact, disquieted by these several management-level shifts, and suspecting that they had contributed to unrest within CNA, Frosch called a special meeting of the CNA Policy Council (held on 11 January 1967) to air some of the navy's grievances.

Then, on 1 February 1967, Frosch informed Dr. LePage that the navy had begun to examine the possibility of an alternative to Franklin as CNA's sponsor. Over the following weeks, three avenues were explored to help the navy make up its mind as to the most appropriate course of action. One possibility was simply to remain with the Franklin Institute—although a decision on this was to be held in abeyance until Franklin had had a chance to address what had been troubling the navy. A second option was to form a new and independent nonprofit corporation expressly for the purpose of administering CNA's contract. This option had the least appeal, for three reasons. First, there was apprehension over whether such an organization—with a strong vested interest in the continuation of the contract—could remain objective in its decisions on CNA's study program. Second, there was concern that an independent and possibly free-spirited organization might decide to branch out into fields other than work for the navy. Finally, there was a preference for choosing an organization with a proven record of quality.

The third and most promising option being considered by the navy was to find a new parent organization from among the other nonprofit groups around, or from a number of potentially interested universities. Of the nonprofit groups, the Rand Corporation, Cornell Aeronautical Laboratories, and the Stanford Research Institute (SRI) were contacted. Of these, SRI seemed both the most interested and the most able to provide the right kind of backing. The navy therefore asked SRI to consider seriously how they would manage CNA if they were selected. The navy's clear preference, however, was for a university, because of the navy's successful association with the academic community over the years (including, of course, with Columbia University for ASWORG's contract and with MIT for OEG's contract). So, during the early part of 1967, the navy communicated with Northwestern University, Johns Hopkins University, Princeton University, and the Universities of Rochester and Virginia. These schools were selected because they had some background in related kinds of analysis and in systems analysis in particular. Each had members on its faculty or administrative staff who were known by people in the Navy Department or DoD to have done similar work. As it turned out, Rochester and Virginia expressed the most interest.

The University of Rochester's interest, however, was not automatic. In fact, the university's chancellor, Dr. W. Allen Wallis, held strong reservations when first approached about managing CNA. His reasons, in some respects, were an echo of MIT's some twenty-five years earlier. That is, CNA's work appeared to have little relation to the university's main academic pursuits. He also thought that the university's managerial staff was too small to handle another major responsibility like CNA's contract.

Nonetheless, on 13 April 1967, Chancellor Wallis met with Secretary of the Navy Paul Nitze—at the latter's request—to discuss the prospects further. Secretary Nitze advanced three principal arguments to support his contention that Rochester was well suited for the task. The first was that Rochester had working for it several people unusually qualified to run CNA responsibly. For example, William Meckling, dean of the College of Business Administration, had been director of OEG's Economics Division and later of NAVWAG, before leaving CNA to become dean in September 1964. Prior to that, he had been a systems analyst at Rand. Patrick Parker, then associate dean under Meckling, had been on CNA's staff between 1963 and 1965, and subsequently on the staff of the assistant secretary of defense for systems analysis. The university's dean of the College of Engineering, Robert Loewy, was a former chief scientist with the air force. In addition, Elliott Montroll, Rochester's Albert Einstein professor of physics and astronomy, had served as a director of research at the Institute for Defense Analyses (IDA). Lastly, Wallis, himself, had had experience with operations research and systems analysis with the Office of Scientific Research and Development (OSRD) and Rand. Hence, it was clear that Rochester was well staffed with administrators whose backgrounds gave the school unique qualities to run CNA.

Nitze's second argument was that the navy had few good candidates at its disposal. Many other universities, for example, preferred at the time to refrain from involving themselves in defense-related research because of the fear of student and faculty upheaval. The third and final point was the importance to the nation's security of having an organization like CNA be able to conduct objective and high-quality studies of military issues. One way to ensure that the scientific excellence and objectivity of CNA was preserved was to arrange for a strong link between it and the academic community. The outcome of this meeting with Secretary Nitze was a change of mind by Wallis, who began to look favorably on the idea of managing CNA's contract.

By May 1967, the navy had grown increasingly convinced that its first option—to stay with the Franklin Institute—was no longer viable, due to its supposed disenchantment with the institute's exercise of CNA's management. In the meantime, SRI informed Nitze that, after having examined the proposal, it felt reluctant about taking on the responsibility for CNA.

In any event, by this time the navy was beginning to tilt even more toward the selection of a university. There were several reasons for this. A university's emphasis on intellectual excellence, it was believed, would set the standard for CNA. Additionally, the academic environment of a university, with its many available disciplines, would provide a rich source of expertise that might occasionally be tapped. Further, a university was expected to show a greater willingness than, say, a corporation to let CNA pursue an independent course in its study program, because CNA's work would remain outside the mainstream of a university's academic concerns. Finally, the navy felt that a university would ensure a conservative management philosophy.

On 8 May, the University of Rochester sent a letter to Secretary Nitze indicating its desire to manage CNA; the University of Virginia did likewise on 17 May. Chancellor Wallis's letter delineated in considerable detail the basis for a contract that would permit Rochester to guarantee CNA's workability. Many of the suggestions contained in the letter were originated by Patrick Parker and William Meckling, mentioned earlier as being, respectively, the associate dean and dean of the University's College of Business Administration, and former CNA employees.

A total of twelve conditions were put forth, nine of which had special significance. The first proposal called for 25 percent of CNA's budget to be allocated to CNA-initiated—as opposed to navy-requested—research, and for another 6 percent to be spent on academic leave. The goal of this first proposal was to attract and keep the best possible analysts. Next, Wallis suggested that 5 percent of the budget be used to encourage unclassified research at the university, on issues of possible use to the navy. The kind of research undertaken would be at the university's discretion, but would likely be in such subjects as statistics, systems sciences, applied mathematics, and the social sciences. These funds would provide the "most tangible benefit" to the university in return for its assuming CNA's administration. The remaining and largest portion of the budget—64 percent—would, of course, go to support CNA's navy-initiated research program.

The fourth of Wallis's conditions devised procedures whereby CNA and the relevant officers within the Office of the Chief of Naval Operations (such as Op-090 and Op-96) could agree on each year's study program. The aim was not to make the program rigid but to prevent the program from being subject to frequent and disruptive change.

It was also strongly recommended that the top several people running CNA be given "prompt and systematic access to important policy documents and data which affect the planning and utilization of Naval forces." Wallis added that the director of CNA should be "considered part of the highest councils of the Navy, in matters relating to force planning and analysis, evaluations of fleet operations and readiness, and . . . estimates of the effectiveness of present and future Naval weapons systems."[20] Unfortunately, this situation had not always existed over the previous four and a half years. Just as important, Rochester urged that CNA studies be distributed as widely as appropriate, regardless of whether the navy happened to agree or disagree with the findings. This requirement was needed to ensure CNA's objectivity; the navy, however, would be able to express its dissent in the front of such a study, if it felt so inclined.

The eighth condition proposed revising how naval officers were assigned to CNA. That is, these officers should be accountable first and foremost to CNA, rather than to OpNav, to prevent their feeling compelled to support preconceptions held by the navy. The result, it was hoped, would be greater independence of thought. Finally, Wallis proposed forming a group of people to review the quality of CNA's work and to help choose its president and other top management staff.

In closing, Wallis asserted that "all of the foregoing conditions seem to me necessary to provide for a healthy relationship among the University, CNA, and the Navy; to provide the basis on which an organization of the highest quality, compatible with the broader objectives of the University and the Navy, can be built and maintained; and to insure the maximum effectiveness of the important work which CNA will do for the Navy."

As a consequence of this letter, and because of the experience of several of the University of Rochester administrators, the navy decided to convene with university officials. A meeting was therefore held in Secretary Nitze's office on 30 May, with Wallis, Meckling, and Parker present. During that meeting, substantial agreement was reached that Rochester would be the navy's choice, and that the contract would reflect most of the points outlined in Wallis's 8 May letter. Another issue brought up at the meeting was the university's choice of Charles J. DiBona as head of CNA. At the time of the meeting, DiBona was still on active duty as a lieutenant commander in the navy, although he had submitted his resignation on 11 April. Secretary Nitze and the Chief of Naval Operations, Admiral David L. McDonald, initially objected, however. Their reason was that DiBona's switch from a fairly junior officer to the president of CNA might meet with unease among admirals and other high-echelon people, among whom he would suddenly have to be treated as a peer.

To Wallis, however, it was absolutely critical that a "first-rate" head of CNA be selected. Of the several candidates considered, DiBona stood out as the best qualified. He had graduated second in his class from the U.S. Naval Academy in 1956 and had been selected as a Rhodes Scholar, receiving first-class honors in politics, philosophy, and economics from Oxford. During his eight years in the navy, he served on both submarines and destroyers. Then, in April 1963, he went to the Office of the Assistant

Secretary of Defense (Comptroller), where he worked as an analyst for Alain C. Enthoven, deputy assistant secretary of defense for systems analysis. Beginning in August 1966, he spent his last year of naval service as special assistant to the under secretary of the navy, Robert H. B. Baldwin. There was no question, then, that DiBona was well qualified to head CNA. So, within a week of the 30 May 1967 meeting in Nitze's office, a compromise was arrived at between the navy and Rochester. It was agreed that Rochester's William Meckling would occupy the presidency of CNA until the end of 1967, during which time DiBona would act as the executive vice president. DiBona would then become president on 1 January 1968, providing everything had worked out satisfactorily in the meantime—especially his relations with high naval officers.

With the choice of Rochester final—short of a signed contract—the navy proceeded to inform members of Congress about the proposed change from the Franklin Institute to the University of Rochester. On 23 June 1967, Admiral Zumwalt, along with Admiral John K. Leydon, Chief of Naval Research, visited the Armed Services and Appropriations Committees of both the Senate and House.

Then, on 27 June, Secretary Nitze met with Dr. LePage, to advise him of the navy's decision to terminate the contract with Franklin as of 31 July. A follow-up letter to LePage summed up the situation as follows:

> The Navy has for some time been critically examining its relationship with the Center for Naval Analyses and the Franklin Institute to ascertain the degree to which the characteristics of the sponsoring contractor impinge on the basic problem of establishing and maintaining a competent and objective analytical group working on naval problems. Our conclusions from this examination have led us to believe that a return to a university as sponsor would be of major importance in the continuing improvement of the Center . . . .[21]

Two days later, Admiral Zumwalt, Chancellor Wallis, and William Meckling addressed an assembly of CNA staff to discuss some of the major implications of the change in sponsorship. Shortly after the contract with Rochester went into effect on 1 August 1967, further clarification was provided by Meckling in his new capacity as CNA president. He reviewed some of the major provisions in the contract, many of which reflected (sometimes verbatim) the conditions spelled out in Wallis's 8 May letter. The contract specified, for example, that CNA's budget be divided into three areas: 72 percent to support analyses conducted in accordance with agreements reached with the navy, 23 percent to support research that CNA decided was important (even over navy objections, if necessary), and 5 percent to fund unclassified research conducted on the university's campus.

To encourage a high degree of stability, CNA's study program was to be "subject to minimum revision. . . .To this end, the Directors of CNA's operating groups [OEG, INS, NAVWAG, SEG, MCOAG] and Op-96 [the Director of the Systems Analysis Division] will formulate an annual CNA study plan, addressing the work to be done and the allocation of resources." The program could then be altered only if the president of CNA and the navy's scientific officer to CNA, the Director of Navy Program Planning (Op-090), agreed that there had been a significant change in priorities. In short, the navy could not unilaterally stop a piece of analysis.

Also included in the contract was the provision that studies would be distributed as widely as possible, regardless of their findings.[22] It was felt that such a guarantee was a prerequisite for useful and relevant research, and for the "scientific integrity" of analysts. The wide dissemination of results was expected, furthermore, to stimulate a healthy debate among diverse audiences, thereby providing feedback of use to future studies.

In addition, naval officers assigned to participate in CNA's study program were to be under an assistant technical director for naval matters (later shortened to simply director for naval matters, or DNM). This position was to be filled by a senior captain selected by the navy, but subject to the acceptance of the president of CNA. The new arrangement also provided for the lengthening of an officer's stay at CNA to up to three years and the broadening of his privileges and responsibilities to include, among other things, the directing of certain studies. The purpose in making these changes was to derive the greatest gain from an officer's participation in CNA's work—that is, to benefit from his practical operating experience and technical knowledge, and from his "user's" point of view.

Finally, a Board of Directors was formed, consisting of senior officials of the University of Rochester and other persons who had distinguished themselves in their own fields and who had an intimate familiarity with defense analysis. Acting in an advisory capacity, the board was to meet three times a year, with the purpose of helping the president of the University of Rochester evaluate CNA's work. The board was designed, in effect, to serve as a guarantor of high-quality analytical standards at the center. However, while the university, through means of the board, had a strong oversight role, it also had the responsibility of protecting CNA's independence by not permitting itself to intrude into the results of studies. The university stressed this point to the Senate Armed Services Committee in 1972:

> We do not attempt to dictate the findings of CNA's studies. Just as we expect the Navy to refrain from applying pressure to the CNA study program, we refrain. Pressure from either source—by the Navy or the University—would taint the independence of CNA and the

> quality of its research product. From our own point of view, identification with the findings of [a] study would risk drawing the University into too controversial a role. As an institution, the University neither approves nor disapproves government policies, including foreign policy and military activities. We are, however, interested in public service, and for that reason we provide for CNA the conditions that help the Navy find objective answers to its cost, manpower, and policy problems.

Although the new contract gave CNA considerable freedom, it also imposed new responsibilities, especially in the planning of its study program. Meckling considered this function to be as important as any that he, DiBona, and the heads of the operating groups would have. Hence, to support him in this aspect of running CNA, Meckling created the position of senior scientist in the Office of the President, to be filled by two people: Frank Bothwell and, from his OEG directorship, James Tyson. Besides assisting Meckling in the planning of CNA's study program, they were to take part in formulating individual studies throughout the organization, and in reviewing their progress. They were also expected to form the nucleus of any study group that had to be assembled to respond to urgent requests for analytical assistance coming from the top echelons of the navy.

Meckling's choice to replace Tyson as OEG's director was Dr. Erwin Baumgarten. Since first joining OEG in the middle of the group's Korean War mobilization, Baumgarten had had several fleet assignments, had held the Chair of Physical Sciences at the Naval War College, and had been attached to NATO's assistant secretary general for sciences as a visiting professor on loan to the Ministry of Defense in Bonn, Germany. For the year and a half before his appointment as OEG director, he had headed INS.

Dr. Baumgarten's assumption of OEG's leadership could not have come at a more critical time. Just as OEG had been embroiled in the events of the Korean War when Baumgarten joined the group back in the early 1950s, it was now about to be caught up in the events of Southeast Asia. For the same reason, it was fortunate, indeed, that the search for a solution to CNA's management problems had ended so favorably. With the responsibilities that loomed immediately ahead, OEG (and the other operating groups, too) could not afford to be distracted any longer.

# 5

# New Wartime Responsibilities and the Emergence of Today's OEG

## The Navy's Involvement in Southeast Asia

Although the nation's attention tended to be riveted on the ground battles in Southeast Asia, the navy's role both on the surface and in the air was equally crucial. A simple but generally overlooked fact is that the other aspects of the war could not have occurred at the levels they did if the navy had not enjoyed uncontested use of the seas. Indeed, fully 96 percent of the prodigious quantities of materials needed to run the war in Vietnam was transported by ships. Furthermore, naval power in its own right was exercised along the entire coastline of Vietnam, on its rivers and canals, and, especially, in its airspace.

One of the navy's early large-scale efforts in the Vietnam War was Market Time, an operation discussed briefly in the last chapter. Until 1964, the Viet Cong had made do with an assortment of Soviet, Chinese, French, and captured American arms. By then, however, pitched battles had become common enough to warrant a switch to standard weapons, using the same calibers of ammunition. This meant that North Vietnam would have to accelerate its shipment of arms to the South, with sea routes the most favored means.

In January 1965, a team of naval officers, led by Captain Phillip H. Bucklew, went to Vietnam to survey the infiltration problem. The so-called Bucklew Report concluded that the only way to stop the supplies to the Viet Cong was for U.S. forces to augment Vietnamese naval forces. The study's conclusion was not acted on immediately, however, because its other observation—that increased sea patrols would have to be accompanied by the blocking of land and river routes—needed to be acted on simultaneously to achieve success.

Then, on 16 February, a camouflaged, 100-ton-capacity ship was sighted in Vung Ro Bay on South Vietnam's central coast. Air strikes were called in, resulting in the sinking of the ship in the bay's shallow water; another strike was ordered against an area on the beach where crates were seen. Over the next few days, confusion ensued as Vietnamese Special Forces attempted to recover or destroy the supplies on the sunken ship and on shore. The episode, later dubbed the Vung Ro Incident, confirmed two long-held beliefs. The first was that more than just one such shipment must have been made, for the caches on shore were large. (The ship itself was loaded with enough supplies to outfit an entire enemy battalion.) The second was that South Vietnamese forces, which had performed disappointingly, were unable to prevent these infiltration efforts without U.S. assistance.

As a result of the Vung Ro Incident, a meeting was arranged in March 1965 by General William C. Westmoreland, commander of the U.S. Military Assistance Command, Vietnam, to discuss arrangements for combined U.S.-Vietnamese patrols. Also attending the week-long meeting were representatives from the Commander in Chief, Pacific (CinCPac), and Commander in Chief, Pacific Fleet (CinCPacFlt). Two kinds of seagoing traffic were thought to account for North Vietnam's efforts at infiltration: junks that traveled up and down the coast and mingled with similar craft engaged in legitimate trade; and ships at least as large as a trawler that approached the coast in a perpendicular course.

To interdict the first kind of traffic, the conferees concluded that "the best tactic . . . would be to assist and inspire the Vietnamese navy to increase the quality and quantity of its [own] searches." To deal with the trawlers, they recommended that a conventional patrol be conducted by U.S. Navy ships and planes. For this purpose, they recommended that a patrol zone be established, extending forty miles from shore, and that authorization be gotten from South Vietnam to "stop, board, search, and, if necessary, capture and/or destroy any hostile suspicious craft or vessel found within [its] territorial and contiguous zone waters." The Joint Chiefs of Staff approved the proposal on 16 March; the plan went into effect that same day, with two destroyers reporting for duty. The operation was given the code name Market Time a week later. On 1 August, after several months of quite rapid expansion, operational control of Market Time passed from Commander Task Force 71 (CTF 71) to Commander Task Force 115 (CTF 115), the new designation for the Commander of the Coastal Surveillance Force. (Both commands received analytical support from OEG, as mentioned in the last chapter.) The operation was later credited with having forced the Viet Cong to modify their supply system extensively. It was estimated that during 1966, for example, Market Time cut the enemy's seaborne supplies from three-fourths of all he received to about one-tenth.

While Market Time forces were trying to seal off the coast, another operation, called Game Warden, got under way. The purpose of this operation was "to assist the government of South Vietnam in denying the enemy the use of the major rivers of the [Mekong] Delta and the Rung Sat

Special Zone" (Figure 5-1)—a goal recommended earlier by the Bucklew Report. To accomplish this mission, the navy formed the River Patrol Force (Task Force 116) in December 1965, under Rear Admiral Norvell G. Ward. It was planned that Game Warden forces would initially be built up to consist of 120 river patrol boats, each bristling with an array of weapons, and supported from the air by UH-1B helicopter gunships piloted by army personnel until navy crews could replace them in late 1966. Also, a dock landing ship (LSD) and tank landing ship (LST)—later replaced by four specially outfitted LSTs—were stationed in the region of the Delta to serve as floating bases for the patrol boats. (Later, however, it was found that bad weather, particularly in the monsoon season, too often impaired patrol boat operations, prompting the navy to abandon its offshore basing scheme and turn to the use of support bases in the rivers themselves.)

In April 1966 the first patrols began in the Rung Sat Special Zone, a twenty-mile-square area of dense vegetation and swamps ideally suited to guerrilla warfare. The appeal of the area to the Viet Cong came also from its proximity to the main transportation channels bringing shipping to Saigon. By year's end, the Viet Cong had lost control of the area, and were forced to relocate many of their training sites, munitions dumps, and medical centers. Then, a month after Rung Sat operations began, patrols were extended into the Delta, an equally favored base for Viet Cong activities. Over the ensuing months, the number of units involved in Game Warden rose, reaching a total of 155 of the specially equipped patrol boats by 1967, and 230 by 1968. These, in turn, were supported by increased numbers of helicopter gunships, mobile and non-self-propelled support bases, minesweepers, and craft borrowed from Market Time.

To complement Game Warden, the navy began planning what at first was called a Mekong Delta Mobile Afloat Force. As first envisioned in the latter part of 1966, the force was to consist of assault craft capable of high mobility in rivers, and embarked troops whose mission entailed sustained search and destroy operations. As discussions about the plan progressed, a floating base was added, designed to accommodate a full army brigade[1] and whatever the navy needed to provide support. Elements of the new force arrived at Vung Tau in early January 1967 and began training with the 2nd Brigade of the U.S. 9th Infantry Division, which had been reorganized to better fit its new role. A few days later, CinCPac designated the force Task Force 117, or, more descriptively, the Riverine Assault Force. The force was officially activated on 28 February, under the operational control of Commander Naval Forces, Vietnam, Rear Admiral Ward, who was relieved in April by Rear Admiral Kenneth L. Veth.

Early operations centered on Rung Sat, to help clear the area of Viet Cong who were increasing their attacks against shipping traveling the waterways between Saigon and the sea. The Riverine Assault Force did not

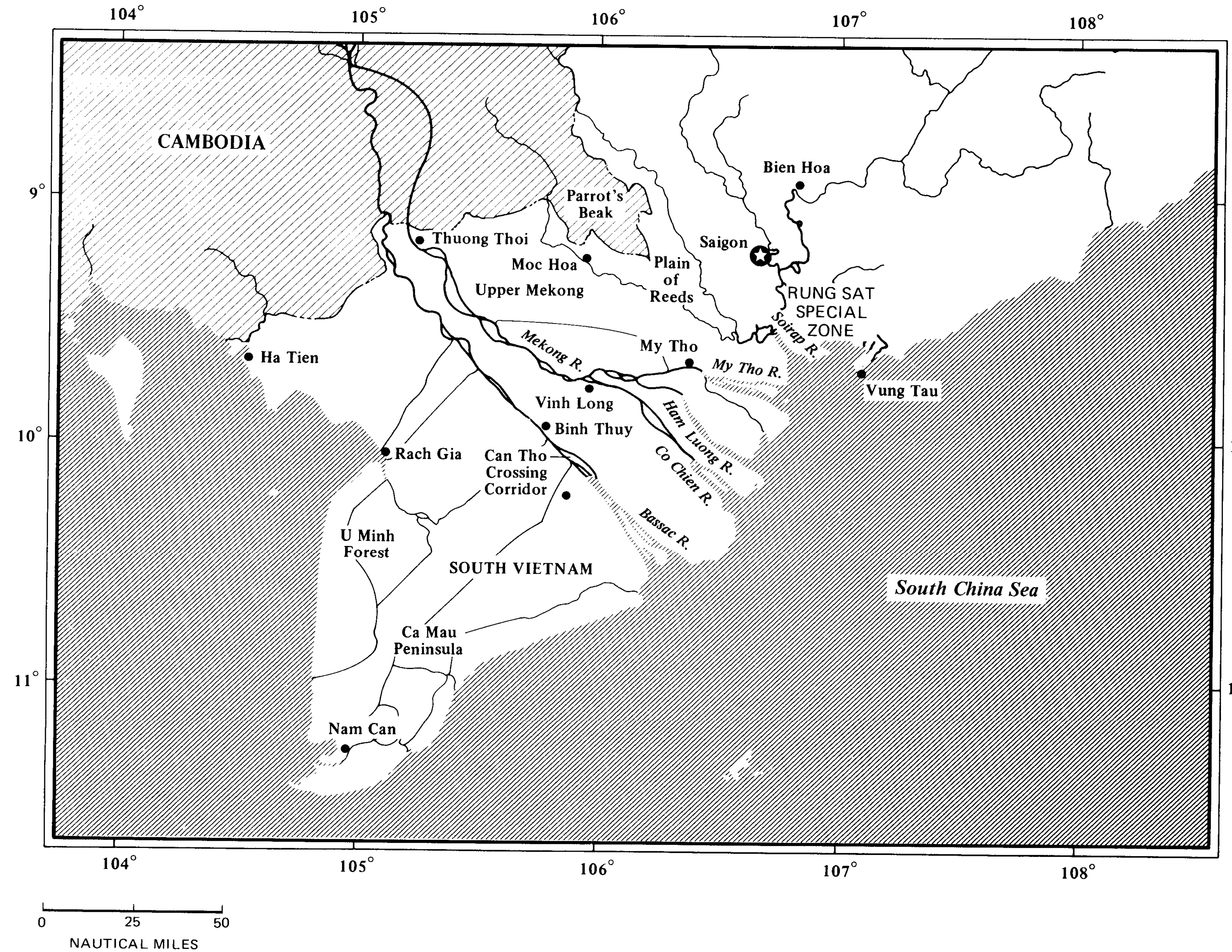



Figure 5-1. Mekong Delta and Rung Sat

become fully operational, however, until summer, when it began extensive actions in the Delta, too. The assault craft, developed specially for this kind of operation, proved immensely versatile. Besides being able to drop off and pick up troops, it could also provide close gunfire support, supply ammunition, and evacuate the wounded. Furthermore, it seemed able to go wherever navigable waters were available. Supporting it were helicopters and fixed-wing aircraft, and an assortment of weapons, such as 105-mm howitzers mounted on barges.

The most severe test of the river forces came during the Tet Offensive of 1968, when the Viet Cong threw their whole weight behind an assault on the cities of South Vietnam. The massive scale of the offensive gave unmistakable credence to the claim that despite the activities of Market Time, Game Warden, and the Mobile Riverine Force, large amounts of material were still getting through via the waterways. The explanation for this was threefold. First, because of limited resources, patrols had to be restricted to just the major rivers, leaving enemy operations in most of the smaller rivers unhampered. Also, as Market Time forces succeeded in curbing infiltration from the sea, the enemy simply turned to inland supply routes that crossed the borders of Cambodia and Laos. Last, South Vietnamese ground forces had resisted patrolling the banks of rivers—because of a preference for more familiar search-and-destroy missions—even though such patrols were essential to the effective and safe conduct of waterway interdiction. Even after taking these deficiencies into account, however, the river forces performed well. In IV Corps, for example, the Mobile Riverine Force managed to counterattack again and again during the Viet Cong offensive and was later commended by General Westmoreland for having "saved the Delta."

Evidence began to mount that enemy supplies were indeed being transported across the Cambodian border. Some of these supplies were entering South Vietnam west of Chau Phu, some were coming across the Plain of Reeds, and still others were crossing the border at the "Parrot's Beak," west of Saigon. These crossing points had effectively been beyond the reach of Game Warden operations, where only thin coverage could be achieved. The new Commander Naval Forces, Vietnam, Vice Admiral Elmo R. Zumwalt, decided in the fall of 1968 to combine assets from Market Time, Game Warden, and the Mobile Riverine Force—in addition to elements of the Vietnamese navy—in order to begin a concerted effort to close off the Cambodian border. This large-scale operation was subsequently called Sea Lords, an acronym for Southeast Asia Land, Ocean, River, and Delta Strategy. Its aim was to set up a barrier extending along the Cambodian border, from the Gulf of Thailand to an area between Parrot's Beak and the outskirts of Saigon. The barrier, in fact, consisted of four separate campaigns, with the first launched in November 1968 and the last under way exactly a year later. Their success was attested to by the sharp increase in contacts with the enemy, resulting in heavy Viet Cong losses and the destruction or seizure of large quantities of supplies. As a significant outcome, the enemy was prevented from shipping and stockpiling enough material in the Delta to unleash, for some time, anything like the massive assault of Tet.

Besides conducting surface operations, the navy also took the war to the air. In mid-May 1964, navy aircraft began Yankee Team operations, in which planes were sent over Laos to conduct reconnaissance missions. More than half of these planes reported antiaircraft fire during the first month of operations, resulting in the loss of two planes (and in hits on several others) in that period. The first of these two casualties—in fact, the first combat loss of a high-performance, fixed-wing navy aircraft—occurred on 6 June when a Crusader, launched from the carrier *Kitty Hawk,* was downed by ground fire. As the amount of antiaircraft fire slackened shortly after the second loss, however, fewer planes were hit, resulting in no further losses to navy Yankee Team aircraft over the next half a year.

Naval air power was brought to bear in a more dramatic way following the second Tonkin Gulf incident. On 5 August 1964, the day after the destroyers *Maddox* and *C. Turner Joy* were attacked without provocation by North Vietnamese torpedo boats, President Johnson announced on television that retaliatory strikes were being conducted as he spoke. The response was intended to be limited, however, to prevent any widening of the conflict. The operation, called Pierce Arrow, involved sixty-four strike aircraft—F-8s, Skyhawks, and Skyraiders—from the carriers *Ticonderoga* and *Constellation.* They struck four North Vietnamese patrol boat bases, leading to the destruction or damage of twenty-nine of the boats, or more than half of the enemy's force. But the attacks were not conducted with impunity. Two planes from the *Constellation* were shot down over Hon Gai, with the pilot of the lost A-4 Skyhawk—Lieutenant (j.g.) Everett Alvarez—becoming the first POW of the war. Two other planes were hit but recovered.

In December of that year, operation Barrel Roll began, primarily to conduct armed reconnaissance and strikes against choke points in Laos. (In April 1965, those missions which flew into the Laotian panhandle were renamed Steel Tiger.) Although the number of sorties was at first limited to twenty-four in any twenty-four-hour period, the restriction was lifted at the inception of Steel Tiger, thus permitting more frequent reattacks against key targets. Even so, photo reconnaissance showed that, as found in Korea twelve years earlier, the enemy was able to repair closed choke points fast enough that such strikes only minimally impeded the flow of traffic once the attacks eased. It was felt that, again as in Korea, concentrating strikes in particular sections of road permitted the enemy to marshal repair equipment and crews in those areas. Often, too, it was virtually impossible to guarantee a loss of enemy access to bypasses. Nonetheless, evidence suggested that traffic was slowed just by the mere presence of aircraft overhead. This seemed true even in the case of reconnaissance aircraft, enabling these planes to have a disproportionate influence on the movement of traffic.

By the beginning of 1965, U.S. officials and military commanders believed that to discourage the Viet Cong and North Vietnamese from attacking U.S. personnel in South Vietnam, retaliatory missions should be preplanned, ready to be authorized as needed. The first of these missions, called Flaming Dart I, was approved following a 7 February mortar attack by the Viet Cong against the U.S. compound at Pleiku. Eight Americans were killed and over a hundred wounded by the guerrilla attack. In response, the carriers *Coral Sea* and *Hancock* launched forty-nine planes against North Vietnamese army barracks and port facilities at Dong Hoi. Simultaneously, the *Ranger* sent thirty-four planes inland, to hit the barracks at Vit Thu Lu. The *Ranger's* planes were prevented from completing their mission because of poor weather; at Dong Hoi, however, at least ten buildings were destroyed. The sole U.S. loss was an A-4 Skyhawk.

Just three days later, on the 10th, Viet Cong guerrillas struck again, blowing up a hotel in Qui Nhon being used to house U.S. enlisted men. Twenty-three Americans died, with about an equal number wounded. Admiral U. S. Grant Sharp, Commander in Chief, Pacific, recommended a prompt response. Flaming Dart II took place the next day, involving almost a hundred planes from the carriers *Coral Sea, Hancock,* and *Ranger.* Because of monsoon conditions, and the resultant poor visibility and low ceiling, the strike against the barracks at Chanh Hoa had only limited success. Moreover, heavy antiaircraft fire downed three of the aircraft and damaged several others.

Until mid-February 1965, these air strikes against North Vietnam had been in retaliation for specific acts of aggression against U.S. forces, that is, a strategy of "tit for tat." But the long-term result of these strikes, particuarly their ability to deter future aggression aimed at U.S. forces, came into serious question. Hence, at Admiral Sharp's direction, plans were prepared to begin a series of systematic air strikes against North Vietnam, quite apart from any retaliatory campaign. President Johnson approved the operation, code named Rolling Thunder, on 13 February, and the first of the strikes—of an eventual fifty-seven strike series over three years—was launched on 2 March.

The purpose of Rolling Thunder was to force the enemy to capitulate as the raids escalated and drew ever closer to Hanoi. However, controls over Rolling Thunder were at first quite strict, seriously reducing the operation's effectiveness. These restrictions emanated all the way from Washington

The shadow of a U.S. Navy reconnaissance plane passes near a burning Communist Vietnamese PT boat after it was sunk by aircraft from the Seventh Fleet carriers USS *Midway* and *Hancock.* (Official U.S. Navy photo.)

through a lengthy chain of command, beginning with the president and his national security advisor and passing through the secretaries of defense and state, the Joint Chiefs of Staff, and CincPac. Commanders were told, for example, the day to make a strike, often without much thought to weather conditions. The number of sorties by task and target was specified, too.

Attacks were limited to primary targets or to one of two alternatives, with planes required to dump unexpended ordnance in the South China Sea. Prestrike reconnaissance, furthermore, was prohibited. Finally, aircraft responsible for assessing bomb damage were to accompany or immediately follow strike aircraft, with later assessments to be conducted unescorted and at medium altitudes only. As Rolling Thunder progressed, some of these rules were relaxed and greater flexibility was granted to the operational commanders—though not enough to satisfy forces on the scene.

To make coordination between the U.S. Air Force and Seventh Fleet simpler, North Vietnam was eventually divided into seven geographic regions called "route packages" (Figure 5-2). The navy flew missions in route packages II, III, IV, and VIB, while the air force flew in route packages I, V, and VIA. These divisions ensured that resources could be used economically, and permitted each service to run its own program of target development, intelligence collection, and target analysis.

An area in the Tonkin Gulf was chosen as the center of operations for Task Force 77, and given the code name Yankee Station (Figure 5-3). Later, this point was moved closer to the coast of North Vietnam, to reduce the time it took planes to reach their targets. A second locus of operations, called Dixie Station, was established shortly afterwards (in the spring of 1965), located about one hundred miles southeast of Cam Ranh Bay. The station was created at the request of General Westmoreland, who had been so impressed by the support provided to ground forces by carrier-based aircraft that he felt a permanent carrier presence off South Vietnam was needed. Although the main mission from Dixie Station was to fly regular close support in South Vietnam, it also included the training of aircrews to eventually take part in the campaign in the North. The responsibility of maintaining both stations made it necessary by June 1965 to deploy as many as five carriers in the region.

North Vietnam's air defense system expanded over the years, as strikes by the United States were alternately suspended and resumed. In April 1965, reconnaissance revealed the first surface-to-air missile (SAM) site under construction, some fifteen miles southeast of Hanoi. By the end of the year, more than sixty sites had been located, protecting the vital military-industrial complex around Hanoi and Haiphong.[2] This number increased to about six hundred by spring 1968, defending a variety of lucrative targets, including the main lines of communication leading to the South. Their effectiveness became increasingly poor, however, as the number of SAMs expended to shoot down one aircraft kept rising: by 1968, the ratio had reached sixty-seven to one, or more than twice as many SAMs fired per kill than two years earlier. As SAM defenses proliferated, so also did North Vietnam's aircraft inventory (Figure 5-4). Not only did the number and quality of fighters increase—with MiG-21s

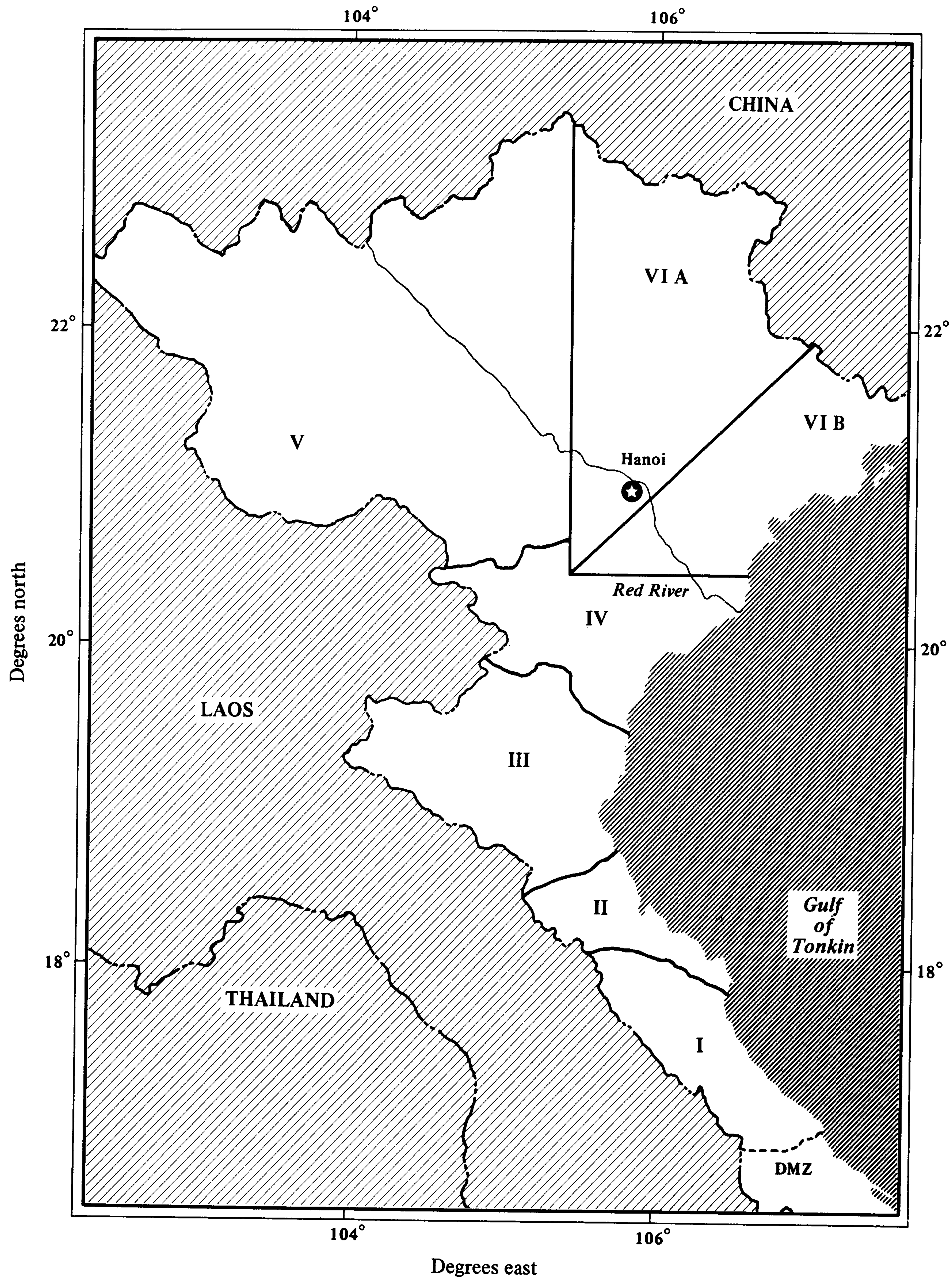



Figure 5-2. Division of North Vietnam into Route Packages

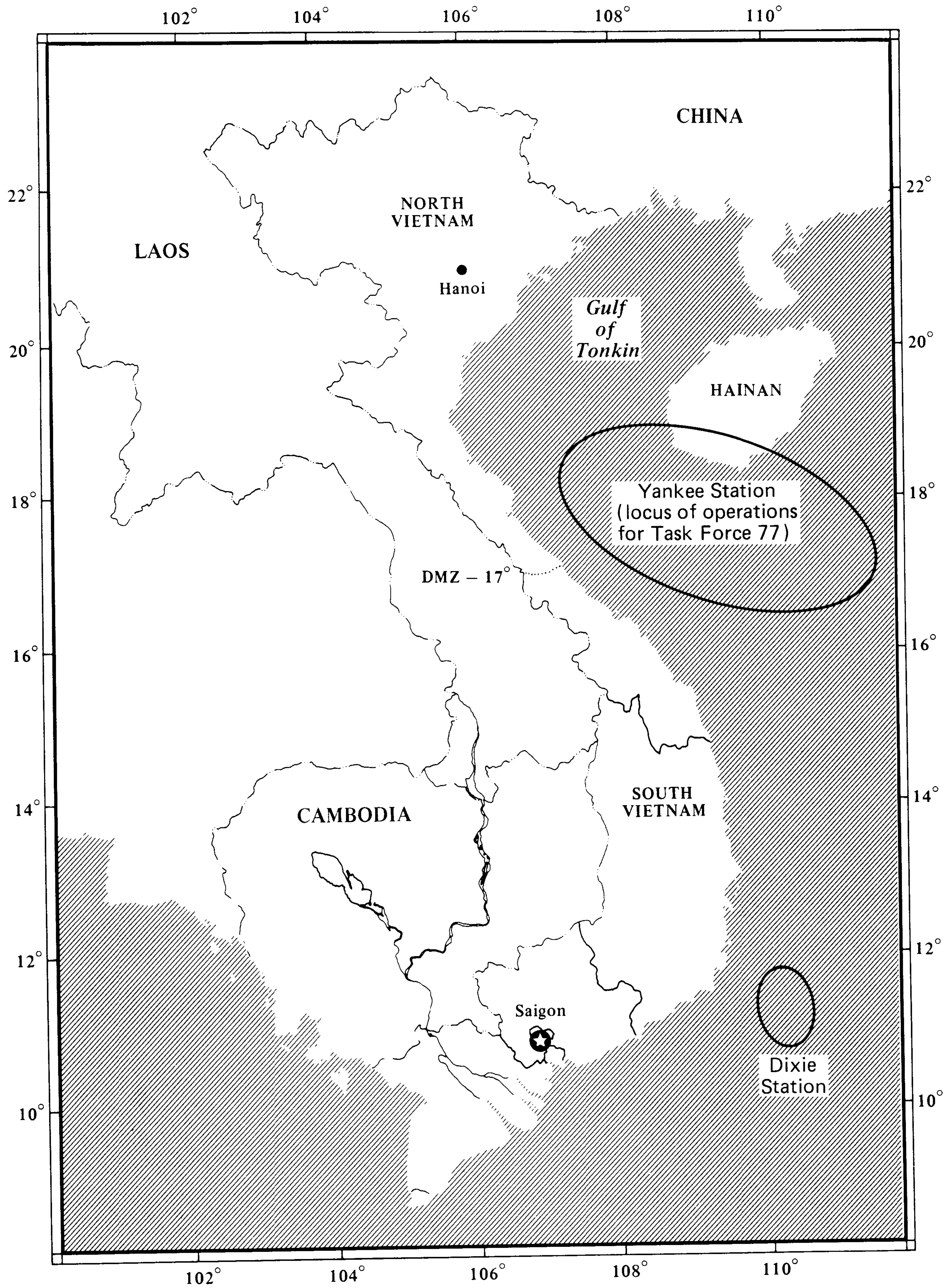



Figure 5-3. Location of Yankee and Dixie Stations

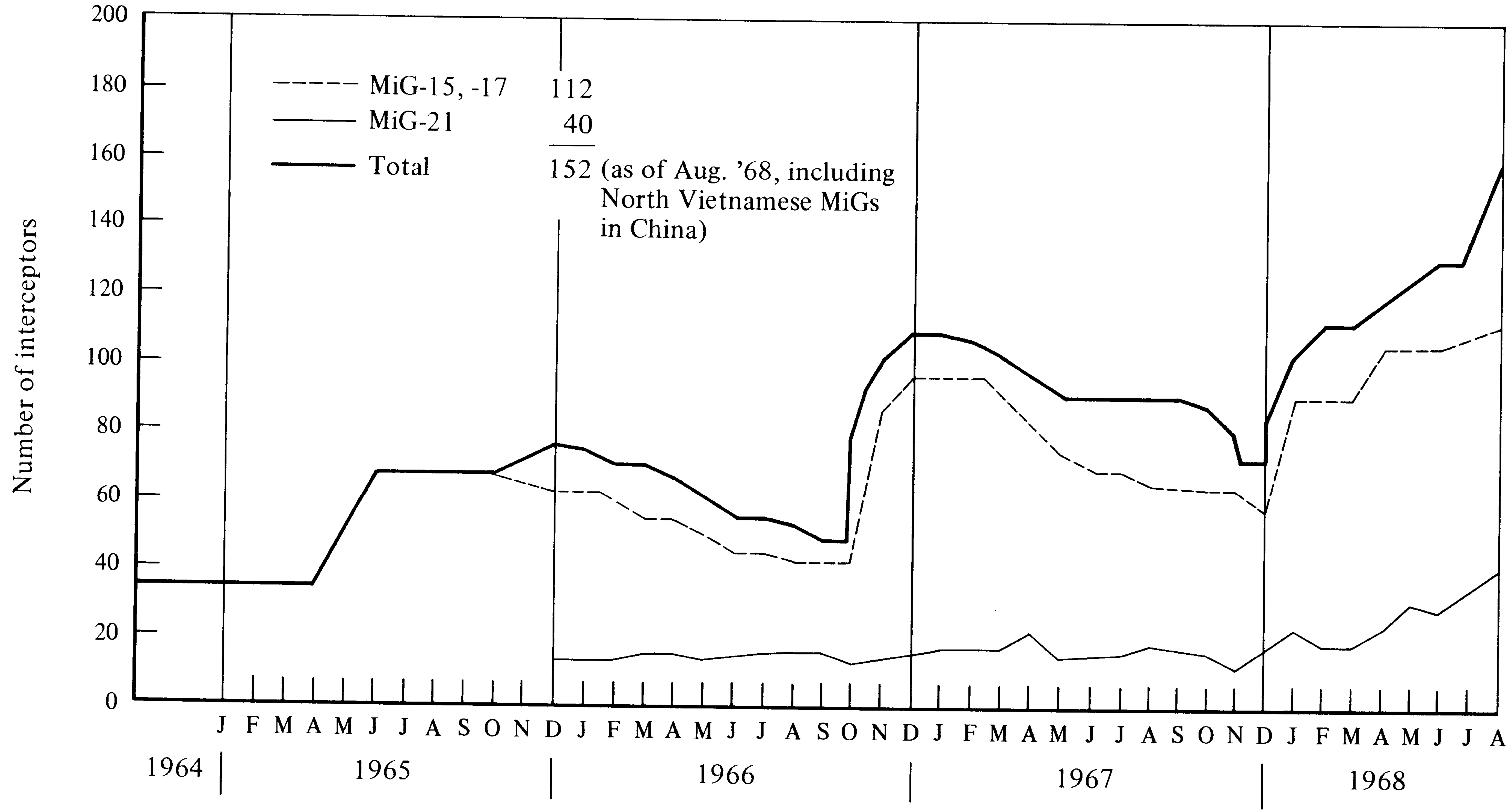
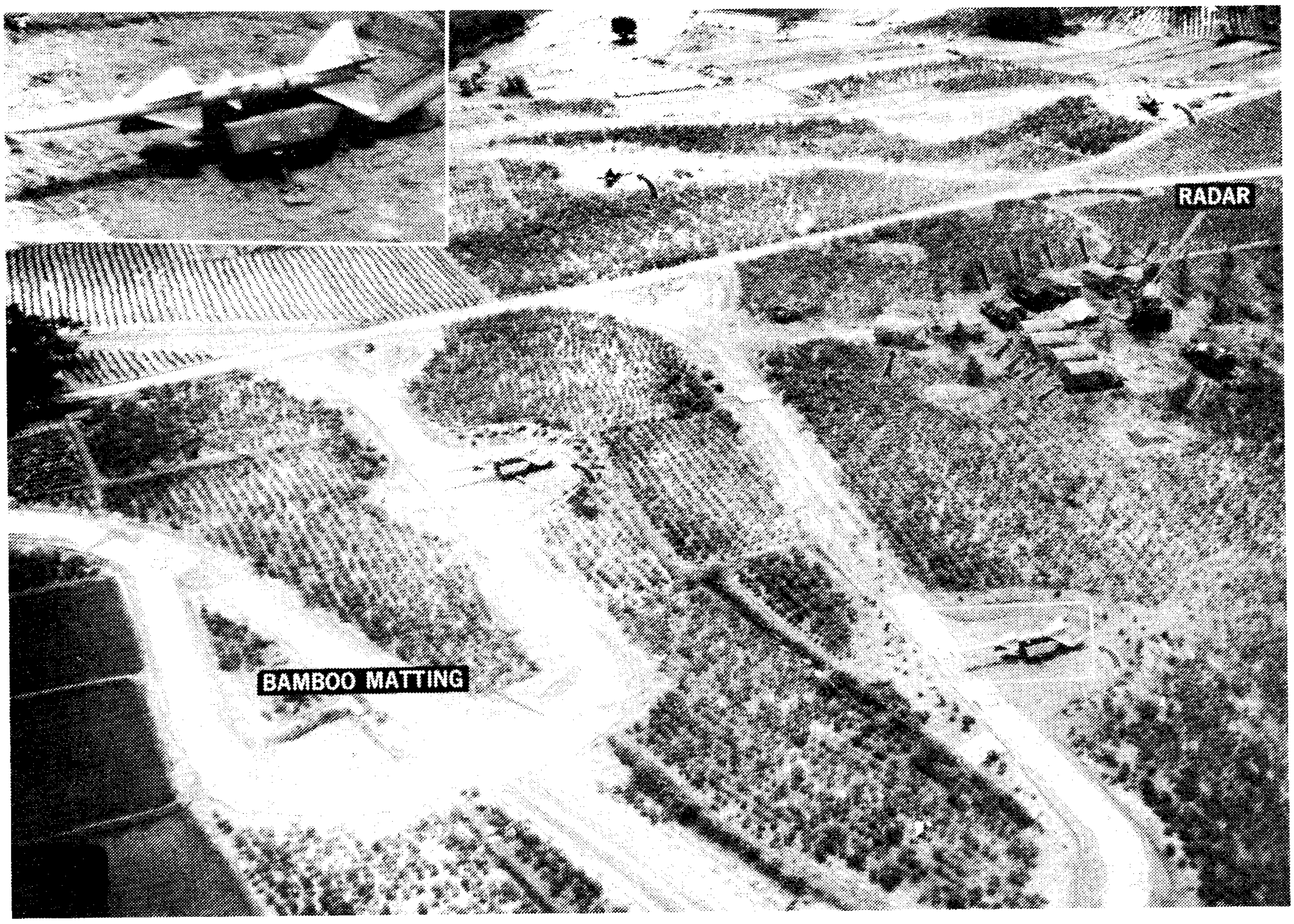



Figure 5-4. North Vietnam's MiG Inventory




Reconnaissance photograph of a surface-to-air missile (SAM) site in North Vietnam. (Official U.S. Air Force photo.)

assuming a greater portion of the action previously shouldered by MiG-15s and -17s—but their aggressiveness and proficiency increased, too. The most effective element of the North's air defense system, however, proved to be antiaircraft artillery and automatic weapons, found to be quite effective against fighter-bombers attacking at low levels and against planes engaged in flak suppression. These weapons were deployed quickly following the Tonkin Gulf incidents, reaching a total of roughly eight thousand by 1968.

One last facet of the North's air defense network that deserves mention was its early-warning equipment. By 1968, this equipment had been modernized and broadened to provide extensive overlapping coverage of all North Vietnam and into Laos to the west, and over the Gulf of Tonkin to the east. The radar net was considered capable of detecting and tracking planes above fifteen hundred to two thousand feet—altitude discrimination had been enhanced by the addition of height finders—and of simultaneously coordinating air defense even when faced with multiple penetrations. Ground-control intercept (GCI) radars helped direct MiG operations in the Haiphong-Hanoi-Thai Nguyen areas and, to a lesser degree, in the southern panhandle.

These defenses made Task Force 77 pay a high price for its incursions into the North: three hundred planes were destroyed and another one thousand damaged during the three years that Rolling Thunder was in effect. On the other hand, much had been accomplished:

> The damage to the enemy had certainly been heavy. His transportation system, roads, rail lines, and bridges had been wrecked. His above-ground fuel system had been destroyed. His war-making industry had been levelled. His other main industries had been severely damaged. All major electric power generating plants had been severely damaged. His airfields and his air force had been rendered ineffective. His military complexes had been devastated. In those 37 months, the enemy had not won a major ground battle. He had certainly not succeeded in subjugating South Vietnam by force.[3]

How much could have been gained by the enemy in the absence of the bombing campaign is strictly speculative. It is undoubtedly true, however, that had the enemy been permitted to function uninhibited, they would have been able to inflict much heavier losses on our forces in the South. In that sense, anyway, Rolling Thunder was a success. Indeed, the cessation of bombing on 31 March 1968 resulted not from any military judgment about the campaign's demonstrated or potential effectiveness, but from political considerations outside the ken of this discussion.

The few, albeit important, operations just described represent just a portion of the U.S. Navy's air and blue and brown water missions in Vietnam. Not mentioned, for example, were naval gunfire, employed to support friendly troops and to interdict enemy supply lines; amphibious assaults, conducted mostly by a Seventh Fleet force known as the Amphibious Ready Group/Special Landing Force; and mine warfare, directed at selected waterways and harbors to reduce the movement of war supplies. All these operations posed a host of new and old problems that required ingenuity and adaptability. The paucity and inadequacy of certain assets, the inappropriateness of certain established tactical doctrine, and the inhospitality of the natural environment—to cite just some of the handicaps—had to be tackled systematically but with dispatch. OEG's support of the navy in Southeast Asia during this period expanded rapidly, as the need to overcome these handicaps became more pressing.

### OEG's Southeast Asia Combat Analysis Division

By 1965, OEG had already committed considerable resources to the war in Southeast Asia. Analytical assistance, for example, was being provided to the Director of the Air Weapons Systems Analysis Staff (Op-05W), Captain Jack M. James. Much of this work centered on the causes of lost or damaged planes during the earlier missions by naval aircraft. Also, in the summer of 1965, OEG set up a team of field representatives assigned to the Commander in Chief of the Pacific Fleet. These initially included George Haering, who headed the team (and who previously had been OEG's scientific analyst to Op-05W), John H. Fry, and Robert L. Hubbard. Haering was later awarded the Navy Distinguished Public Service Award for his work on alternative tactical air basing systems and on naval air operations in Southeast Asia. Ervin Kapos and Francis E. Shoup arrived at CinCPacFlt in 1966. Because much of the conflict, as far as the navy was concerned, revolved around air strike warfare, these analysts concentrated on such areas as aircraft attrition from antiaircraft fire, the effectiveness of enemy SAMs, electronic intelligence, and sortie rate capabilities. Lastly, other analysts—including Phil E. DePoy, Howard W. Kreiner, James F. Brennan, and Marvin B. Mullenix—were sent to the Western Pacific, assigned to Commander Seventh Fleet and to Task Force 77 operating in Yankee Station off the coast of North Vietnam.

By 1967, with the fighting in Vietnam intensifying, the navy felt that the collection and analysis of data on the war needed to be better coordinated. Hence, in August of that year, Vice Admiral Bernard A. Clarey, the Director of Navy Program Planning (Op-090), agreed to act on a proposal by the Deputy CNO for Fleet Operations and Readiness (Op-03) to consolidate the navy's combat analytical effort. By doing so, Clarey and others believed they could assure themselves of a more complete evaluation of the war, which would prove useful.

The result, on 15 September 1967, was formation of the Southeast Asia Combat Analysis Group (SEACAG) within Op-03.[4] Headed by Captain James (Op-03Z), who also retained his title of Op-05W, SEACAG was to function as an ad hoc group, to be dispersed once the conflict was over. Its members—totaling about thirty-five officers and operations analysts—were drawn from within the Office of the Chief of Naval Operations. Their participation in SEACAG was to take priority over their other duties.

SEACAG's mission was to conduct analyses of navy combat activities in Southeast Asia—including tactical air warfare, weapons systems effectiveness, ordnance requirements, electronic warfare, riverine warfare, and such operations as Market Time and Game Warden—to improve the navy's capabilities. Its specific functions were to:

(1) form a summary data base for all activities, as well as separate data bases for each warfare area
(2) conduct analyses of critical problem areas with regard to current operations and near-term requirements
(3) review the need to collect particular kinds of data in support of ongoing or planned analyses
(4) maintain close coordination with combat units to determine the precise nature of problems being encountered

(5) keep an up-to-date and readily accessible repository of all navy analyses pertaining to combat operations in Southeast Asia.

SEACAG began immediately to investigate many of the key issues. In a progress report to the Vice CNO, Admiral Horacio Rivero, just a few weeks after SEACAG's inception, Captain James noted that "the specific problems being addressed in Game Warden are the number of helicopters required, the requirements for speed, armor, and armament in the river patrol boats, and whether or not there is a need for an integral assault force to ensure control of the river banks." He added that the areas being investigated in Market Time were its "overall effectiveness, considering weather and sea conditions, and the degree to which the absence of all-weather patrol boats causes the effectiveness to drop off."

Meanwhile, the navy was encouraging OEG to expand its own Vietnam-related analysis in support of SEACAG. As a result of a meeting on 8 and 9 August, led by Admiral Zumwalt and participated in by CNA officials and OpNav, OEG agreed to increase its level of involvement. The group expected to commit as many as twenty scientists to the effort, brought together over the next month or two. These were to consist of ten OEG analysts already engaged in work on Southeast Asia, with the rest taken from elsewhere within CNA: three from the Institute of Naval Studies, one from the Systems Evaluation Group, and six from NAVWAG's Naval Objectives Analysis Group (NOAG). Also proposed was the tentative allocation of manpower among the several lucrative study areas, with air warfare accounting for almost half the analysts, and surface operations, coastal interdiction, logistics, command and control, and intelligence accounting for the remainder.

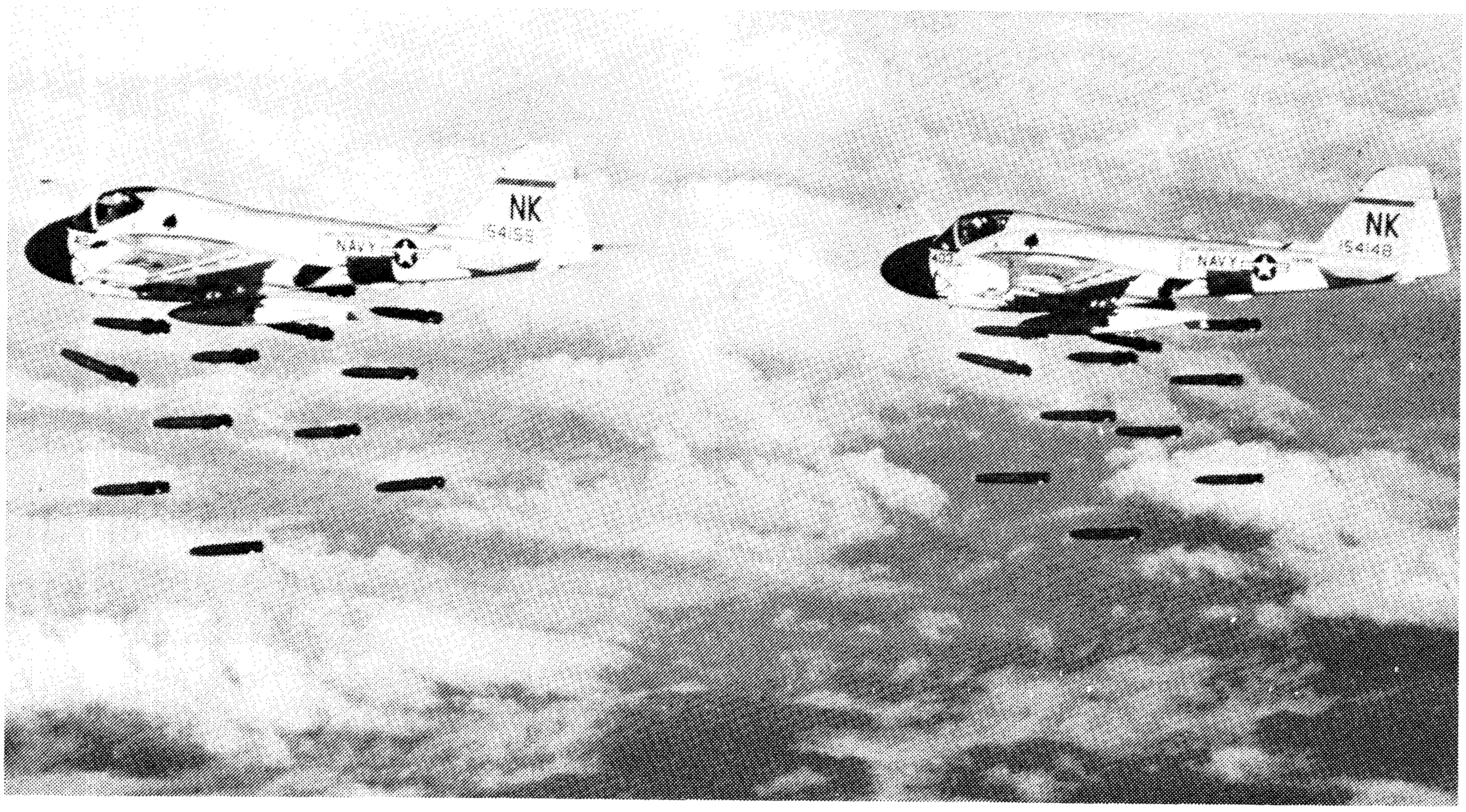
On 18 September 1967, OEG's director, Dr. Erwin Baumgarten, formally set up the Southeast Asia Combat Analysis Division (SEACAD). He appointed Ervin Kapos, then returning from a year's field assignment with the Commander in Chief of the Pacific Fleet, as SEACAD's director. A little over a year later, in December 1968, Dr. Phil E. DePoy took over as SEACAD's director upon Kapos's departure. The division's twenty Washington-based analysts were responsible for conducting studies to support the CNO's Southeast Asia Combat Analysis Group (SEACAG) and to help navy commanders in the field make operational decisions. Importantly, the division maintained the active field program described earlier. Of the seven analysts sent out, four were assigned to Commander in Chief, Pacific Fleet, and three to Commander Seventh Fleet, who usually stationed two of the analysts with carrier division commanders in the Gulf of Tonkin. The division had an unusually high ratio of support personnel to analysts so that the prodigious amounts of combat data could be kept as free of gaps, inconsistencies, and errors as possible. This extraordinary effort to keep the data base both accurate and complete was deemed well worthwhile, for the sake of protecting the credibility of study results in the politically volatile atmosphere that existed in the United States at the time.

Although most of the effort in the field was devoted to the air war, the program in Washington was spread among all areas germane to the navy's involvement in the conflict. As initially structured, OEG's SEACAD directed about 45 percent of its analytical resources to the air war, about 35 percent to the surface war, and the remaining 20 percent to combat support, such as command and control, reconnaissance, intelligence, and communications. The situation that existed in each of these three areas warrants some discussion, before we get into specific studies.

The all-important air warfare program, run largely by Robert Hubbard, was divided almost equally between analysis of the effectiveness of U.S. air operations and analysis of the enemy's countermeasures. The reason for arbitrarily dividing the air program this way was that high American officials were almost totally absorbed with the most visible aspect of the campaign—that is, its cost in terms of aircraft attrition. There was enormous pressure, therefore, to devote the entire study effort to the causes of these losses. Hence, if SEACAD had not made a point of setting aside at least a portion of its analysis for the purpose of examining the effectiveness of the air campaign per se, little would have been learned about the subject. In that case, what makes an effective strike, an effective attack sortie, or even an effective weapons delivery in actual combat would never have been properly understood. Simply recording operational experiences, without subjecting the data to analysis, would have had minimal value.

SEACAD's air-related program followed three principal avenues: one, evaluation of systems and weapons newly introduced into combat; two, analysis of combat aircrew survival and rotation, and how these affected the availability of pilots; and, three, preparation of a monthly compendium of combat statistics.

The first avenue demanded immediate attention from the division. Two A-6A squadrons, for example, had already been deployed when suspicions about the supposed all-weather capability of the plane began to surface. OEG's representatives stationed with the Seventh Fleet immediately began to dig for case studies of A-6A attacks, for which available photographs showed the target and the location of bomb craters attributable to that particular plane. From these photographs, it was then possible to measure the distance of misses and thus derive some idea of the plane's attack accuracy. Similar data collection went on among the analysts assigned to the Commander in Chief of the Pacific Fleet and those back in Washington. These data, along with the results of navy tests of the plane under




Two A-6As from the USS *Constellation* drop bombs on installations in North Vietnam. (Official U.S. Navy photo.)

simulated combat conditions, were expected to supply the grist for a proper evaluation of the A-6A's performance.

A comparable effort got under way for the A-7A, when the first squadron, VA-147, deployed with the USS *Ranger* in November 1967. In that instance, a member of OEG's SEACAD went with the squadron for the duration of its deployment. His job included doing studies on the A-7A for the local commander and, more important, accumulating information on the plane's activities for final analysis back in Washington once the deployment had ended.

Two weapons being evaluated as part of this same program were the Walleye and Shrike. The first was a television-guided glide bomb introduced into combat in 1967. There was skepticism about its unusually high probability of scoring hits, so analysis of its performance was considered important. The second weapon, the Shrike, was an air-to-ground missile designed to home on enemy radar being used for early warning in the perimeter defense—that is, primarily SAM defense—of a target. A problem being confronted with Shrike's use stemmed from the fact that in certain areas of North Vietnam, the enemy was trying to protect so many targets that, although each target was presumably defended separately, it appeared to the attackers as an "area" rather than "point" defense. The resultant density of target signals apparently reduced the missile's effectiveness. It was a problem that SEACAD needed to examine.

The second avenue of SEACAD's air-related program involved an investigation into the potentially critical undersupply of pilots that was anticipated for the not-too-distant future. One factor bearing on this subject was, of course, aircrew survival. It was necessary, therefore, to figure out how to improve search and rescue operations. Pilot rotation policies were an even stronger influence on the supply of aircrews and were, to some extent, manipulable.

The last avenue involved OEG's SEACAD and the navy's SEACAG jointly publishing a monthly statistical summary. For the first several months, the summary contained data restricted to the air war: sorties, planes lost and damaged, combat aircrew recovery, employment of new weapons, enemy defenses, and so on. Later, however, it included data from surface operations and, eventually, from selected combat support functions. Continually updating the statistical information prevented raw, undigested data from accumulating in such quantity that there would be little realistic hope of processing–and, more important, analyzing–it once the campaign was over. Also, it provided officers throughout the navy with a statistical source they could readily draw from, instead of their having to ask for assistance each time the need for operational data arose.

Turning to surface warfare, a portion of OEG's SEACAD analysts, headed by Lawrence S. Cohan and later by Jerome Goldschmidt, focused on the navy's attempts to prevent the enemy from infiltrating South Vietnam with supplies brought in by sea. In the North, interdiction of seaborne traffic generally called for a mix of surface gunfire, air attacks, and mining. Up to then, however, insufficient consideration had been given to what force mix might best be suited to this effort. Rather, circumstances and personal experience–not analysis–had guided the decision making. If there were indeed a preferred force mix, its determination would have to await a better understanding of the capabilities of each system and weapon contributing to the mix. As far as coastal interdiction off South Vietnam was concerned, there already existed a significant body of analysis; however, models developed earlier needed to be replaced or modified, to conform with new conditions.

Yet another aspect of the surface effort was the riverine campaign, involving forces from Game Warden, the Riverine Assault Force, and Market Time. Here, one goal was to devise an effective scheme for conducting operations in the Mekong Delta. In Game Warden, in particular, there was a persistent shortage of helicopters for backing up the river patrol boats. Since it was unlikely that additional helicopters would be diverted to Game Warden–at least until the utility of helicopters in Game Warden operations had been demonstrated analytically–SEACAD was under pressure to do the necessary study as quickly as possible. The subject was therefore given the highest priority. A less immediate goal was to help the navy determine how its in-country riverine operations could be linked to extranaval objectives in South Vietnam. That is, the navy had to be prepared to translate its military gains into political and civil payoffs, such as control over territory and the local populace.

SEACAD's early work in combat support functions—the third and final area to which the division devoted resources—related in one way or other to the flow or use of information. A typical communications problem of the navy in Southeast Asia concerned "message servicing," that is, the need to retransmit messages because the intended receiver either did not get a clear copy the first time or failed to copy the message at all. If messages could have been sent just the one time, the threat of saturated circuits would not have posed a problem. But actual communications required frequent retransmissions. SEACAD believed that more could be learned about the principal causes of the frequent need to retransmit messages. The division also decided to investigate how communications stations might minimize the effect of retransmissions on their overall performance. Finally, by determining tolerable error rates under actual combat conditions, it would be possible to set realistic requirements for future communications systems.

Another support function examined by SEACAD was command and control. Of particular interest were the results obtained from using a specially outfitted ship to help protect the carrier task force at Yankee Station by providing early warning of an air attack. The ship would assume a nearly fixed position off the coast of North Vietnam, somewhere on the axis along which an attack would likely come. The functions of the ship were the following: to provide early warning of a threat not only to the ships of the task force, but also to the carrier's planes operating over North Vietnam; to control the provision of emergency services to aircraft returning in trouble, because of low fuel, battle damage, or whatever; and, finally, to control weapons systems, such as the interceptors on barrier patrol off North Vietnam or its own missiles. As the functions of this early-warning ship proliferated, it became increasingly necessary to devise improved management schemes and to allocate special supporting equipment.

Lastly, in the area of reconnaissance, the main problem was one of resources. Intelligence was collected with three principal aims in mind: to be able to warn friendly forces of impending danger or to alert them to lucrative targets; to assist in the planning of longer-range operations; and to contribute to a more far-reaching, national intelligence-collecting effort. Each of these tasks competed for manpower and facilities, and it was by no means clear that resources had been allocated effectively. In addition, it was necessary to look at whether the tactical commander in Southeast Asia could afford to devote any sizable fraction of his reconnaissance forces to the requirements of higher authority when his own requirements were hard enough to fill. Other typical questions concerned whether intelligence reached the users in time, to what extent it was put to use, and whether the costs and risks were commensurate with the value of the end product.

Once some of the general problems had been defined, SEACAD's analysts could begin organizing and becoming acquainted with the ever-expanding store of operational data. Only then could they draw conclusions about how the navy's operations in the conflict might be conducted more effectively and efficiently.

### Analysis of Operations in Southeast Asia

A significant portion of the analytical effort expended by OEG on the war in Southeast Asia had to do with the causes and other circumstances of lost and damaged aircraft in the various air operations–Yankee Team, Barrel Roll, Pierce Arrow, Flaming Dart, Rolling Thunder, and so forth–in which the navy took part. One typical study, conducted by Ervin Kapos and John H. Fry while assigned to CinCPacFlt, examined the combat attrition of carrier-based aircraft for the year 1966. In the study, the term *combat* encompassed several types of missions. These included strikes, armed reconnaissance, flak suppression, SAM suppression (code-named Iron Hand), escort, and combat air patrol. The term *combat support* likewise included several types of missions, such as unarmed reconnaissance, electronic countermeasures, and tanker flights.

It was found that combat losses in Southeast Asia amounted to about 120 planes in the course of nearly 100,000 combat and combat-support missions flown during 1966. This gave an attrition rate of 0.12 percent or, stated another way, of 1.2 planes lost for every 1,000 sorties flown. When the data were broken down by country, almost 90 percent of these losses occurred over North Vietnam. The remaining losses were split between South Vietnam and Laos. Curiously, the trend for the year revealed a sharp decline in the attrition rate in North Vietnam beginning in May, from almost five to just under three losses per 1,000 sorties. The principal reason for this decline, it was felt, was the assignment of route packages in February (refer back to Figure 5-2), allowing both planners and pilots to familiarize themselves with the areas of North Vietnam for which they were responsible. Other elements, however, also contributed to the drop in attrition rate. These included the increased level of operational experience acquired by the pilots, stringent restrictions on the use of the more vulnerable A-1 and F-8 aircraft, increased reliance on electronic countermeasures to protect attack aircraft, and, less certainly, the onset of good weather.

There were substantial differences in the loss rate not just among the three countries involved–North and South Vietnam and Laos–but also among the route packages within North Vietnam. Specifically, the navy's area of responsibility in North Vietnam seemed to consist of a low- and high-loss sector. The sector that experienced a relatively low loss rate comprised route packages II and III, in the southern region of North Vietnam. The high-loss sector, on the other hand, comprised route packages IV and VIB, which were farther north. The differences in loss rates between these two sectors was shown to be a factor of 4—statistically highly significant. Although, at first glance, operations in route package VIB appeared no more hazardous than those in route package IV, this was misleading because a large fraction of the sorties flown in route package VIB were for armed reconnaissance, for which the loss rate was low. However, the loss rate for strike missions in the heavily defended Hanoi-Haiphong area of route package VIB during Rolling Thunder 52 (November and December 1966) was almost ten times the overall attack attrition rate in North Vietnam.

The relative hazards of operations in route packages IV and VIB were illustrated by carrier-launched strikes conducted in each. For example, on 16, 17, and 18 September, two carriers of Task Force 77 conducted strikes against the Ninh Binh railroad complex. Then, on 21 September, all three carriers of the task force sent planes against the rail facilities at Thanh Hoa. In each of these attacks, extensive support was provided for the strikes, in the form of attempts to knock out antiaircraft guns and SAMs. The four attacks involved a total of 476 sorties, of which almost a third were devoted to the support role. With just one A-4C lost en route to the target, the resultant attrition rate amounted to slightly over two planes per 1,000 sorties during these major strikes in route package IV.

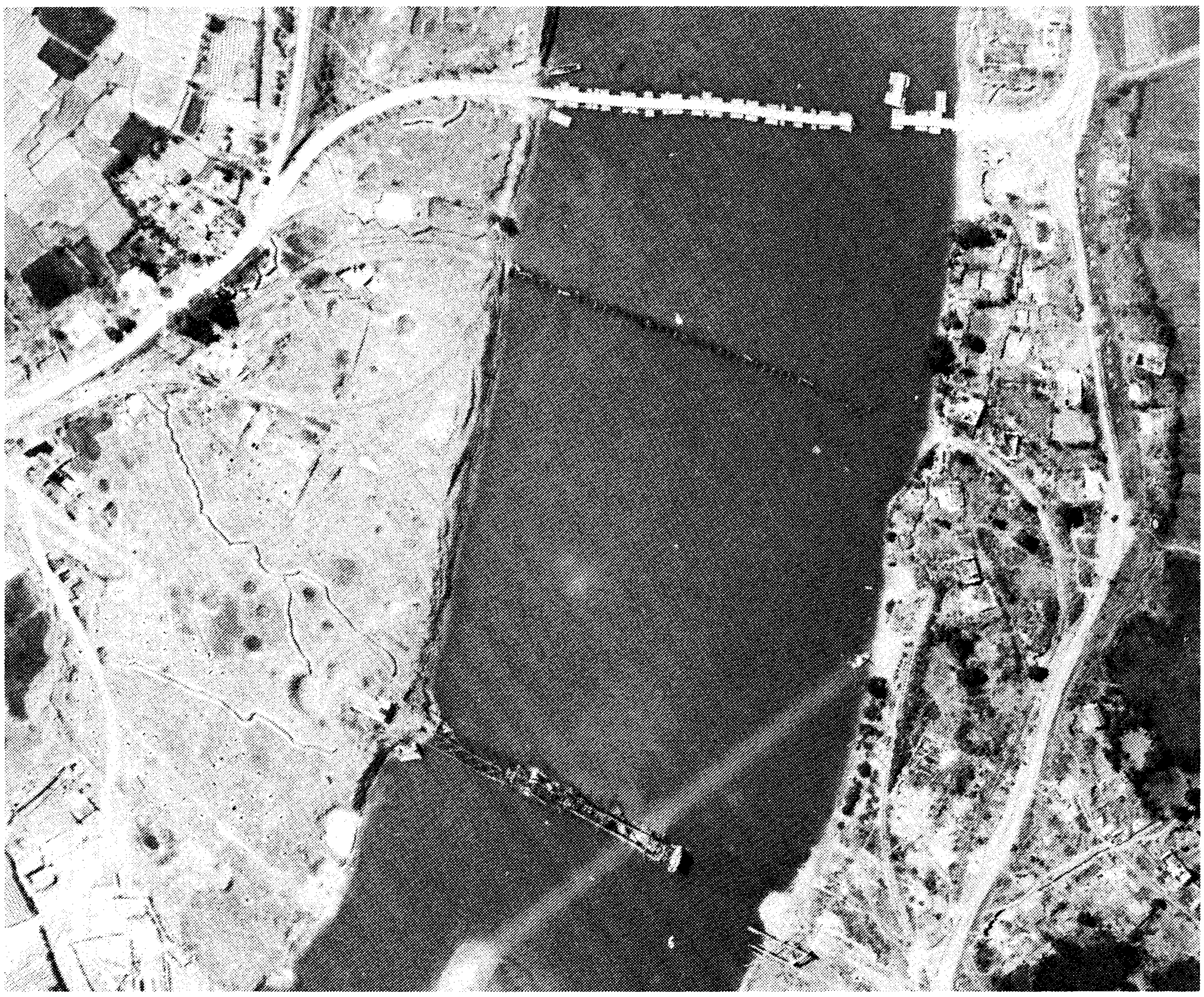
Three months later, on 2, 13, and 14 December, planes from all three carriers attacked the vehicle depot at Van Dien, the petroleum storage facilities at Can Thon, the bridge at Xuan Mai, and the barracks at Nguyen Xa. All targets were in the heavily defended Hanoi area. The attacks on these three days involved, respectively, 75, 58, and 73 sorties, for which a little under half were for support (for example, for flak and SAM suppression). Nevertheless, five planes were lost, for an attrition rate of about 24 per 1,000 sorties during these major strikes in route package VIB—vastly higher than for the other route package.

OEG found that antiaircraft guns, including small and automatic weapons, continued to account for the great majority—in fact, 80 percent—of the losses. Apparently, however, the presence of SAMs had an influence on this outcome. That is, about a third of the losses to antiaircraft fire occurred en route to or from the target area at altitudes of five thousand feet or less. But the main reason for their flying so low was that these altitudes were believed to lessen the SAM's effectiveness. In the meantime, the low altitudes placed the aircraft in much more dense flak, thereby certainly contributing to the 80 percent figure. Other areas considered in these studies of aircraft losses and damage were the relative vulnerability of different types of aircraft, the number of losses that could be directly attributed to SAM and MiG defenses, and the probability of a loss or of severe damage given a hit. The importance of these studies of attrition was considerable, as reflected in the enormous commitment of OEG's resources and the influence of study results on the tactics employed by navy aircraft. Despite the size of this vital effort, however, it represented only one of several areas of the war in which OEG became involved.

During the period from 1 April 1968—the day after President Johnson prohibited bombing north of 20°N. latitude—to 1 November—when all bombing was stopped—naval air operations over North Vietnam were directed against lines of communication in an attempt to reduce the flow of men and material into the South. OEG decided to study this period, with four aims in mind: to determine the amount and distribution of effort expended; to evaluate the relevance of previously developed principles of interdiction; to document tactics developed during the course of the campaign; and to measure the effects of tactical air and relate them to enemy activities.

After the restrictions were applied, navy operations centered on three defined areas below the 20th parallel. Within each area, twelve to fifteen points were selected for strikes. These points—called traffic control points—included vulnerable segments of highways, choke points, waterways, and ferries. The idea was to select enough of these targets in each designated area to curtail enemy movement. This was achieved first by striking the targets to render them unserviceable and then by seeding the area with weapons fitted with long-delay fuses or antitampering devices to discourage repair crews from entering the damaged area. Ultimately, strikes and seeding operations were concentrated in the southernmost portion of the permissible attack region, with increasingly more planes assigned to conduct armed reconnaissance against vehicles. The percentage of night flying during the campaign rose to its highest in the war, and pressure was kept on the enemy around-the-clock.

Over the six months of the campaign, some minor changes were made in the emphasis placed on targets and the choice of weapons. Nevertheless, the campaign was notable for its consistency of objectives. Several factors concerning the campaign stand out. For the first time in the war, air power was concentrated in an area small enough to permit continuous operations, yet big enough to avoid difficulties in managing participating forces. Also, forces seldom had to be diverted from interdiction to other missions. Although some planes were assigned to fight MiGs, and others were engaged in knocking out SAMs, there was no large-scale assignment of forces to counter enemy defenses or provide self-protection. The campaign was run, furthermore, by the forward commanders rather than by an extensive, remote network of decision makers. This permitted more



Prestrike view of pontoon bridge and bypass at Dong Phong Thuong in North Vietnam, taken by the Tactical Reconnaissance Squadron operating from the USS *Kitty Hawk* on Yankee Station off North Vietnam. (Official U.S. Navy photo.)

freedom to choose targets, to respond to changing tactical situations, and to allocate forces. Finally, the weather was generally good during this period.

A desirable goal in the analysis of such a campaign would have been to relate the effort expended by tactical air to results obtained against the enemy's supply system, and to relate changes in the supply system to changes in the level of enemy support to his forces in South Vietnam. However, while a considerable body of statistics had been accumulated, by which the amount and distribution of the tactical air effort could be measured, the results could not be related to enemy activity with any confidence. The principal obstacle to such an evaluation was the United States's relative inability to read the enemy's intentions. It was especially difficult to understand the degree to which the status of the enemy's logistics and lines of communication affected his operations in the South. OEG's analysis was therefore limited to four objectives: determining the amount and distribution of effort expended; evaluating the continued applicability of previously developed ideas on conducting an interdiction campaign; developing and evaluating new tactics during the course of the campaign; and measuring quantitatively the effects of tactical air strikes.

It was convenient in the analysis to regard operations as designed primarily to limit either routes or vehicles. The former included traffic control points, roads, bridges, causeways, stream crossings, and waterways; the latter included vehicles, water craft, and rolling stock. Attempts to cut off routes tended to be quite successful, as attested to by observed reductions in enemy traffic and the eventual drop in the movement of supplies. The effort involved in achieving these results was prodigious, however, requiring all routes—coastal and inland waterways, trails, and ever-multiplying bypasses—to be cut. As might be expected in interdiction operations, it took several months of concentrated effort for these results to become apparent. Further, where the enemy could meet his needs by short bursts of activity, interdiction was less likely to succeed.

The search for, and destruction of, vehicles was necessary to complement the route-limited aspect of the campaign, even though the effort expended outweighed the number of trucks and water craft actually destroyed. The worth of these kinds of attacks, however, went beyond just the destruction of trucks and cargo. A strong armed reconnaissance effort forced the enemy to use smaller convoys and to operate at night, at a slower pace, and over much shorter distances. The outcome was a deceleration in the flow of supplies.

The interdiction effort took account of principles derived from previous combat experience. By comparison with similar operations in the Korean War, OEG found that considerable progress had been made. Night operations had become routine, as a variety of tactics and equipment were developed to enhance the United States's ability to detect and attack the enemy at night. In addition, ships were able to provide more effective support by using gunfire to cut back on the traffic using coastal highways. For this campaign, at least, command and control relationships were established for the most part by forward-area commanders and effectively managed to maintain cooperation between the services.

Although the campaign seemed ultimately to accomplish its objective of curtailing the movement of supplies, some doubted whether any attempt at interdiction in a place like Southeast Asia could cost less in time and resources. Much, it was decided, would depend on the practice of granting sanctuary status to otherwise lucrative targets, and the level at which the enemy could be forced to use up his own resources on the battlefield. In the campaign being considered, the enemy, for all practical purposes, had unlimited access to supplies from other countries. Also, his lines of communication subject to attack had become considerably shorter after 1 April 1968. While he did make some abortive attempts at large-scale engagements in South Vietnam, his operations continued to be characterized by short, small-scale, low-cost attacks. Under these circumstances, his logistical requirements were minimal.

OEG found that the available data on the movement of enemy personnel and supplies failed to reflect any major response to U.S. tactical air operations until late in the campaign. Significantly, the enemy's system for infiltrating troops remained relatively invulnerable to attack from the air; at best, such attacks could only keep these movements off the highways and on foot. As already indicated, however, the enemy was unable during this period to employ in any large and decisive offensives the people and supplies that did get through.

Had all of North Vietnam been subjected to bombing–instead of there being safe sanctuaries that the enemy could exploit at will–the campaign might have achieved its goals with fewer reattacks and thus less expensively. With the forces available, striking all of the North would have necessitated a more strict and careful allocation of resources to cover the larger area. It would have been necessary to permit strikes against the sources of supplies rather than just the routes along which the supplies traveled. Notably, the level of effort achieved probably could not have been realized if the weather had been bad. Given the situation that actually existed–that is, the fairly small area of the North targeted and the presence of good weather–a three-carrier force was found to be adequate. If, on the other hand, the campaign had been extended into a period of bad weather, more all-weather planes might have been needed. In that case, enlarging the targeted area might have diluted the effort even more, degrading its effectiveness.

Finally, OEG noted that the navy's experience in the campaign indicated that no major changes in accepted principles of carrier-launched interdiction were urgently called for. The A-6A was shown to be valuable for a number of interdiction-related tasks, especially for detecting and attacking trucks. In fact, it was suggested that the A-6A strength be increased if interdiction was to continue being a major mission for carrier aircraft. The A-7 and A-4 also did well against both watercraft and trucks. OEG proposed, however, that more effective weapons for destroying trucks–including a better bomb and heat-seeking missile–should be developed. More effective means of delivering so-called denial weapons (for example, those designed to detonate after a delay, so that enemy repair crews would be deterred from venturing into a damaged area) were recommended, too. OEG pointed out, however, that a balance should be maintained in the mix of planes and ordnance made available. It was feared that too many specialized weapons and pieces of equipment would take up too much space, to the possible exclusion of adequate numbers of general-purpose weapons.

Another interdiction campaign investigated by OEG was Market Time, described earlier as an attempt by U.S. and South Vietnamese naval forces to prevent the enemy from infiltrating the South with seaborne supplies. The historical basis for Market Time can be traced back to the end of the French involvement in Indochina in 1954. Subsequent political events encouraged the North Vietnamese to organize opposition to the new government of South Vietnam by infiltrating personnel into the South to organize political and, secondarily, military forces. Between 1959 and 1964, North Vietnam shifted from an organizing and propaganda role to more direct military support of the Viet Cong. The Ho Chi Minh Trail came into being, leading through Laos and into South Vietnam, along which the North Vietnamese began to move arms and other supplies by truck. The Delta region of South Vietnam was the focus of insurgent resistance at that time, so additional efforts were made by the North to provide weapons to main-force units operating there. These weapons were infiltrated by sea, in commercial vessels and trawlers.

With the onset of "Vietnamization" of the war in 1969, the responsibility for Market Time was gradually turned over to the South Vietnamese. Early in 1970, the Commander of Navy Forces, Vietnam, examined the ability of the Vietnamese navy to run Market Time with the assets scheduled to be given to it. As a result of this investigation, it was suggested that the air barrier (one of three barriers along South Vietnam's coastline) be phased out in favor of a chain of radar stations, to become fully operational by early 1972. Then, in November 1970, the Chief of Naval Operations, Admiral Elmo R. Zumwalt,[5] predicted that the North Vietnamese and Viet Cong would try to escalate their efforts at coastal infiltration because of the political situation in Cambodia. Accordingly, he asked OEG to conduct a study of the current threat and to predict the adequacy of the planned surveillance radar network.

While OEG spearheaded the study, various navy commands assisted, including the Commander in Chief of the Pacific Fleet, the National Ocean Surveillance Intelligence Center, and the Naval Fleet Operational Intelligence Organization. Close contact was maintained with the Commander of Naval Forces, Vietnam, throughout the study, and two OEG members visited Vietnam during February 1971 to assess the threat. They found that the enemy had indeed placed increased emphasis on coastal transshipments and seaborne infiltration (Figure 5-5).

The enemy's use of trawlers appeared to pose the largest threat because the trawlers could infuse large amounts of material into the enemy's supply system. Twenty trawlers, in fact, had attempted to infiltrate the South's coastline since August 1969, nineteen of which were spotted by Market Time forces. Of these, two were destroyed as they approached the coast, sixteen aborted their missions and returned to North Vietnam, and only

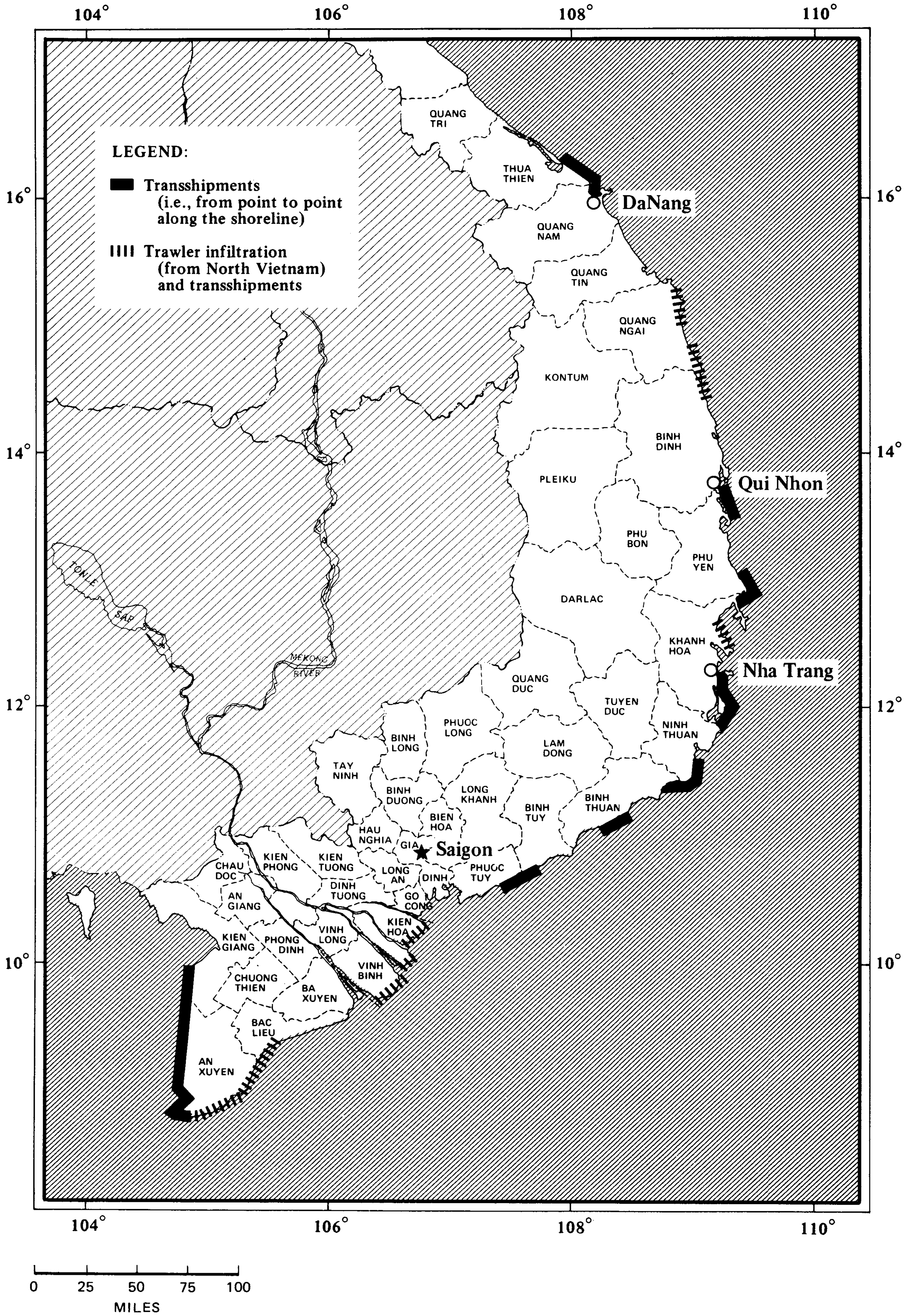



Figure 5-5. Areas of Highest Threat for Market Time Forces

one managed to get through and unload its cargo. There was also, of course, the threat of junks and sampans, which were quite adept at avoiding detection. Market Time forces found it particularly difficult to discriminate between the few boats engaged in transshipping enemy supplies, and the many engaged in innocent business. Junks and sampans, furthermore, enabled the enemy to move supplies in the shallow, tidal inshore waters off the southernmost portion of South Vietnam known as IV Corps. Finally, there were a few indications that the enemy was employing lightering from merchant ships.

Since the inception of Market Time, much work had been done to gauge its effectiveness. An earlier example of this was described in the last chapter. This time, however, OEG was to anticipate the operation's *future* effectiveness—following the turnover of assets, including the radar network, to the Vietnamese navy—on the basis of mathematical models developed for this purpose. The models were useful in the following ways: revealing existing and potential weaknesses in Market Time operations; predicting the contribution of future systems (such as the shore-based radar network) to Market Time effectiveness; finding ways to come up with something more precise than just an upper bound for estimates of effectiveness; and comparing alternative plans for conducting Market Time operations.

A detailed review of the inner barrier's effectiveness yielded an estimate of the probability of capturing or destroying an enemy junk or sampan. The estimate was based on a number of assumptions, including the percentage of time the radars on patrol craft would be operable, the patrol's speed of advance along the barrier, the junk's or sampan's speed, and the probability that an enemy boat, once intercepted, would be captured or sunk.

Some of the assumptions, however, were subject to change, especially if certain aspects of performance turned out to be less optimistic than forecast. For instance, the probability of detecting a junk was estimated on the expectation that the enemy's movements through the inner barrier were conducted without any knowledge by him of how the barrier operated. Yet this assumption may not have been entirely valid. Additionally, a review of procedures used by patrol craft crews in choosing which of several detected boats would be searched indicated that the enemy might be able to find ways to avoid being searched. One such tactic could be used if the patrol craft made a habit of searching the nearest junk. In that case, the junk could avoid being investigated simply by making sure that another junk (an innocent one) was always between it and the Market Time craft. Also, estimates of the availability of patrol craft and radar could be affected by unusual problems with equipment, such as engines and generators.

As far as the threat from trawlers was concerned, most of the work focused on the probability of sighting and intercepting a trawler, rather than on the ability of Market Time forces to capture or destroy it. Again, the results varied according to the realism of assumptions. A related issue was the questionable ability of a single patrol craft to handle a well-armed trawler. Since it took a trawler quite some time to unload, forces other than the patrol craft could be instructed to head to the location of the trawler for an attack. Hence, a better measure of Market Time's effectiveness might be the probability of spotting, intercepting, and trailing a trawler, then directing other (more heavily armed) forces to the site for the

U.S. and South Vietnamese personnel inspect a boat they stopped in South Vietnamese waters as part of Market Time operations. (Official U.S. Navy photo.)

kill. Basic to all this, of course, was an understanding of the effectiveness of the planned coastal radar sites, which was likewise modeled.

OEG's study led to several recommendations. Patrol craft should be tailored to a particular mission in a particular area, for example, because many sections of the South Vietnamese coast differed in terms of coastal waters, weather, the nature of the threat, and even local fighting practices. Improved tactics were suggested—including signals among units taking part in the operation—to make attacks on heavily armed trawlers go more smoothly. Further, it was suggested that the coastal surveillance system be supported in two ways. The first involved fully manning outer-barrier stations, where surveillance could provide as much as a couple of days' reaction time, compared with the couple of hours provided by shore-based radar. The second way of supporting coastal surveillance involved concentrating at least a portion of Market Time forces in high-threat areas of the inner barrier. Finally, it was recommended that communications be made more secure, that command and control be upgraded, and that the reaction time of both planes and boats be improved so they could be vectored to targets quicker.

Besides Market Time, the group also traced the evolution of Game Warden, to determine the effect river patrols were having on Viet Cong activities, especially in the Mekong Delta and Rung Sat Special Zone. Game Warden forces were designed to interdict Viet Cong infiltration and resupply and to eliminate Viet Cong insurgency in their areas of operation. The nature of the threat, a description of the Delta and Rung Sat, and the setting up of the operation (including the kinds of forces used) were discussed earlier. It is worth elaborating, however, on the procedures employed by Game Warden forces in pursuit of their goals of interdicting and harassing the enemy, and of patrolling and sweeping the rivers of mines.

River patrol boats normally operated in pairs, staying midstream and within radar range of one another. Operating orders emphasized the need for random patrols to be alert to possible mining, ambushes, and booby traps. Precautionary measures were also taken to prevent the Viet Cong from learning the exact location of patrol boats. Among these measures was the restricting of radio communications, because it was assumed that the enemy was monitoring U.S. circuits through the use of captured equipment. Another measure involved not responding with automatic weapon fire if attacked by snipers employing only small-caliber, non-automatic weapons, unless the crew could pinpoint the source of the sniping. In this way, neither the exact location nor the armament of the patrol boat would be needlessly disclosed.

All river traffic was considered suspect, particularly during the nighttime curfew (civilians were informed of the curfew by means of leaflet drops

U.S. Navy patrol boats patrol a canal in the Mekong Delta. (Official U.S. Navy photo.)

and loudspeaker announcements). During the day, patrol boats conducted random searches of watercraft when there were too many such craft for all to be inspected. According to an estimate by the Commander in Chief, Pacific, this procedure resulted in about 60 percent of all spotted junks and sampans being investigated.

Patrol boat crews were warned to approach contacts at an angle that would allow the most weapons to be trained on the target. At night, the approach was to be made at high speed, with the patrol boat's lights extinguished. Once the patrol boat was close enough, it would illuminate the contact and order all occupants to show themselves. The boat's crew would then call for the junk or sampan to pull alongside, usually in midstream, but would not moor itself to the suspect craft. At this point, the patrol boat was vulnerable to hand grenades and mines and had to be cautious of Viet Cong decoy tactics. While one of the paired patrol boats conducted the search, the second would position itself to have a clear line of fire to both sides of the river. Inspections included a thorough search of the cargo, the passing of poles under the hull to check for contraband, and the checking of occupants' identification cards for known Viet Cong.

At first, patrol boats were allowed to fire only warning shots to stop junks and sampans, enabling too many suspicious craft to evade inspection. The rules of engagement were therefore quickly revised, to allow patrol boats to direct fire against craft that refused to stop. After a while, the Viet Cong began using heavier weapons—large-caliber machine guns, mortars, rifle grenades, and rockets—and, after the Tet Offensive, resorted to bunkers from which to fire. Originally, standard procedure called for patrol boats, when fired on, to leave the area while returning fire and calling for backup. Eventually, they found enemy fire could be suppressed by remaining to fight.

Since Game Warden efforts were initially centered on Rung Sat, it was there that results were first discernible. In one operation, over sixty Viet Cong were killed; more important, the operation disrupted a major base area, consisting of an arms factory, a training area, mine storage facilities, and a large medical center that required underwater demolition teams to destroy it. Ten river patrol stations were established during this particular operation (Figure 5-6), which afterwards were retained as part of the entire Game Warden network. Though the intense tempo of operations in Rung Sat taxed both the crews and their boats, OEG found that Game Warden forces managed to hamper severely—though never, by any means, totally deny—enemy activities in the region. Certainly, enemy attempts to close the sea lanes to Saigon—a major Viet Cong objective—were stymied.

It turned out that the first Game Warden units to begin operating in the Mekong Delta were deployed in areas that were serving as the Viet Cong's principal supply corridors. This meant that the enemy's traditional routes across the major Delta rivers were interrupted from the outset. OEG found that as the enemy shifted his activities, Game Warden forces proved highly adaptable and tactically innovative. Patrol areas were adjusted, too, to reflect increasing or decreasing numbers of contacts and to benefit from intelligence reports (Figure 5-7). The group also found that during the 1968 Tet Offensive, when the Viet Cong launched multiple, simultaneous attacks against South Vietnamese towns, Game Warden forces could be credited with saving several provincial capitals throughout the Delta. An analyst at the time also noted that the enemy appeared to be limiting his movements to lesser waterways, where the patrol boats had a harder time gaining access. Another conclusion drawn from the study was that mobile afloat bases provided riverine operations with a flexibility that permitted forces to respond to an ever-shifting threat. Finally, helicopters were shown to perform an essential role in providing fire support, observing enemy movements, and evacuating the wounded.

High above all this activity on the ground and in the rivers was yet another aspect of the conflict, as U.S. planes engaged North Vietnamese MiGs in air-to-air combat. The phase of the air war analyzed by one OEG

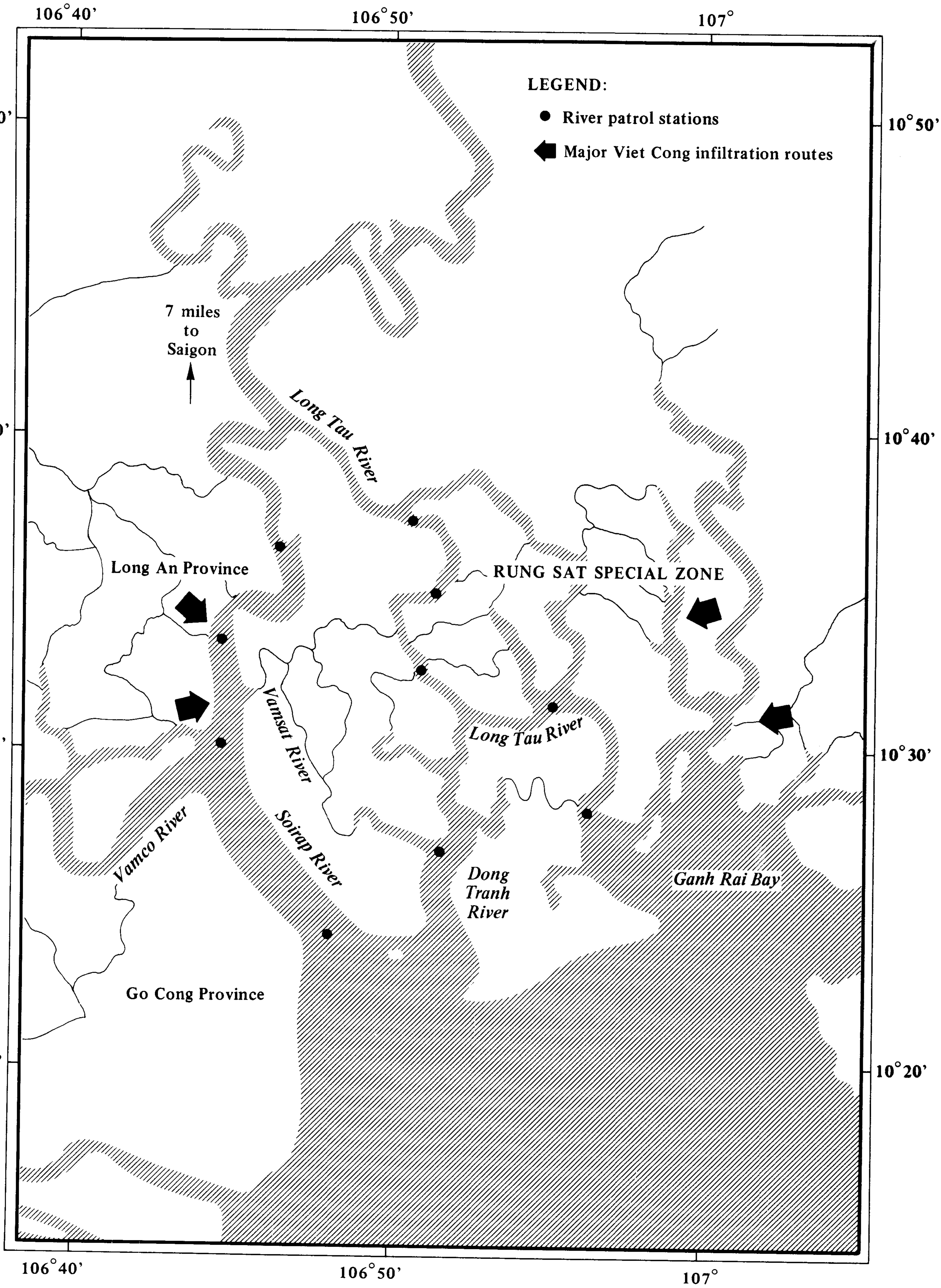



Figure 5-6. Location of River Patrol Stations in Rung Sat

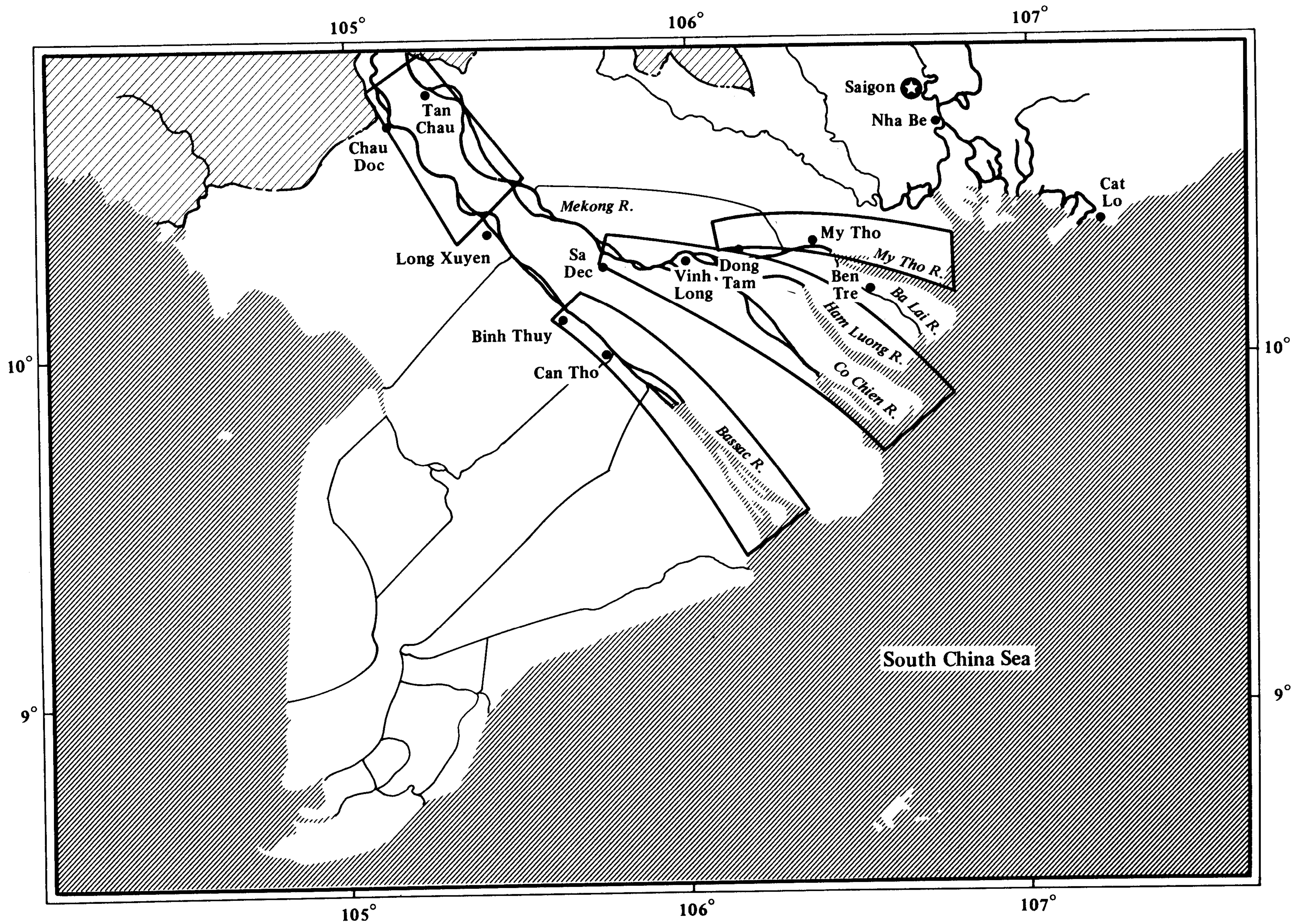



Figure 5-7. Areas of Mekong Delta Patrolled by Game Warden Forces (1968)

study resulted from the March 1972 invasion of South Vietnam by North Vietnamese forces. The specific air campaigns that led to air-to-air operations were Freedom Train, the name given to air operations south of the 20th parallel, which began in early April 1972; and Linebacker, the name given to the entire air and surface campaign against the North, which began in May and ended in November.[6] Air attacks against North Vietnam during 1972, like those in 1965, at first faced restrictions in terms of targets and number of sorties. The bombing was allowed to increase in intensity and scope, however, as North Vietnam's armies in the South made early gains.

When U.S. bombing was stopped in late 1968, North Vietnam had a system of nine airfields capable of handling jet aircraft. By April 1972, the number of such airfields had increased to eleven, with a twelfth completed shortly thereafter and an additional field built during Linebacker. In contrast with the early tendency to construct airfields in the Hanoi-Haiphong area, North Vietnam's strategy in establishing airfields after the 1968 bombing halt was to strengthen air defenses in the lower regions, closer to South Vietnam (Figure 5-8).

At the beginning of the period investigated by OEG, the North Vietnamese had more than two hundred MiG aircraft. These comprised a mix of combat-ready MiG-21s, -19s, and -17s, with most located at four major airfields: Phuc Yen, Yen Bai, Kep, and Gia Lam. These major fields, all within one hundred miles of Hanoi, took in an area that was considered primary for MiG defense. The reasons for restricting MiG defensive responsibility to this area were probably the extensive bombing of southern airfields by the United States, a desire to concentrate on the defense of important military and industrial targets within the area, and the proximity of ground-control facilities to airborne MiGs.

For the purposes of the study, OEG placed each air-to-air incident into one of three categories. The first consisted of "sightings," in which visual contact was made with an enemy or unidentified aircraft but without significant maneuvering by either side. The second category was termed "encounters," in which visual or radar contact was followed by a serious attempt by one or the other aircraft to get into a firing position but without a shot actually being fired. The last category was "engagements," in which at least one of the aircraft fired ordnance.

By far most MiG attacks—a little over three-fourths of all engagements—between April and November 1972 were directed against air force rather than navy planes. Air force encounter rates for the period were five to ten times higher than navy rates. The difference in these rates was probably attributable to the locations within the main MiG defensive area that each service was assigned. The navy's sector of operations consisted largely of flat coastal plains; the air force's sector, on the other hand, was farther

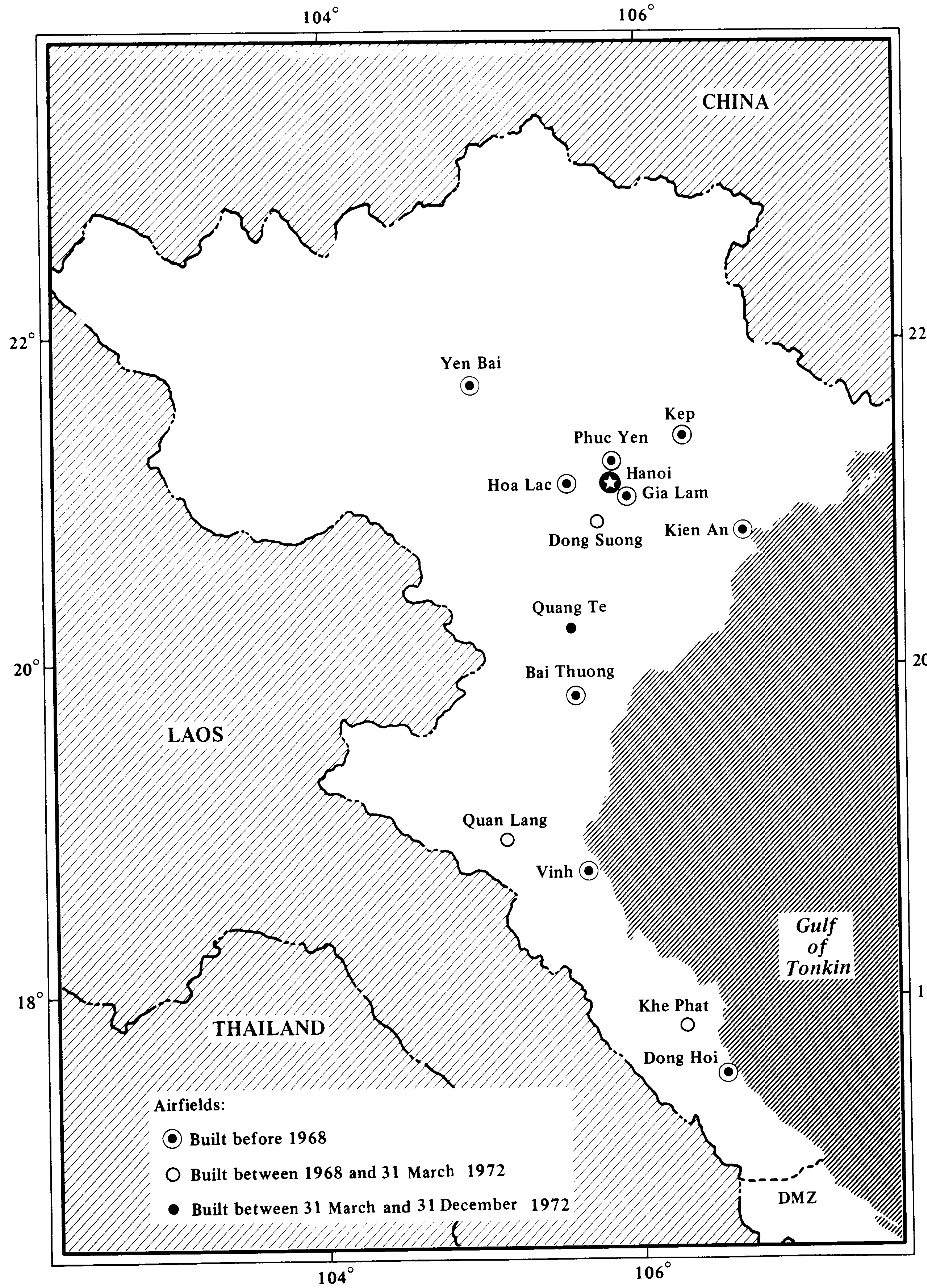
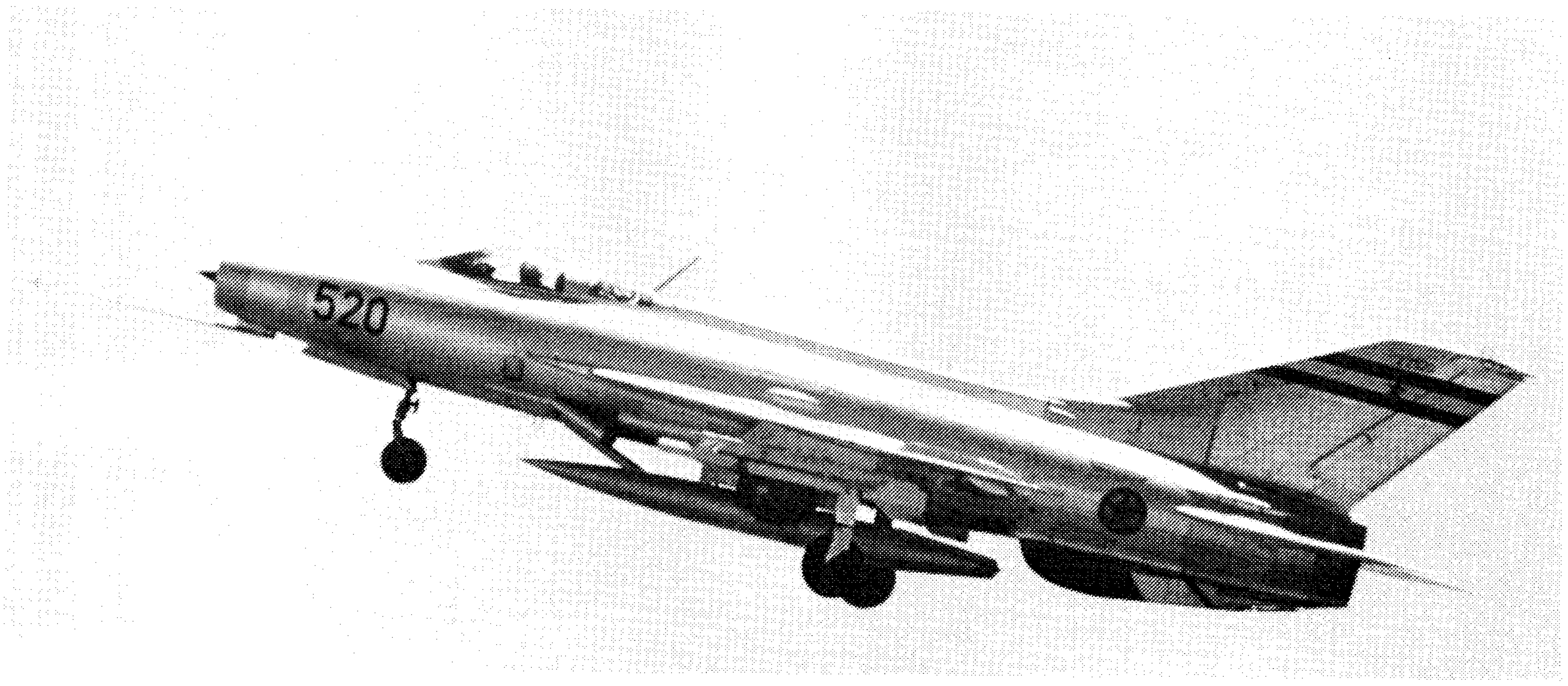



Figure 5-8. North Vietnam's MiG Airfields



A Soviet MiG-21 Fishbed delta-wing fighter aircraft, of the kind used to try to counter U.S. Navy and Air Force raids into North Vietnam. (Official U.S. Navy photo.)

inland, deep within the MiG defensive area (Figure 5-9). MiGs flying in the navy sector faced three hazards they did not encounter in the air force sector. These included early detection by shipborne radar looking up the Red River valley, denying MiG pilots the element of surprise; SAM-equipped ships sailing near the coast; and navy aircraft orbiting off the coast to protect special-mission aircraft operating in the Tonkin Gulf. Also, in an attempt to distribute his forces most effectively, the enemy placed more of his SAM sites in coastal areas rather than in the mountainous terrain to the west, thus requiring MiGs to concentrate their efforts in the latter region.

U.S. forces took several steps to counter the MiG threat. One measure was to bomb North Vietnamese airfields, mostly below the 20th parallel where the MiG threat against B-52s was particularly acute. OEG found, however, that strikes against MiG bases met with mixed success. On the positive side, the campaign was unquestionably successful in cutting off MiG access to airfields and airspace in the southern region of North Vietnam. After April, in fact, there was very little MiG activity south of the 20th parallel. A Defense Intelligence Agency assessment described the five jet airfields in that southern region as "rendered temporarily unserviceable by U.S. air strikes" between June and early October, even though some repair efforts were made. The group attributed the apparent abandonment of southern bases to other factors, too. These included problems in providing fuel and maintenance services to outlying areas; the lack of enough combat-ready MiG-21s and -19s to cover all areas; and a desire to concentrate MiG defenses around high-priority targets near Hanoi.

For the most part, however, strikes were ineffective in keeping closed any airfields the North Vietnamese were determined to reopen. Though North Vietnamese fighters were hindered by the cratering and seeding (with

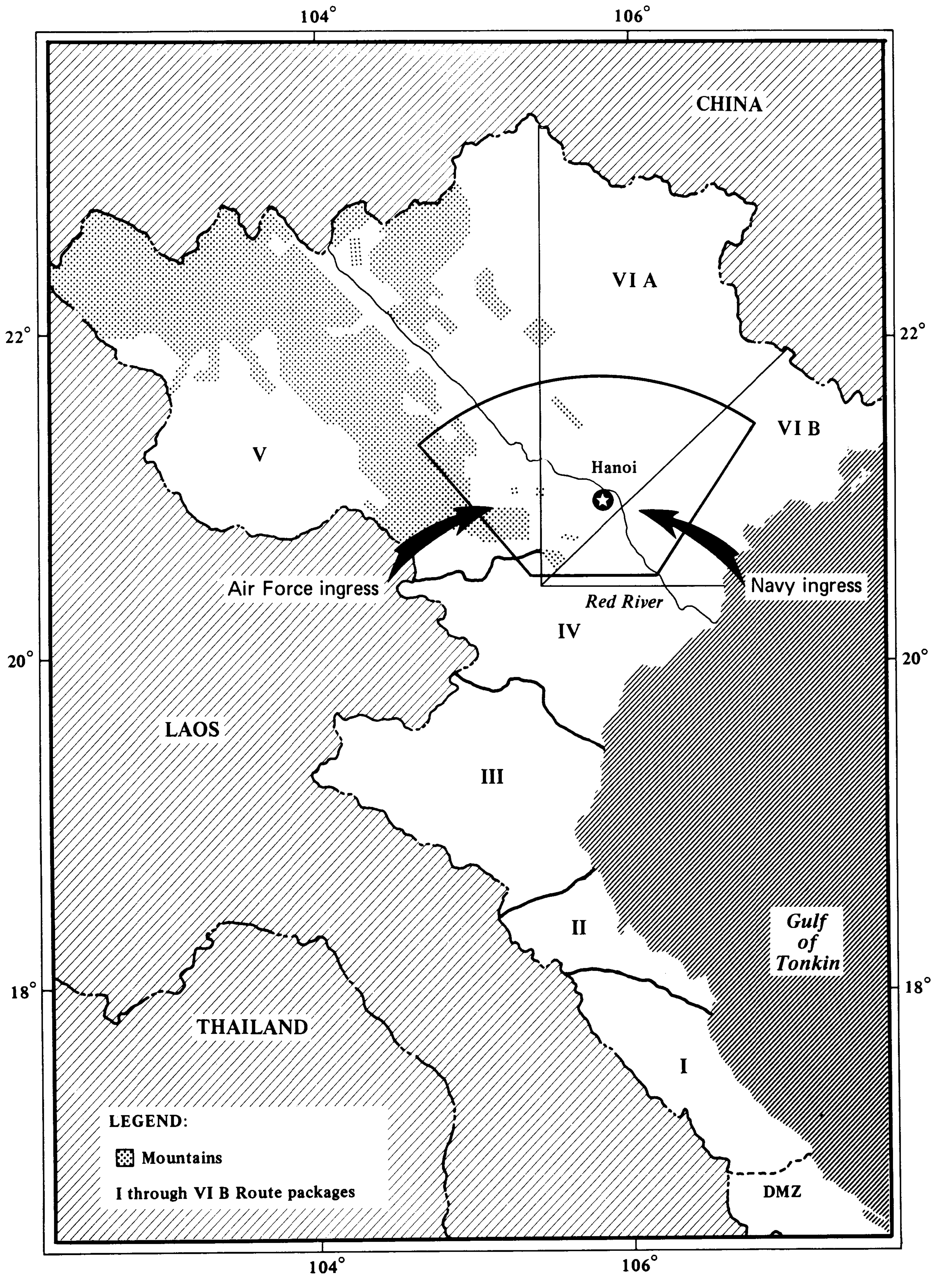


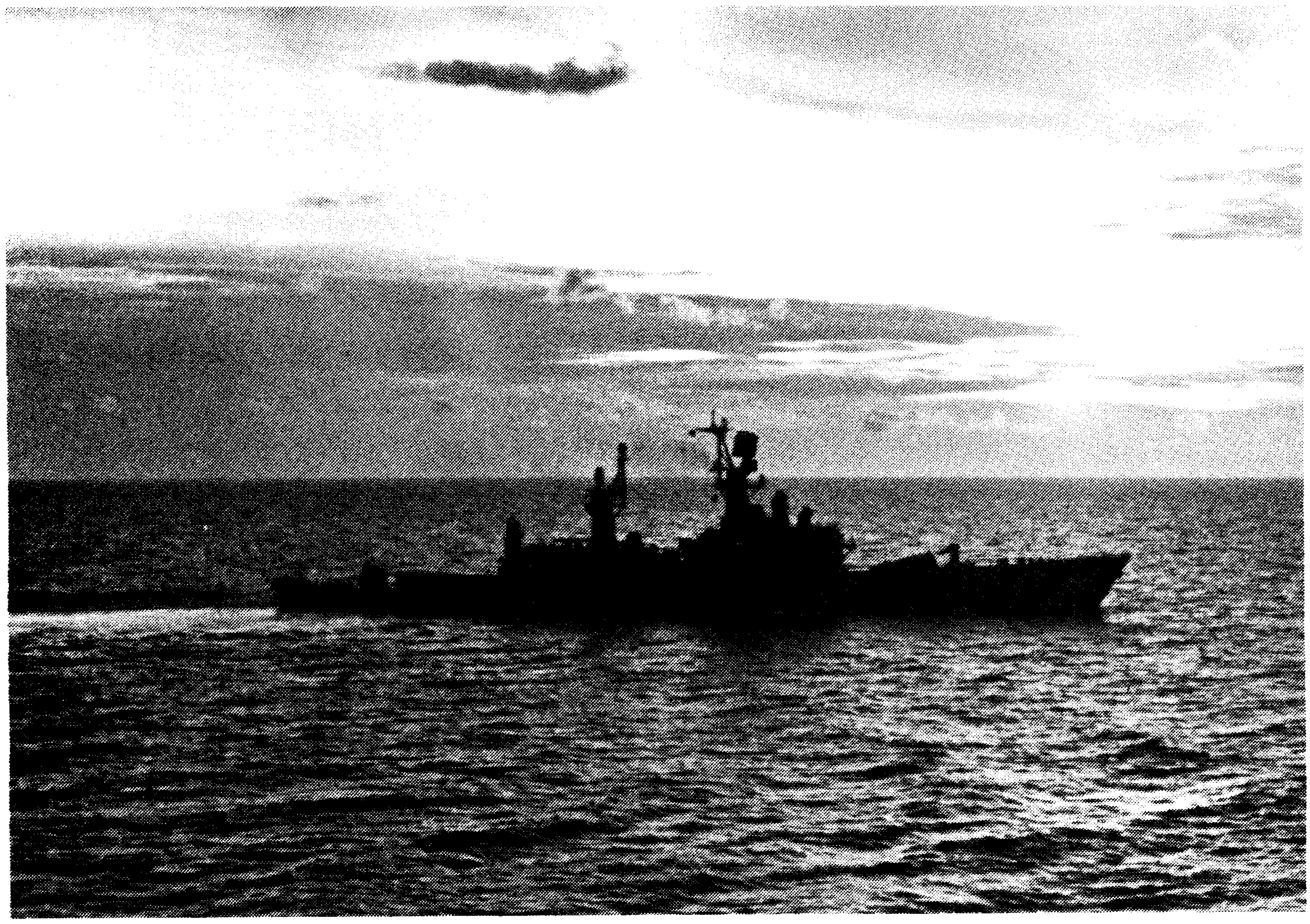

Figure 5-9. Navy and Air Force Approaches into Major MiG Defensive Area

delayed-action bombs) of runways, their small size and light weight enabled them to operate from fairly primitive fields. Furthermore, bombed concrete surfaces were patched quickly by various makeshift means, such as gravel or steel plates. OEG concluded, therefore, that the MiG threat could be suppressed only by destroying the planes themselves, for the effort required to keep airfields out of service would have been prohibitively high.

Because the bombing of airfields produced only modest results, other measures to counter MiGs were necessary. One of these was an early-warning system, designed to detect airborne enemy fighters and broadcast warnings to friendly planes likely to come under attack. The system consisted primarily of navy and air force electronic intelligence and reconnaissance aircraft, surface ships stationed off the coast, and land installations. These elements of the system not only provided early detection and warning, but also directed U.S. planes to intercept MiGs by providing, for example, MiG range and bearing. OEG found that there was a positive relationship between success and the percentages of engagements with early warning. The MiG-21's tactic of hit and run, moreover, made early warning imperative. The value of the system was made evident by the air force/MiG-21 exchange ratio of thirty-one to twelve kills with early warning, compared with three to seven kills without. (In the latter case, engagements often began with the MiG already in a firing position, as a result of its having successfully remained undetected until the last moment.) The need for early warning was less apparent in navy exchange ratios against its more common foe, the MiG-17, because of the ability of navy fighters to outmaneuver that aircraft even if early warning was unavailable.

Still another means of reducing the MiG threat involved the use of electronic countermeasures. These were aimed mostly against the acquisition and control elements of North Vietnam's ground-control intercept (GCI) system, used to direct MiG intercepts of U.S. strike forces. Enemy SAM and early-warning radars were principal targets for jamming. Although the successful jamming of GCI radars would have denied MiGs access to information essential to the tracking of U.S. planes, OEG's analysis showed that early attempts at jamming had limited success. Later improvements in equipment and procedures were judged to have produced better results in terms of disrupting the enemy's command and control network.

The single most effective measure in negating the MiG threat, however, was the use of fighter aircraft as combat air patrol (CAP) and as escorts protecting the strike force. The navy tried hard to provide enough fighters to fill these roles. Indeed, nearly a third of all planes on a given mission were assigned to prevent MiGs from shooting down the strike aircraft. The positioning of CAP aircraft was kept flexible, varying from one carrier to



The guided missile frigate USS *Wainwright* on station in the Tonkin Gulf, providing early warning and navigational support during air operations in North Vietnam. (Official U.S. Navy photo.)

another and from one target (that is, type of MiG) to another. The aircraft generally preferred to stay out over the water until the strike force had reached land, whereupon they would take up their positions. OEG's study revealed that CAP and escort aircraft were highly effective. Specifically, MiGs were able to fire at a navy strike group in only three engagements during the period examined. More important, none of these MiG firings resulted in the downing of a strike aircraft.

As an overall measure of the entire air-to-air war, U.S. Navy planes shot down seven MiGs to every one loss between April and November 1972. (The locations of MiG kills by navy fighters are shown in Figure 5-10.) When navy and air force kills were combined, the outcome was a loss to North Vietnam of about a third of its combat-ready MiG inventory in just the first couple of months of the period. By August, the enemy's inventory of combat-ready planes had been seriously depleted, resulting in a decline in MiG activity. In fact, heavy MiG losses in the earlier months produced such a sharp dropoff in enemy activity that no kills—and only one engagement—occurred in November, the last month analyzed by OEG.

With the signing of the Paris Agreement in January 1973, the United States's involvement in the fighting in Vietnam ended. OEG's role, however, continued. Because of the war's length, many operational data still

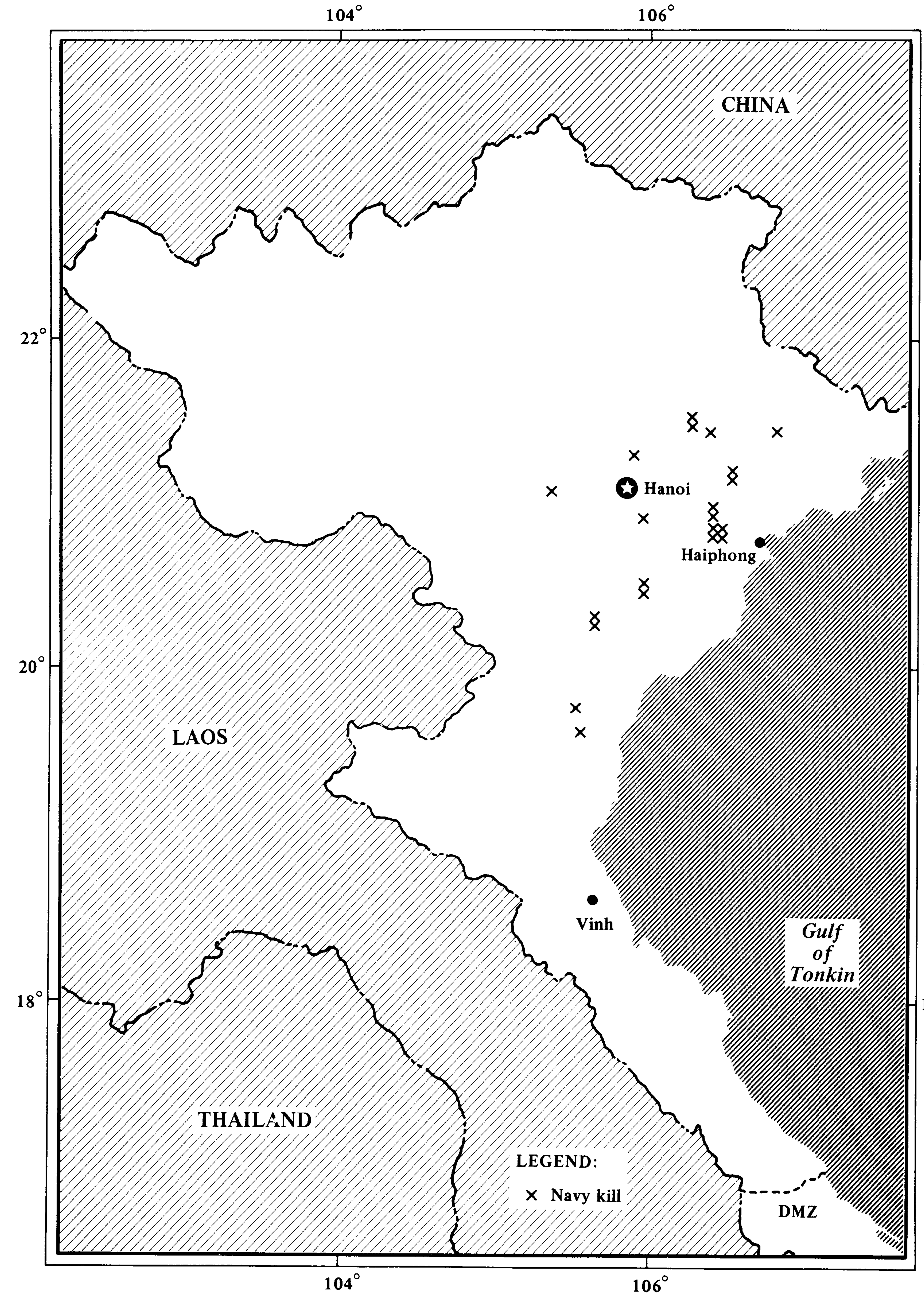



Figure 5-10. Location of Navy MiG Kills (April to November 1972)

had to be sorted and analyzed. The increased tempo of the conflict in the last year, moreover, had placed such a strain on analytical means—sometimes to the point of diverting resources away from the group's CNO-directed study program—that the navy's immediate needs had to be met first. A more comprehensive overview of events had to be deferred until the war was over and the press for near-term combat analysis had subsided. For the next few years, therefore, a scaled-back effort continued to be devoted to the reconstruction, recording, and analysis of operations in Southeast Asia.

**Red-Side Operations Analysis Section**

Beginning at about the time America's involvement in the conflict in Southeast Asia began to recede, OEG passed through several significant changes that ultimately led to the group as it is formed today. The first involved a switch in the group's directorship. Because of the sudden poor health of Dr. Erwin Baumgarten in the latter part of 1969—and the likelihood of a long period of convalescence—he and Charles J. DiBona, CNA's president, felt that a replacement should be found. (It was agreed that upon his return, Baumgarten would join the CNA management staff as a senior scientist.)

DiBona's choice as the new OEG director, Mr. Ervin Kapos, took over in October 1969. Prior to his appointment, Kapos had spent a year as director of the Marine Corps Operations Analysis Group (MCOAG). Before that, he had been in OEG for ten years, where he served for a little over a year as head of OEG's Southeast Asia Combat Analysis Division (SEACAD). Kapos was awarded the Meritorious Public Service Citation by Secretary of the Navy Paul R. Ignatius, for his field support of the Commander in Chief, Pacific Fleet, during the Vietnam War. The citation noted that Kapos's work was "instrumental in saving lives of combat aircrews, reducing aircraft attrition, and improving ordnance allocation methods, thereby significantly contributing to the combat effectiveness of the U.S. Pacific Fleet."

The second major change that occurred at this point stemmed from a 1970 decision by the Assistant Chief of Naval Operations for Intelligence, Rear Admiral F. J. Harlfinger (Op-092), "to enlist the assistance of the Operations Evaluation Group... in developing an operations analysis system for evaluating intelligence collection [operations]." Specifically, he wished to establish within OEG the capability to apply operations analysis techniques to Soviet naval operations—called "Red-Side" operations analysis—in support of the Naval Intelligence Command. Explained Harlfinger:

> It is all but impossible to analyze the effectiveness of even individual friendly [operations] without being able to determine the effects of these activities on the enemy. These effects, in turn, cannot be

> determined unless we are able to reconstruct and analyze the enemy's actions and tactics .... It is evident as a result of combat analysis efforts of recent years that a Red-Side operations analysis capability is urgently needed to provide a basis for evaluating and optimizing our own operations.

In sum, the U.S. Navy needed to better understand just how well its main adversary might fight, should a conflict arise.

In continuing discussions between OEG's Kapos and the Naval Intelligence Command concerning implementation of the Red-Side research program, the group agreed to begin work on related projects. One such project involved providing assistance to Commander Task Force 168 in analyzing a Soviet naval exercise. There were several objectives in doing so. One was to assess the proficiency with which individual Soviet units–ships, submarines, planes, and so on–fulfilled their roles in the exercise. Another objective was to evaluate the technical capabilities and general performance of these units and their equipment, and to compare the results with earlier observations. A third goal involved examining the strategic implications of the Soviets scheduling the exercise at that particular time. Yet another goal was to evaluate the degree of success obtained by U.S. and Allied observers of the exercise and to recommend improved techniques.

Above all, however, there was a desire to derive insights into Soviet tactical doctrine. Since the Soviets would obviously know better than us the capabilities and limitations of their systems, their choice of tactics should reveal something about these capabilities. That is, as an alternative to simply watching systems in use, analysts could take a description of Soviet tactics and work back to an understanding of what the Soviets know are their systems' capabilities. Also, it was recognized that an indirect way of measuring our own effectiveness was to observe how the Soviets modified their operations in response to what we do. We, in turn, could then detemine how we should operate.

Analyzing exercises conducted by our own forces was difficult enough; analyzing enemy exercises posed a decidedly monumental task. Indeed, the circumstances peculiar to the observation of enemy exercises only compounded the sort of problems typically associated with the observation of U.S. naval exercises. Possible limitations included conflicting data obtained from different sources; missing data because an event in the exercise (the time, say, at which detection of an air raid occurred) could not be observed; and reduced confidence in the inferences drawn from the data that were collected. Hence, methods had to be devised to compensate at least in part for these gaps and deficiencies.

Despite OEG's deepening involvement in such work–and the strong support for this work by the Chief of Naval Operations, Admiral Zumwalt–no formal Red-Side division was immediately created within the group. The reason was a funding ceiling imposed on the CNA contract by the House Appropriations Committee. Concerned, however, that the ceiling might jeopardize planned Red-Side operations analysis, the Director of Navy Program Planning, Admiral C. E. Bell (Op-090), urged that OEG's efforts nevertheless continue. He stressed that, for the time being, attention should focus on just the most pressing problems that could be handled by current OEG members. In the meantime, Admiral Zumwalt brought the matter to the attention of Senator John C. Stennis (D-Miss.), chairman of the Senate Appropriations Committee.

Finally, a separate Red-Side Operations Analysis Section was set up within OEG in November 1970, although it was more than a year before a specific task order could be written up and specially earmarked funds acquired. Kapos served initially as its head, with John G. Pierce eventually taking over. In staffing the section, Kapos persuaded the navy to provide him with eight officers: four intelligence specialists and four line officers (for example, a submariner and reconnaissance expert) with intelligence-related backgrounds. OEG likewise contributed eight people.

Because of OEG's close relationship with the fleets, as well as with the Office of the Chief of Naval Operations and the Washington elements of the intelligence community, the group was in a particularly advantageous position to undertake this unusual program. Even so, the program was innovative. First, there was no tradition of operations analysis of the Soviet navy; much of the group's work therefore had to start from scratch. Also, data available for analysis of the Soviet navy were unfamiliar in type and quality, requiring the development of new techniques for handling the data. Lastly, the small section within OEG assigned to Red-Side analysis was responsible for covering *all* areas of Soviet naval warfare, not just one or two facets of it.

One of the most important projects that came out of the program was a comprehensive description of Soviet naval tactics. Published by the Naval Intelligence Command under the title "Red ATP-1," the document was intended as a counterpart to the basic NATO doctrinal publication called "ATP-1" (Allied Tactical Publication 1). Three critical warfare areas covered by the document were anticarrier warfare, antisubmarine warfare, and fleet air defense. Navy acceptance of the publication was assessed by the director of Naval Intelligence, Rear Admiral E. F. Rectanus, in May 1972:

> The reaction to the "Red ATP-1" has not only been extremely favorable, but, in more than one case, efforts are being made cooperatively to improve our knowledge of Soviet operating patterns and tactics. This linkup between user and analyst is most desirable

> and will further the already broad interface between [OEG] and the fleet, a historic relationship that is unique among the services.... The "Red ATP-1" has served to prove out Admiral Zumwalt's concept of Red Side. Succeeding work ... will demonstrate the full maturity of this approach to the problem of predicting the pattern of Soviet tactical operations.

Besides "Red ATP-1," many other reports were prepared by OEG's Red-Side Operations Analysis Section. Some of the subjects examined were Soviet antiship missile capabilities, employment of Soviet submarines in antisubmarine warfare, Soviet shipborne fighter control, Soviet electronic intelligence surveillance, air-to-surface missile attack tactics, and command and control aspects of Soviet anticarrier warfare. Many of these reports served a dual role by being useful in their own right while also providing the detailed analytical backup to what had been said in the more expansive "Red ATP-1." That is, although "Red ATP-1" was intended for the ship's general staff, the many detailed reports backing it were intended largely for just the intelligence officers, so they could confirm the accuracy of "Red ATP-1" should questions come up.

**The Tactical Analysis Group**

The origins of yet another major change in OEG during this period of the 1970s date back a few years. In June 1966, Vice Admiral Charles B. Martell, the Director of ASW Programs (Op-095), established what was called the Tactical Analysis Group (TAG). Its purpose was to help fleet commanders plan and conduct fleet antisubmarine warfare (ASW) exercises, and subsequently to reconstruct and analyze them. TAG members were to serve a threefold function: to provide urgently needed analytical support to fleet commanders; to supply the Chief of Naval Operations with valid, analyzed ASW data on which he might base decisions concerning long-range plans and force levels; and to collect data on ASW equipment and training for use by the material and training commands. By being on hand throughout the entire exercise, TAG members were expected to ensure continuity of effort in a program that previously had been somewhat haphazard.

For the next several years, the TAG program was run on a multicontract basis, involving ten companies—including Grumman and Lockheed—and some thirty-five civilian analysts. The Chief of Naval Operations decided, however, that the administration had grown too burdensome, that quality control was poor, and that the separate contractors were too often at odds with one another. So, in September 1970, he asked OEG to take over management of the program, with OEG's director, Ervin Kapos, as technical manager for TAG.[7] The idea was that OEG would assume technical responsibility for all TAG activities, to go into effect as current contracts expired—nominally scheduled for the end of December 1970. The one exception was the contract for "surveillance TAG," held by Arthur D. Little, Inc., which the navy planned to extend beyond its March 1971 termination date because of that company's "expertise in an extremely specialized field."

By consolidating the TAG program under a single organization, the navy expected to increase the program's overall effectiveness as a consequence of improved coordination, flexibility, and responsiveness. According to Robert A. Frosch, assistant secretary of the navy for research and development and chairman of the CNA Policy Council:

> CNA's OEG has been selected to perform this function [the management of TAG] because of the special competence that this organization has built up over the past 30 years. They maintain a professionally trained and Navy-oriented staff, and have the capability to furnish centralized management for the Tactical Analysis Group effort. This will result in the efficient allocation of personnel support to meet changing fleet exercise priorities and special project needs, and a firmer integration of major CNO studies with the data base from fleet exercises.

The Director of ASW Programs (Op-095), by then Vice Admiral Turner Caldwell, was to continue as TAG program director on behalf of the Chief of Naval Operations, Admiral Zumwalt. To guarantee that the TAG program, as submitted each year by OEG, reflected the goals of the CNO and fleets, a steering committee was set up, with Op-095 as chairman. The commanders of the ASW and submarine forces in the Atlantic and Pacific oceans were represented on the committee, too, as was the DCNO for Fleet Operations and Readiness (Op-03) and the Center for Naval Analyses. To enhance the continuity of the TAG program, changes in the priorities and tasking specified in the annual program (or in the six-month update) were to be made only if agreed to by both the Program Director (Op-095) and Technical Manager (OEG's director). It was recognized, however, that such changes might be required, to keep the program flexible and responsive.

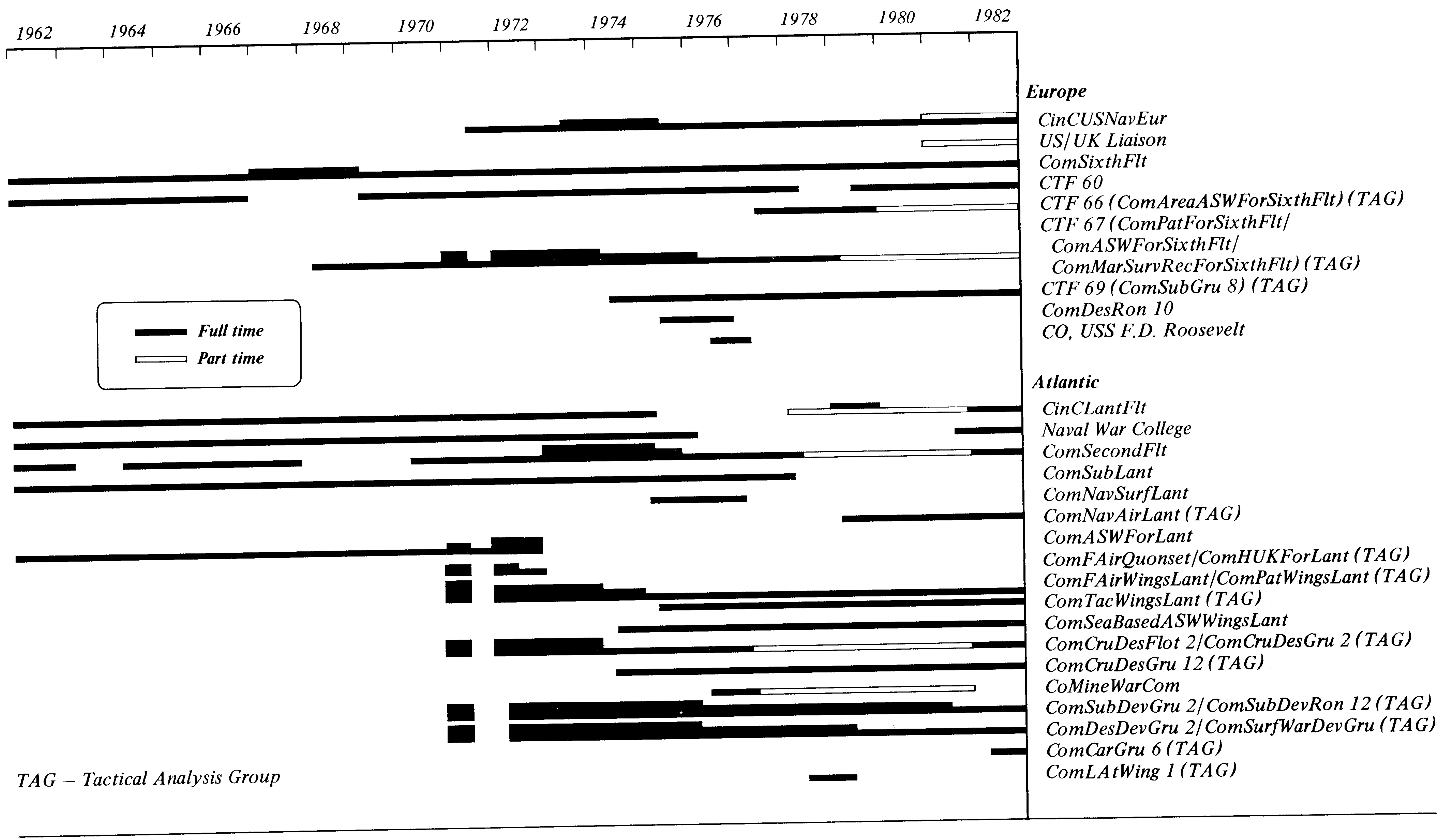
OEG was expected to have most of its TAG analysts on site by the beginning of January 1971, ready to pick up where the several contractors had left off. To do this smoothly, liaison with the operating commands was essential. In addition to the many TAG analysts in the field, two were to stay in Washington. The functions of these two analysts consisted primarily of developing and managing the annual TAG program and carrying out broad analyses of fleet operational experience and tactics that could not be readily handled at the individual commands. These analyses were expected, at times, to integrate work done by the various field teams. Other functions of the two Washington-based analysts included monitoring the quality of TAG analysis in general; serving as a link between TAG teams in the field and the Chief of Naval Operations and Chief of Naval Material; and being available to augment the TAG commitment at a particular command, in response to a temporary shift in workload or priority.

The first analysis program proposed by OEG was due in the hands of the steering committee by 1 January 1971. It was to cover just the following six months, that is, the remainder of FY 71. The proposal noted that under the old TAG program, analysts worked on tasks that were assigned to the individual operating commands by the Chief of Naval Operations. In the actual day-to-day running of things, however, assignments were made by the host commands, which had a better feel for their own requirements. OEG suggested that to a large extent, it would be desirable to preserve this decentralized approach.

OEG's proposal pointed out that there would be about twenty-three analysts taking part in the TAG program. This was down from the number assigned to TAG before the group took over, because of reduced funding for the program for the latter half of FY 71. Taking this into account, OEG recommended a particular allocation of analysts among the commands. The allocation was based on several factors: the anticipated TAG program at each command; the objective of ensuring that OEG TAG analysts concentrate on well-defined tasks; the number of analysts assigned in late 1970, and how well they met requirements; the expected priorities of the Director of ASW Programs; and the cost of filling assignments. Within this framework, OEG was reluctant to assign fewer than two analysts to any one command, for fear of impairing the ability of an analyst to devote his time to specific tasks. To ensure maximum continuity of the TAG program, the group decided to satisfy about a third of its manpower needs by recruiting from among those who had been TAG analysts before OEG became involved. The rest would come from current OEG members and new hires.

There were eight TAG commands at the time: Commander ASW Force, Pacific (ComASWForPac), and Commander Submarine Force, Pacific (ComSubForPac), in Hawaii; Commander ASW Force, Atlantic (ComASWForLant), and Commander Fleet Air Wings, Atlantic (ComFAirWingsLant), in Norfolk; Commander Fleet Air Quonset (ComFAirQuonset) in Quonset, Rhode Island; Commander Submarine Development Group Two (ComSubDevGru Two) in New London; Commander Destroyer Development Group Two (ComDesDevGru Two) in Newport; and Commander ASW Force Sixth Fleet (ComASWForSixthFlt) in Naples, Italy. These, of course, have been added to extensively, as shown in Figure 5-11. The figure traces the history, including manpower levels, of all of OEG's field assignments since 1962 (when OEG was absorbed by CNA) and indicates which were associated with the TAG program.

OEG also proposed many of the topics that should be examined at each command over the first several months. At the ASW Force in the Pacific,


1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
Full time
Part time
Europe
CinCUSNavEur
US/UK Liaison
ComSixthFlt
CTF 60
CTF 66 (ComAreaASWForSixthFlt) (TAG)
CTF 67 (ComPatForSixthFlt/
ComASWForSixthFlt/
ComMarSurvRecForSixthFlt) (TAG)
CTF 69 (ComSubGru 8) (TAG)
ComDesRon 10
CO, USS F.D. Roosevelt
Atlantic
CinCLantFlt
Naval War College
ComSecondFlt
ComSubLant
ComNavSurfLant
ComNavAirLant (TAG)
ComASWForLant
ComFAirQuonset/ComHUKForLant (TAG)
ComFAirWingsLant/ComPatWingsLant (TAG)
ComTacWingsLant (TAG)
ComSeaBasedASWWingsLant
ComCruDesFlot 2/ComCruDesGru 2 (TAG)
ComCruDesGru 12 (TAG)
CoMineWarCom
ComSubDevGru 2/ComSubDevRon 12 (TAG)
ComDesDevGru 2/ComSurfWarDevGru (TAG)
ComCarGru 6 (TAG)
ComLAtWing 1 (TAG)
TAG – Tactical Analysis Group

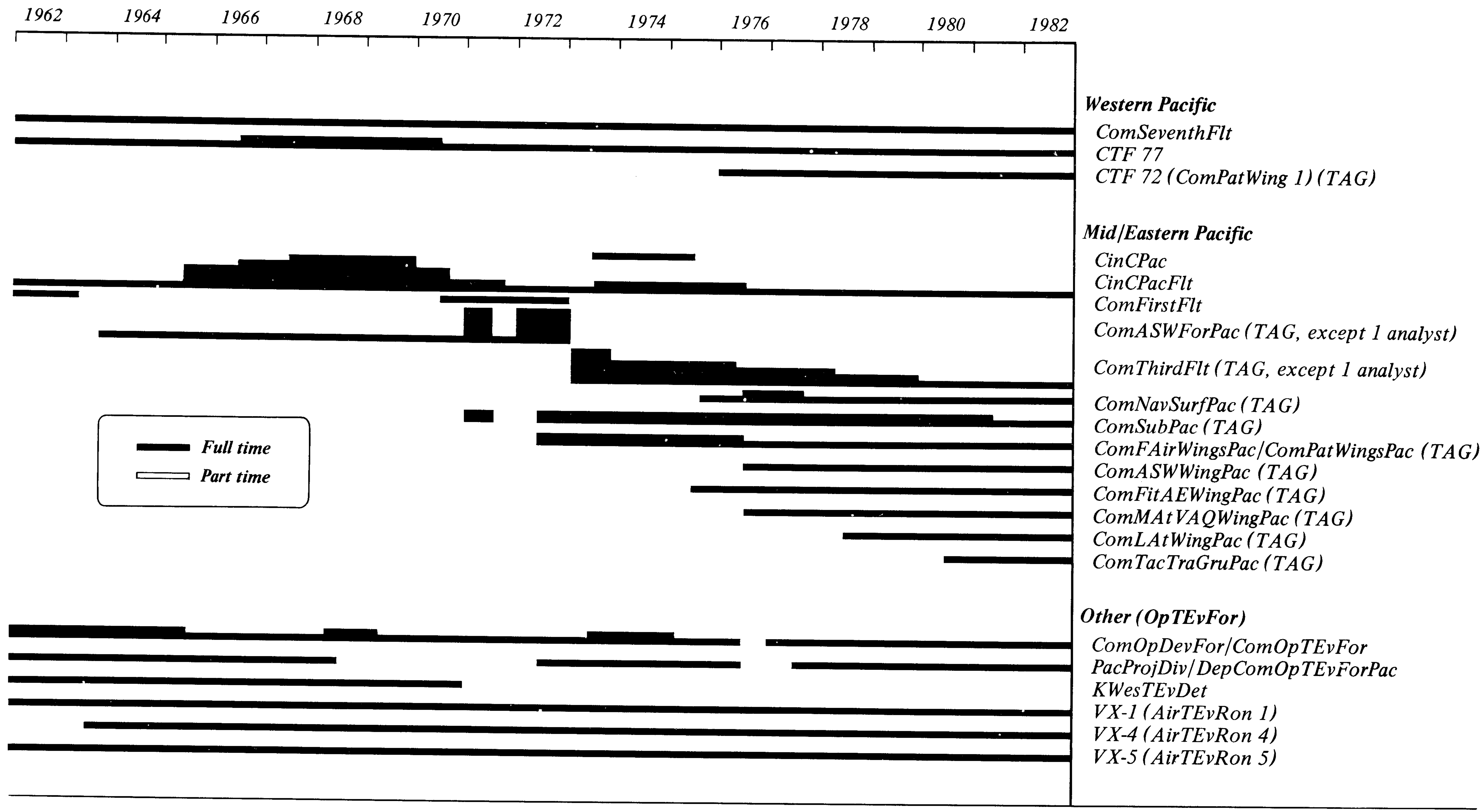



Figure 5-11. OEG Field Assignments (Since 1962)

for example, there was a need to interrelate the antisubmarine and antiair aspects of task force defenses, on the basis of results from upcoming exercises. The TAG analyst at the equivalent force in the Atlantic was to concentrate on broad questions concerning the surveillance of Soviet submarine operations in the Atlantic Ocean and to appraise U.S. capabilities in fulfilling this mission. The Submarine Force in the Pacific wished to look more closely at the role of U.S. submarines in defending against enemy submarines, in escorting task forces and convoys, in conducting surveillance, and in mining. Finally, there was a program already in place at Fleet Air Wings in the Atlantic to determine the effectiveness of various types of ASW patrol planes and to better integrate the operations of a mix of such planes from a single carrier deck.

Adding the twenty-three TAG analysts greatly enlarged OEG's overall field program–in fact, the program just about doubled (Figure 5-12). The TAG assignments, which were oriented toward ASW analysis and exercise evaluation, were made longer (typically well over two years) than the normal field assignment. In anticipation of the need to fill all these posts, CNA's president, Charles DiBona, and OEG's director, Ervin Kapos, put out a call for group members to select locations to which they wished to be sent. These locations included Japan, where analysts supported the Seventh Fleet; Gaeta, Italy, in support of the Sixth Fleet; San Diego, in support of the First Fleet; Key West, in support of the Test and Evaluation Detachment; and Point Mugu and China Lake, California, in support of Air Test and Evaluation Squadrons Four and Five, respectively.

At the non-TAG commands, work went on as usual. An analyst assigned to the Commander in Chief of the Atlantic Fleet, for instance, was working in two separate areas: the protection of merchant shipping in the Atlantic in the event of a war, and the formation of a fixed-perimeter antisubmarine defense for protecting attack carrier strike forces operating in the Norwegian Sea. In addition, two analysts were stationed in the Western Pacific: one with the staff of Commander Seventh Fleet, aboard the flagship, and another with Commander Task Force 77, aboard one of the carriers. The former was evaluating the effectiveness of airborne electronic intelligence and the most efficient deployment of a then-decreasing number of destroyers. The latter analyst was studying problems associated with task force and antimissile defenses. Other group members, working with the Sixth Fleet in the Mediterranean Sea, were analyzing exercises in the development and evaluation of tactics and were studying the fleet's surveillance and communications capabilities.

At the Operational Test and Evaluation Force, an OEG analyst was helping the command fulfill its two major roles: to recommend to the Chief of Naval Operations whether new equipment should be accepted for service use, and to develop tactics to be used with the equipment. The

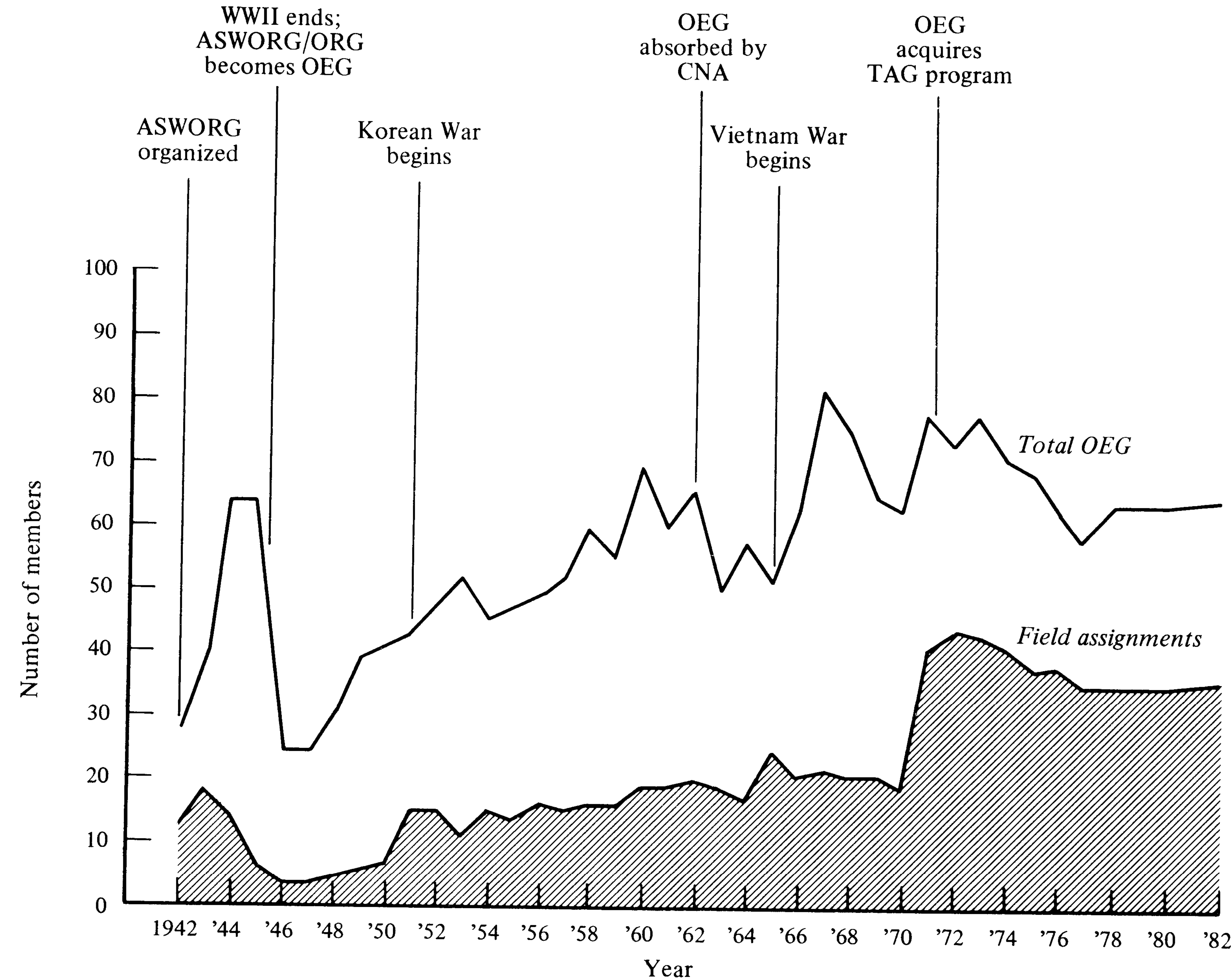



Figure 5-12. Number of Analysts Assigned to Field Relative to Total OEG Membership

analyst was developing measures of effectiveness that would determine how well a specific type of equipment performed its intended job. He was involved in diverse other projects of interest to the command, encompassing evaluations of the performance of various torpedo types, sonar, a surface search radar, the Sparrow air-to-air missile, tactics for delivering air-to-ground weapons, and an airborne direction-finding system. These descriptions cover but a small portion of the work then under way at the many non-TAG commands.

Just a few months after the TAG program's inception, it became apparent that OEG's management of the program would have to be temporarily discontinued pending Congress's approval of the Defense Department's FY 1972 budget. Selection of an interim TAG sponsor for the first six months of FY 1972 was therefore hurriedly pursued. The eventual choice of an interim TAG sponsor was the Palisades Geophysical Institute (PGI), which was to manage the program from July 1971 to February of the following year. During this period, all TAG analysts were placed on leaves-of-absence from OEG and employed by PGI. Once congressional action on the FY 1972 budget had been completed, with sufficient TAG funding approved, the contract reverted to OEG and the analysts again became OEG employees.

Despite this temporary administrative inconvenience, the TAG effort itself remained undisturbed. One analyst, for example, formulated a system for using air-deployable sonobuoys, tethered together in a line, designed to improve the navy's ability to track Soviet submarines as they cross the Pacific Ocean to and from their operating areas off the west coast of the United States. In the Mediterranean Sea, analysts studied the performance of ships and planes equipped with sonar, radar, towed surveillance systems, and other devices in detecting enemy submarines. The time it took for a destroyer, patrol plane, or helicopter to attack a submarine following detection was examined, too. Other work included development of a mathematical model to aid evaluations of alternative force mixes in the detection, attack, and kill of enemy submarines; examination of the surveillance and harassment of Soviet ballistic-missile submarines; and study of the relative effectiveness of different antisubmarine search plans and configurations prior to tests conducted at sea.

In early 1974, discussions began again on the possibility of extending OEG's management of the TAG program to encompass the "surveillance" portion originally kept by Arthur D. Little, Inc. CNA's new president, David B. Kassing,[8] proposed to Vice Admiral Shear (Op-095) that OEG's responsibilities include TAG assignments to the ocean surveillance headquarters in the Atlantic and Pacific Fleets. Although there was some agreement that it was time to integrate into the program this last remaining study area, the issue was left unresolved, as it has stayed ever since.

In the midst of all this, with both the TAG program and the Red-Side Operations Analysis Section on a sound footing, Ervin Kapos left OEG to become vice president of the research firm Ketron. The person appointed in December 1972 as OEG's new head was Dr. Daniel B. Rathbun, an economist, whose previous association with CNA had been limited to a short stint as the director of NAVWAG. His career had been a distinguished one, however, including service as deputy commissioner for data analysis in the Bureau of Labor Statistics, executive director of the President's Commission on Federal Statistics, and head of the ASW and Navy Forces Team in the Office of the Assistant Secretary of Defense for Systems Analysis.

The following year, 1973, saw the TAG program greatly affected by the navy's establishment of the Tactical Development and Evaluation (TacD&E) program and by creation of a new tactics-oriented division, Op-953, in the Office of the Chief of Naval Operations. Vice Admiral Shear, as sponsor of both the TAG and TacD&E programs, decided that OEG's TAG analysts should provide the "basic core of analytical support" for TacD&E projects. This decision was subsequently approved by the commanders in chief. The result was diversification of the TAG program to cover not just antisubmarine warfare, which had been its mainstay since the beginning, but a wide range of warfare areas.

The purpose of the TacD&E program was evident from its name, that is, to develop and evaluate tactics so that the ships, planes, weapons systems, sensors, and all the other equipment that contributes to the navy's defense capabilities may be put to their most effective use. The first step in this process, tactical development, was henceforth to be a much more deliberate process than it was in the past. The second step, tactical evaluation, was expected to proceed both ashore and at sea. The virtue of evaluating tactics ashore was that the analyst could use computer simulations to produce results that were highly reliable statistically. Further, the simulations could be made quite complex—and thus more real—by introducing numerous variables based on past exercises, operations, and analyses. The analyst could then run many replications of each simulation, as well as many entirely different simulations, to allow for alternative combinations of variables. One drawback, however, was the possibility of inadvertently omitting from the simulation some significant factor that might materially affect the outcome.

The virtue of evaluating tactics at sea, on the other hand, was that tests would be operationally real. It was useful to observe real ships, planes, and submarines facing each other, dealing with the vagaries of real weather, relying on real command, control, and communications systems, with real people operating the equipment. But a sea trial represented only one set of conditions, which was a serious liability. Neither enough money nor enough time was available to run tests at sea over and over again—as was possible with computer simulations—giving rise to reduced confidence in the resultant statistical sample. Hence, satisfying the dual requirements of operational realism and statistical credibility required subjecting newly developed tactics to sea tests *and* simulations. In this way, the advantages of each approach might make up for the artificialities of the other.

The process may be illustrated by a simple problem involving the use of direction-indicating sonobuoys to localize (that is, to determine the position of) enemy submarines by picking up their sounds. An analyst might choose to measure the effectiveness of this procedure in terms of "mean localization error," or simply the average distance between the submarine's actual position and the position reported on the basis of the sonobuoys. Assuming a model of the localization procedure is available, it would be possible to enumerate several variables that appear to have a bearing on localization error. These include loudness of the target, speed of the target, loss of sound transmitted through the water, sensitivity of the sonobuoy system, position of the sonobuoys relative to the target, number of sonobuoys, skill of the operator, characteristics of the airborne portion of the system designed to receive and process the signal transmitted by the sonobuoys, and depth of the sonobuoy hydrophones.

Of all these variables, perhaps only the position of the sonobuoys relative to the target, the number of sonobuoys, and the depth of the sonobuoy hydrophones are directly controllable by tactics. The other variables describe the conditions under which the newly proposed tactic will be run. If, further, sonobuoy depth is assumed not to have a strong influence on the accuracy of localization, just two variables remain. Either simulations or operational tests can now be conducted to examine various combinations of sonobuoy numbers and positions that would minimize localization error. If the solution varies considerably under different sets of conditions, a tactic can be recommended for each set.

Representative areas in which new tactics did indeed need to be developed were the following: effective use of the F-14 aircraft and the coordination of all fleet air defense assets; operation of a task group in the face of a highly diversified threat on and beneath the ocean and in the air; use of mine warfare in coordination with task force and amphibious force operations; planning of force deployments and configurations that deceive and confuse an enemy; transmission of messages when emission controls are in effect; and defense of ships, by means of electronic warfare, against such high-speed, low-flying threats as cruise missiles.

The aim, therefore, of OEG's participation in the TacD&E program was threefold. As new systems became available for use in the fleet, an opportunity was presented to determine how best to exploit their capabilities. With old systems that were already deployed, it was possible to devise tactics that overcame technical shortcomings. Such systems might also be candidates for uses quite apart from those for which they were originally developed, if appropriate tactics could be devised. In this way, old systems need not be supplanted immediately but, rather, could continue to function as a consequence of innovative tactics. Finally, as enemy force levels and mixes changed, and the enemy introduced new systems of his own, there was, of course, a need to develop new tactics to counter them.

## The Operations Evaluation Group Today

In March 1974, OEG's directorship changed hands again. In Rathbun's place was appointed Dr. Phil E. DePoy, a chemical engineer, who for the previous four years had been head of CNA's Systems Evaluation Group (SEG).[9] During that time, SEG was concerned primarily with conducting technical analyses in tactical air warfare, fleet air defense, surface warfare, and communications, in which the physical sciences and engineering played a dominant part. Emphasis was on analyzing the relationship among technical characteristics, costs, and performance; determining the feasibility of proposed systems; and forecasting the technological capabilities of the United States and adversaries. In early 1973, while DePoy was still SEG director, the group became involved in systems analyses, which dealt with the size, mix, and use of future forces, and with the cost of buying and operating them. Earlier, Dr. DePoy had directed OEG's Southeast Asia Combat Analysis Division (SEACAD), having taken over that role from Ervin Kapos. DePoy had also headed OEG's Air Warfare Section and, since joining the group in 1959, served as a field analyst on the staffs of the Commanders of the Sixth and Seventh Fleets, Task Force 77, and Air Development Squadron Five.

When Dr. DePoy became OEG's director, the group comprised some seventy scientists. The structure of the group DePoy inherited was a rather unwieldy one, however. One of its divisions bore the name $C^3$/USW/RSOA/ISCS, a mouthfull of acronyms derived from the three sections and one special project that made up the division. These were, respectively, the Command, Control, and Communications Section, the Undersea Warfare Section, the Red-Side Operations Analysis Section, and the Interim Sea Control Ship Project. The second division of OEG was titled Air/Surface/TacD&E, again derived from the sections that composed it: the Air Warfare Section, the Surface Warfare Section, and the Tactical Development and Evaluation Section. The third and last division was simply called TAG, with eight members in Washington in addition to the twenty-three then stationed at the various TAG commands. One other major component of OEG was the Analytical History Section, responsible for developing a "history" of analysis done of the war in Southeast Asia. Analysts not in one of these divisions or sections in Washington—over half, if OEG's field-based TAG analysts are included—were assigned to fleets and other commands and installations around the world.

As time passed, DePoy gradually peeled away some of the organizational layers, to take into account the decreasing size of the group. Within less than a year—that is, by February 1975—OEG had been reorganized along far simpler lines. At that point, OEG consisted of just five divisions, named according to the broad warfare areas in which the analysts worked: the Air Warfare Division, Surface Warfare Division, Antisubmarine Warfare Division, Undersea Warfare Division, and Warfare Support Division. The sectional breakdown of divisions had been totally eliminated. A year and a half later, these five divisions were pared back to three. The Air and Antisubmarine Warfare Divisions were retained, while the third was named the Antiair/Antisurface Warfare Division. Finally, in November 1981, the name of the last of these three components of OEG reverted to simply the Surface Warfare Division, completing the process begun by Dr. DePoy in 1974 and giving rise to the uncomplicated structure that exists in OEG today (Figure 5-13).

Meanwhile, DePoy appointed Dr. Jamil Nakhleh, a physicist, as OEG deputy director in April 1977, to assist in running the group. Dr. Nakhleh nevertheless retained his position as technical director of OEG's TAG program, which he had held since August 1974 while also heading OEG's then-new Antisubmarine Warfare Division. (DePoy had moved TAG from division status that same month.) Prior to that, Dr. Nakhleh had two assignments with SEG, the first beginning in 1969, when he joined CNA, and the second beginning in 1972, after a period as senior TAG analyst with the Commander of Antisubmarine Warfare Forces, Pacific Fleet (ComASWForPac).

In November 1980, OEG's sponsor changed from the Deputy Chief of Naval Operations for Surface Warfare, Op-03, to the newly established Director of Naval Warfare, Op-095, a position first held by Admiral Kinnaird R. McKee.[10] OEG was accordingly redesignated Op-095EG, in place of Op-03EG—the latter having been in effect since 1954. At the same time, the head of the Tactical Readiness Division (Op-953) was designated Deputy Director of Naval Warfare for OEG Matters. The responsibilities of Op-095 in this capacity include planning and recommending to the Director of Navy Program Planning (Op-090), the scientific officer for CNA, OEG's annual program. He also provides guidance for ongoing OEG projects, advises Op-090 on OEG's performance, involves himself in policy matters, and serves as a member of the CNA Policy Council.

OEG's research program has continued along lines that evolved over the preceding decades. Broadly speaking, OEG is still involved in doing analysis that will get the most out of the forces the navy has on hand now. This, of course, still calls for scientists to go out to the operating commands to help

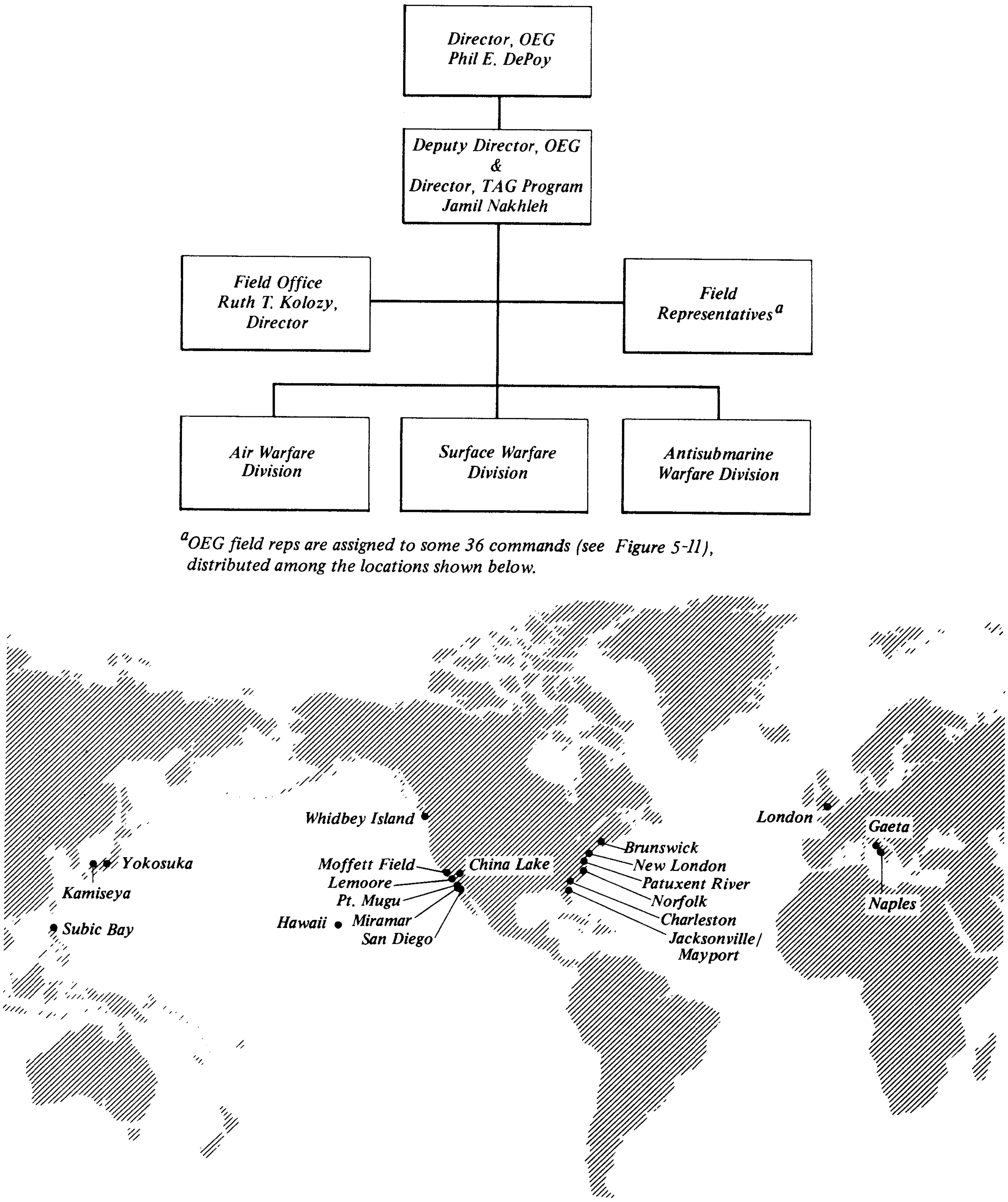



Figure 5-13. Organization of OEG (Early 1980s)

in that process and to ensure that the group's analysis is subjected to the unforgiving rigors of the real world. One of the main ways in which the group achieves its aim is by analyzing naval exercises. The purpose of these exercises is to improve fleet readiness, contribute to the development and evaluation of tactics and procedures, and assess the effectiveness of newly deployed systems. Some exercises involve only one unit—a ship or submarine, say—where crews hone their skills or test a new system. Other exercises require several units, perhaps as many as five to ten ships plus an assortment of planes, all of which are to engage in a specific mission.

Typical missions are antisubmarine warfare, surface-to-surface missile firings, air combat maneuvering, protection of a convoy, command and control, and electronic warfare. Some thirty of these exercises are run each year. The most complex exercises, however, are fleetwide, calling for large numbers of units—up to fifty ships, for example—with differing missions. These exercises can sometimes include the forces of Allied countries. About a dozen of these exercises are run annually, each of which may last as long as ten days.

These various exercises, however, are all subject to artificialities that tend to distort battle operations, no matter how planners may wish it to be otherwise. For instance, the fact that real ordnance is not used in an exercise means that the accuracy of targeting and weapon delivery cannot be evaluated, or the amount of damage truly assessed. To avoid collisions, opposing units, such as submarines, are kept farther apart than would be expected in real battle conditions. Also, since our own forces play the enemy, the capabilities of actual enemy ships, planes, submarines, weapons systems, and sensors—and the tactics that guide their use—cannot be duplicated precisely. Still other artificialities arise from the exercise scenario, including a limited area of ocean in which the battle is to unfold, a specified choice of tactics, and a problem that is simpler than any likely to be encountered in a real war.

Despite these and the many other ways in which exercises imperfectly portray actual situations, tests at sea nevertheless provide the only means of observing how well forces can perform in the real world. It is the only opportunity for naval forces to test their operational capabilities, pitted

The Sixth Fleet aircraft carrier USS *Saratoga* (CV-60) rests at anchor in the Gulf of Cagliari, Sardinia, with other units of the U.S. and Italian navies. Forty-five ships from the two navies had just taken part in an intense ten-day training exercise in the central Mediterranean. (Official U.S. Navy photo.)

against some form of opposition. Hence, it is extremely important that judicious analysis reveal as much as possible from these opportunities.

The role of the OEG analyst in all this is manifold. His first function, once an exercise has been scheduled, is to work with the commander and operations officer to determine the objectives of his analysis. These objectives normally relate directly to the warfare areas or procedures the fleet needs to practice and depend on the types and numbers of units taking part and the exercise scenario that guides the mock battle. In antisubmarine warfare, for instance, the analytical objective may be to determine the ability of the ships and planes of a battle group to detect and track enemy submarines in waters in which sonar detection is difficult. In the area of electronic warfare, the objective may be to evaluate the ability of units in the battle group to maintain total electronic silence during vulnerable periods. Another planning function of the analyst involves specifying the kind of data to be collected by the various participating units and by those analysts assigned to ride the key ships and aircraft as the exercise unfolds. These data are expected to reflect system performance, environmental conditions, major events in the exercise, and a host of other factors pertinent to the planned analysis. The end product is reams of information.

Once an exercise has been run, the OEG analyst first reconstructs the entire episode. "Gross reconstruction" involves plotting, over time, the tracks of the participants as they move about the exercise area, based on logs and satellite data. The other purpose of the reconstruction effort is to record such information as the time and place of attacks and of changes in the disposition of forces. Periods of the exercise that hold special interest may merit "finer-grained" reconstruction and receive closer scrutiny. Thus, information emerges on each aspect of the exercise. For example, summary data on antisubmarine warfare events may show which units detected opposing submarines, whether claimed detections were indeed of submarines, whether the submarines could be attacked, and with what probabilities submarines were attacked and subsequently killed. Similarly, data on antiair warfare will likely show the time an air raid took place, the composition of the raid, the number of enemy planes detected, and the percentage effectively engaged and by whom.

With this information, the analyst can piece together a picture of what actually happened during the exercise, free from the biases that are likely to color assessments made by participants. The performance of various units and equipment can then be evaluated quantitatively. This, in turn, helps form a basis for estimating the fleet's overall readiness and capabilities in the different warfare areas. The analysis also reveals shortfalls in newly developed tactics that were tested during the exercise, leading to the discarding or modifying of tactics and procedures. This process culminates in the drawing of conclusions about the objectives developed by the analyst during the planning stage. The conclusions drawn from the analysis—along with a narrative description of the exercise, and possibly recommendations and supporting evidence—are reported to the exercise participants and to other interested commands in the naval community.

Usually, however, not enough can be learned from just one exercise, particularly when testing a new tactic or procedure. Rather, several, if not many, exercises are required to build a large enough data base for any final evaluation. One OEG project did just that over a two-year period. In that time, the Sixth Fleet ran a series of exercises in the Mediterranean Sea, in which simulated firings were made of the Harpoon antiship cruise missile. Analysts both in Washington and in the field observed, reconstructed, and analyzed the results of these firings from the time Harpoon was first introduced into these Mediterranean-based exercises. On the basis of the battle group's performance in employing Harpoon, these analysts were able to pinpoint problems and recommend solutions.

One set of proposals made by OEG dealt with the need to develop a comprehensive concept of operations for surface warfare. The purpose was to specify priorities among a variety of potential targets, describe doctrine covering how multiple ships equipped with Harpoon should coordinate their attacks, and spell out procedures by which a third party may provide targeting information on an enemy vessel—especially one located beyond the horizon—that is about to be attacked. The concept of operations was also expected to describe what authority the battle group's surface warfare coordinator should have over the launching of missiles, and what information should pass between him and the firing ship. In addition, it was recommended that procedures be developed to help the carrier disseminate information gathered by its surveillance aircraft on sighted targets.

Along similar lines, OEG summarized the antisubmarine warfare performance of a carrier battle group in a series of thirty exercises. The exercises represented a wide sample of geographic locations and scenarios, generally involving multiple threats—that is, other than just a submarine threat—to the battle group. Friendly forces (by convention, dubbed Blue forces) always included antisubmarine planes and usually also included submarines assigned to defend the battle group. "Soviet" (Orange) forces, played by U.S. or Allied units, generally consisted of no more than five or six nuclear- and diesel-powered submarines, although larger numbers of "enemy" submarines were assembled for exercises run in the North Atlantic. Only one or two of these opposing submarines, however, were ever in contact with units of the battle group at any one time.

In the exercise summary, two main factors were considered. The first was the number of times enemy submarines that had penetrated the battle group's outer defensive screen were detected and attacked by antisubmarine forces before they had a chance to fire a torpedo or short-range missile at a high-priority target within the battle group. The second factor was the number of attacks made by enemy submarines. The performance of friendly forces in detecting and attacking enemy intruders was assessed according to the type of unit involved: plane (P-3 or S-3), helicopter, surface ship, or submarine in direct support of the battle group. The type of sensor used was also considered, as was the type of weapon and the probability of a successful attack given a single shot.

In another such effort, OEG took part in a series of evaluations of the operational readiness of the Atlantic Fleet's carriers and airwings. The purpose was threefold: to help the navy determine, in a fairly realistic setting, whether the readiness level of the carrier and accompanying airwing was adequate for carrying out all assigned missions on an extended deployment; to pinpoint areas in need of improvement before deployment occurred; and to compare the readiness level of the particular carrier and airwing with that of similarly outfitted units. In each evaluation, analysts were placed aboard the carrier to assist in the planning, data collection, and analysis. Measures of effectiveness were developed for each of the missions—antiair, antisurface/strike, and antisubmarine warfare—for which the carriers and airwings were responsible. Strike warfare measures of effectiveness, for example, included the percentage of scheduled aircraft that were actually launched and subsequently completed their strike missions, the kind of hits achieved, the ability of fighters to provide cover for the strike group, and the contribution of early-warning and electronic warfare aircraft to the mission.

A sampling of the many other subjects examined by OEG includes these: the navy's peacetime rules of engagement, designed to protect forward-deployed forces that may come in contact with forces of a potential enemy; the effectiveness of the S-3A in antisubmarine warfare, taking into account the plane's attack accuracy and its contribution to a battle group's over-the-horizon defenses; the vulnerability of the Harpoon antiship missile to Soviet shipboard defenses, such as search radars and fire-control systems; tactics governing the use of air-to-surface weapons; the protection of air and sea lines of communication in the area of the Mediterranean Sea; the requirements for setting up antisubmarine barriers in northern waters; and the ability of fighters to identify, maintain contact with, and estimate the position of enemy submarines through use of a towed sonar system.

A particularly large-scale effort being undertaken by OEG in the late 1970s and early 1980s has to do with helping the fleet improve its antiair warfare (AAW) capabilities. Impetus for the project came from concern expressed by fleet commanders that their antiair capabilities were inadequate. While defensive systems have improved over the years—evolving from fighters and guns in the 1950s to a combination of these and surface-to-air missiles (SAMs) in the 1960s to a variety of improved systems today—the threat has been evolving, too. Over those years, exercises against a simulated threat have shown a slight improvement in AAW performance; the results, however, are not good enough. Given the accuracy and lethality of enemy supersonic antiship missiles, any weakness in the AAW shield is serious, indeed.

The navy has long been acutely aware of deficiencies in fleet AAW, which led to a series of studies during the 1970s to determine ways to overcome them. These studies showed that developing and deploying certain new types of AAW-related systems, in conjunction with systems the navy already possessed, would greatly improve the situation. Specifically, they showed that fleet AAW performance could be enhanced by acquiring long-range fighters armed with long-range air-to-air missiles, radars that automatically detect and track enemy planes, automatic-reaction weapons, and better electronic warfare systems. The next step was to determine which currently available system would be useful in the scheme to improve fleet AAW and to begin acquiring systems not yet in the navy's inventory.

Among the first category was the F-14 fighter (equipped with the Phoenix long-range, air-to-air missile), already aboard aircraft carriers. There was also the E-2C early-warning aircraft outfitted with automatic detection and tracking radar and the EA-6B electronic warfare aircraft. Among the second category—that is, systems at various stages of being acquired—were a shipboard automatic detection and tracking radar, and an extremely rapid-fire radar-controlled gun (called Phalanx) designed to fire at antiship missiles. Finally, there was an electronic warfare system designed not only to detect incoming antiship missiles but also to upset their accuracy.

This multifaceted scheme to improve fleet AAW is an ambitious one, warranting considerable care to ensure that projected improvements are in fact realized once all systems are in place. OEG's role, therefore, is to help the navy assimilate these aircraft and new systems, while emphasizing changes in AAW doctrine and procedures. Typically, observations of exercises and operations are crucial to this effort. Also, because of the project's size, many analysts both in Washington and in the field—such as with Commander Naval Air, Atlantic (ComNavAirLant), Commander Fighter Airborne Early Warning Wing, Pacific (ComFitAEWingPac), Commander Tactical Wings, Atlantic (ComTacWingsLant), and Commander Carrier Group Five (ComCarGru Five)—have contributed to it.

A major phase of the project is concerned with what is called the outer air battle. That is, as massed Soviet Backfire bombers carrying antiship cruise missiles approach a U.S. battle group from various directions, carrier-based fighters are sent to intercept and shoot them down. The bombers must be downed, however, before they get within range—150 miles or so—to launch their missiles. The approach being developed involves stationing airborne F-14s—armed with a mix of air-to-air missiles, as well as 20-mm guns—far enough out from the battle group to fulfill this mission (Figure 5-14). It is assumed that the F-14's radar would be the first to spot a Soviet raid. Early warning would also be aided by the presence of E-2C aircraft, a plane resembling the air force's better-known AWACS (Airborne Warning and Control System). Additional F-14s would be stationed a little closer to the battle group, to replace those outer fighters engaging enemy planes. These, too, must be far enough out, however, to be able to intercept Soviet bombers before the battle group can be targeted.

In establishing positions for the outer and inner layers of fighters, and of the early-warning aircraft, OEG needed to consider an array of factors. These included assumptions about Soviet capabilities and tactics, such as the speed and altitude of the Backfire bombers during their approach, the maximum range at which the bombers would launch their missiles, the size and configuration of the raid, the launch characteristics of the antiship missiles, and jamming tactics. Other factors taken into account included the desirable speed and altitude of the F-14s kept on airborne patrol (with the need to conserve fuel a consideration), the range at which air-to-air missiles can achieve a high probability of downing Soviet bombers, the F-14's radar range, and the jamming capabilities of U.S. support aircraft. These factors also contributed to decisions about the size of the sectors to be patrolled by the planes. An additional issue was whether F-14s *not* on airborne patrol—that is, those on the carrier deck—could be expected to take off and still reach any of the waves of attacking bombers far enough away to make a difference.

One final question concerned the number of fighters, both on airborne patrol and on deck, needed to accomplish the mission. It was first necessary to estimate the number of Soviet bombers a single F-14 could engage successfully. This estimate, it was found, depended on the mix of air-to-air missiles with which the fighter was loaded, since the available types of missiles—the Phoenix, Sparrow, and Sidewinder—have different capabilities. With any given missile loadout, it was possible to determine the number of planes required in the outer and inner layers and the number required as deck-launched interceptors, assuming the bombers attack in more than one wave. A second consideration was the number of fighters in a normal carrier airwing and the percentage of these fighters typically available for combat at any one time. It might be the case, for instance, that the number of fully capable F-14s actually available for combat would dictate the mix of missiles that should be used and thus, in turn, the number of planes assigned to the mission.

A concurrent phase of OEG's AAW project concerns the battle group's second line of defense. It is expected that some of the bombers would elude U.S. interceptors long enough to get within launch range of their

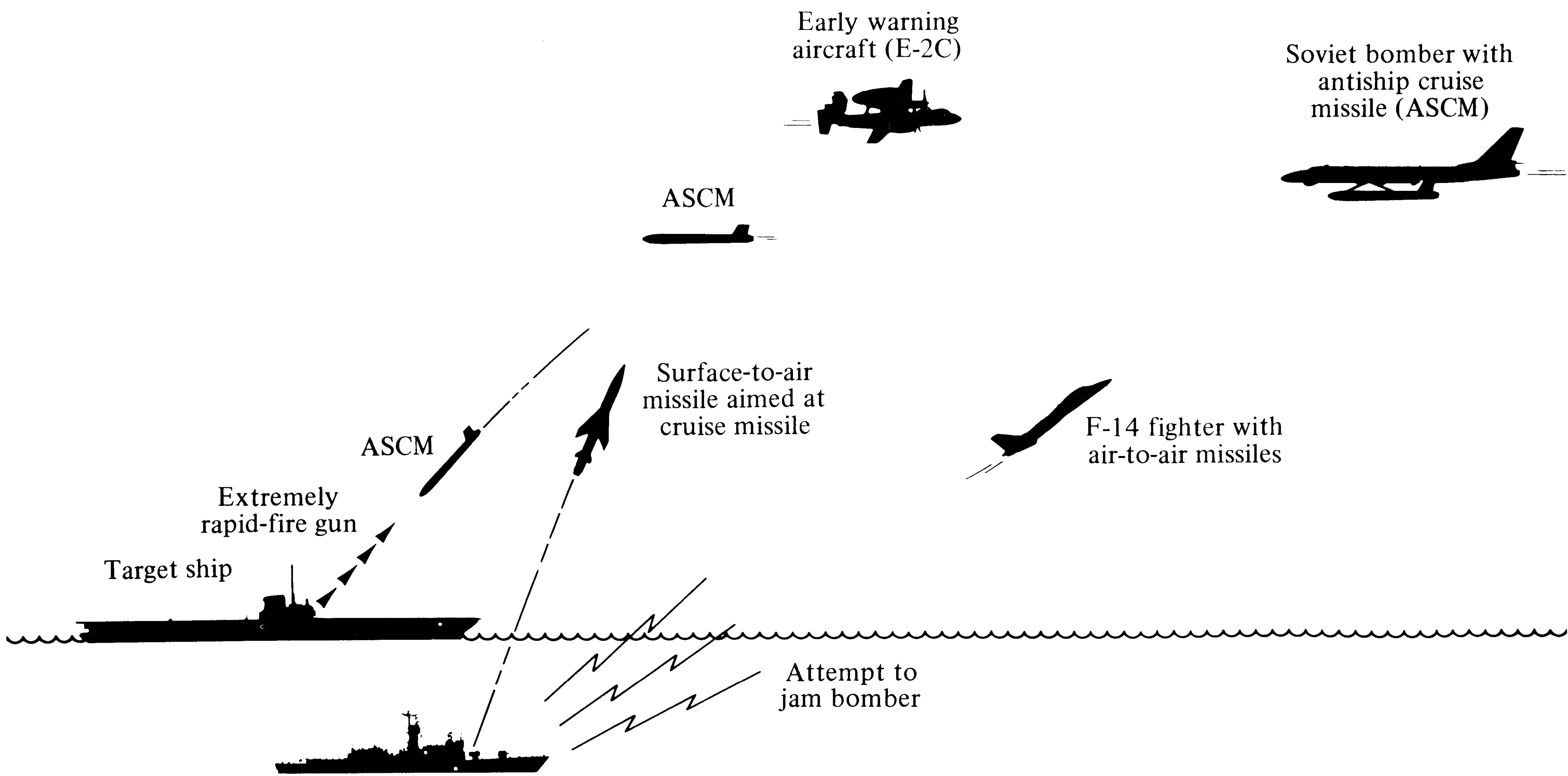
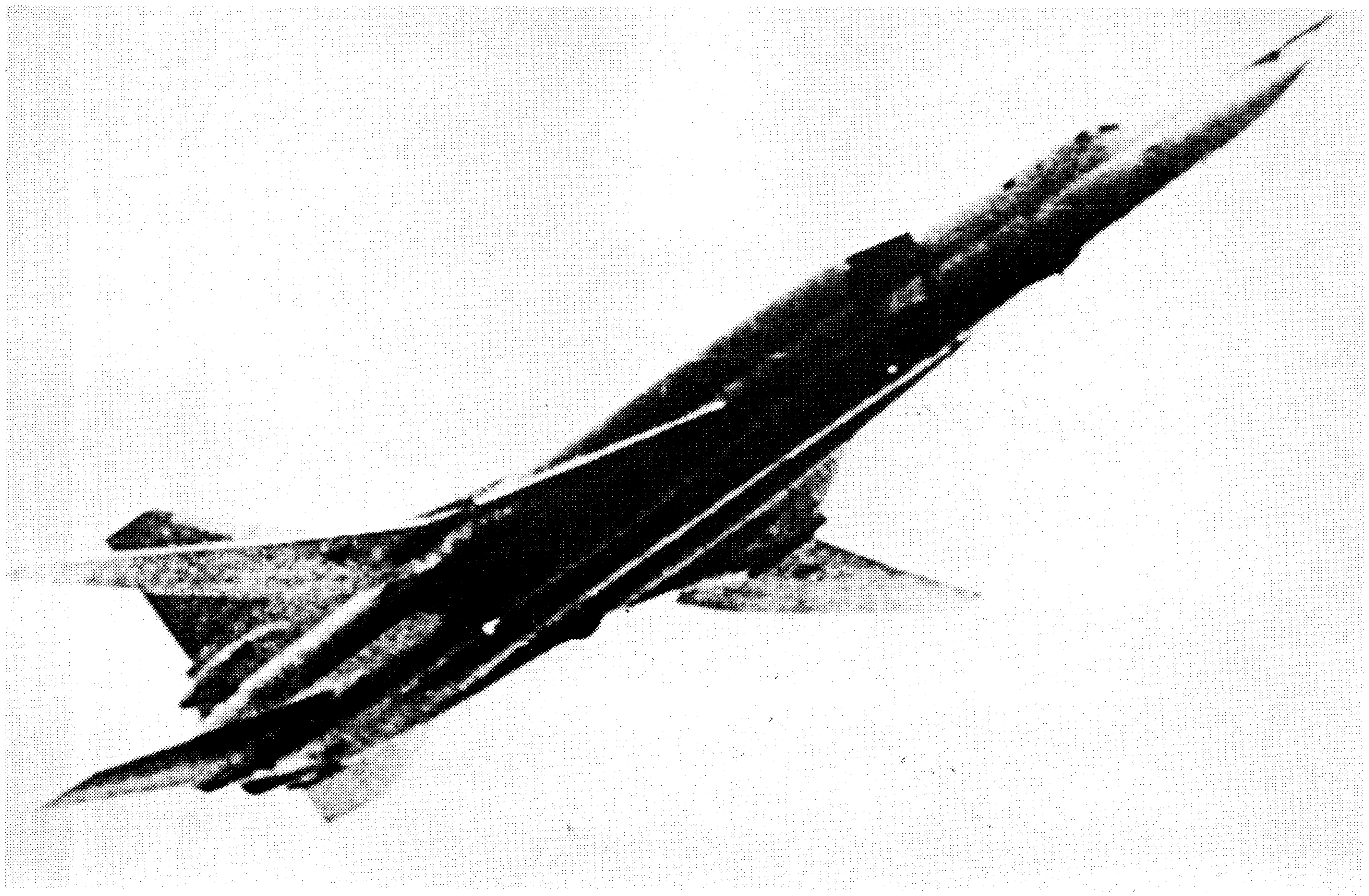
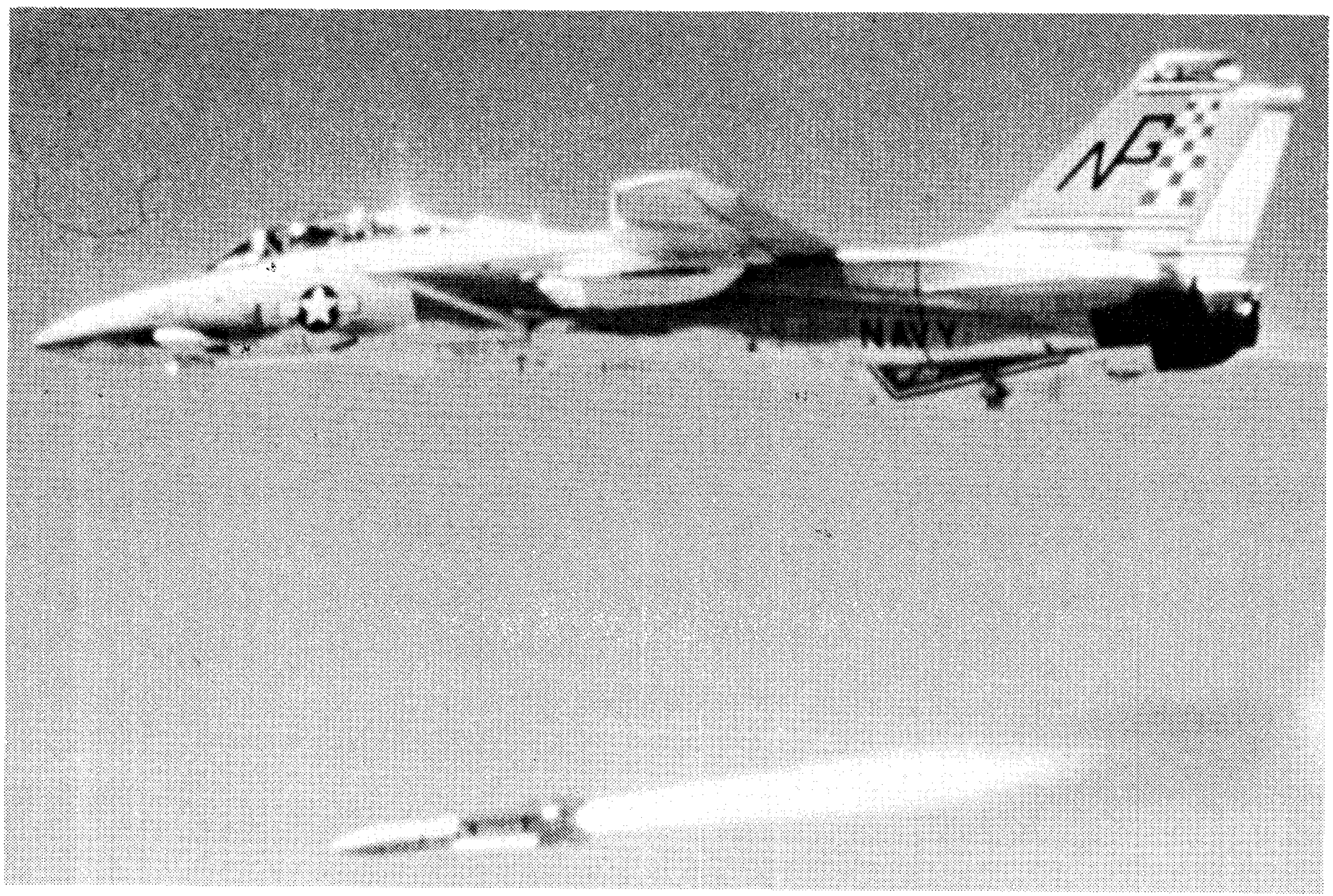



Figure 5-14. Fleet Defense against Bombers Armed with Antiship Cruise Missiles






Top: A view of the Soviet Backfire bomber which, armed with antiship cruise missiles, poses a serious threat to U.S. Naval forces. Bottom: The F-14A Tomcat, shown here firing a Phoenix air-to-air missile, is slated to play a major role in downing the Backfire before it can launch its antiship missiles at the battle group. (Both are official U.S. Navy photos.)

antiship missiles. In that case, the battle group may fire long-range surface-to-air missiles (SAMs), to shoot down the incoming antiship missiles fired by the Backfires. One especially important issue being examined by OEG is the positioning of SAM-equipped ships relative to the carrier or other likely high-priority targets within the battle group. To determine how best to place these ships, it was first necessary to understand the performance capabilities of the types of SAMs to be used for this purpose. This meant knowing not just the outer limits of their capabilities–in terms of range and altitude, among other criteria–but also the limits that could reasonably be expected to produce an acceptable probability of intercepting the Soviet missiles. The capabilities of the targeted antiship missiles, including their trajectories, similarly affect the eventual decision about where to station SAM ships.

Additionally, OEG has been investigating the use of electronic warfare in battle group AAW defenses. Certain electronic warfare systems are expected to aid in the terminal phase of defending against the antiship missiles, as well as in the primary phase involving the outer air battle. (The extremely rapid-fire Phalanx gun would also contribute to the terminal phase.) OEG designed at-sea tests of these capabilities, using a special navy aircraft and later U.S. Air Force B-52s to simulate the Backfire. A major goal has been to develop electronic warfare tactics for the battle group commander, aimed, for example, at denying the Soviets easy targeting. More generally, this and the other phases of OEG's AAW project should help ensure that the fleet is prepared to counter air raids of the kind the Soviets are now capable of launching.

Today's OEG stands in testimony to the cycle that has been sustained over the last forty years by the navy's continual reaffirmation of the need for the type of operations analysis that has long since become the group's hallmark. In response to three wars–including the one in which the group was founded–and occasional periods of instability in various regions of the world, OEG has reshuffled its goals and priorities to best meet the exigencies of the period. Between such episodes, the peacetime requirements of the navy were changing, too, in order to respond to new threats, to take into account new or modified missions, and to accommodate technological developments. It has always been imperative, therefore, that OEG remain flexible enough not to be overtaken by such events. Changes to OEG that stemmed from such circumstances were, in fact, an index of the group's vitality. Ossification of the group at any stage would certainly have ensured its end. Instead, the group proved time and again its capacity for imaginative science and administration, ensuring that its efforts bore the kinds of results most needed by the navy in the context of the moment.

Yet, it was also important that OEG not react reflexively to every pressure for change. Those who helped shape the group assumed the responsibility of distilling the many opinions into a well-reasoned program of management and analysis. The formula settled on by the group in World War II turned out—in part fortuitously, but largely by the farsightedness of the group's founders—to be the most beneficial to the navy. That is, a fundamental lesson from those turbulent war years was that the navy most needed assistance in harnessing to full advantage the capabilities of assets available to it now or in the not-too-distant future. In at least one sense, the most critical threat any military force faces is the one that stands poised against it today. This is true not just in the obvious emergency conditions of a war, a regional crisis, or a period of brinkmanship, but also in "normal" peacetime when the lack of readiness might invite aggression. That is why OEG has remained committed to a program of analysis that concentrates on ways to help the navy derive the greatest lethality from its weapons, the greatest efficiency from its array of sophisticated support systems, and the greatest stealth from its tactics.

Though OEG's role is one of advisor, not of policy maker, its influence on naval decision making has been considerable. At the heart of this success, of course, has been the close integration of a large portion of its scientific staff into the operational levels of the navy, where the results of its work can be translated most readily into improved force performance. Despite this important and intimate side of OEG's relationship with the navy, the group has successfully resisted any inclination to relinquish its members' intellectual independence. Put another way, OEG, while necessarily taking into account the client's own expectations, has always made a point to safeguard the objectivity and scientific honesty of its analysis. By balancing these two seemingly polarized interests—that is, the group's integration into the navy at the operational level and its unbiased analysis—OEG has managed to remain a durable and credible advisor for over forty years.

# Notes

## Introduction

1. The Center for Naval Analyses (CNA) is a nonprofit Federal Contract Research Center (FCRC) that was formed in 1962 to consolidate under one management work being done by OEG and the then-separate Institute of Naval Studies (INS). CNA now comprises two operating groups besides OEG: the Naval Studies Group (NSG), which absorbed INS, and the Marine Corps Operations Analysis Group (MCOAG).
2. At that time, OEG was known as the Antisubmarine Warfare Operations Research Group (ASWORG); it did not become the Operations Evaluation Group until shortly after World War II.
3. Bernal 1939, p. 165.
4. Zuckerman 1966, p. 5.
5. Lanchester 1916, pp. 23-24.
6. For the entire war, 4,837 Allied merchant vessels of eleven million gross tons were sunk. No doubt these losses would have been even more staggering if not for adoption of the convoy system in 1917.
7. That Bernal and Garwood "happened" to choose Coventry and to base their estimates on a five-hundred-bomber raid seems more than happenstance. There is reason to wonder about the possible contribution made by information obtained through Ultra, the method by which the Allies intercepted German radio transmissions and decoded their contents.
8. Morse and Kimball 1951, p. 1.
9. Goodeve 1953, p. 168.
10. Finding the optimal solution to a problem is, in effect, virtually impossible, because any model of the problem is necessarily idealized and cannot take into account every nuance of the real problem. Nevertheless, a well-constructed model should be able to provide a solution that approximates the ideal, or at the very least one that meets the decision maker's needs.
11. Singh 1968, p. 6.
12. The analyst's tools, largely of a mathematical nature, include linear programming, probability theory, queueing theory, war gaming, simulation models, statistical analysis, and others. Interested readers will find no shortage of textbooks describing these subjects in detail.
13. Zuckerman 1966, p. 26.

## 1. The Group's Formative Years during World War II

1. About half a million tons of Allied shipping were lost per month between March and June 1941, prompting Britain to end its practice of publishing the numbers.
2. A single aircraft could search an area one hundred miles square in four hours, whereas five ships would take six days.
3. Baxter 1946, p. 42.

4. The earliest reports of interrogations of survivors indicated that, in the fall of 1939, U-boats were equipped with only sonic listening gear. They had no equipment aboard for echo-ranging or supersonic listening and were not originally aware of the fact that the British *did* have such equipment. By the summer of 1940, however, considerable attention had been given to Asdic by German headquarters, and attempts to reduce the echo from a submarine had gotten under way, though generally to no avail.
5. Testimony given by Vannevar Bush before the Select Committee on Post-War Military Policy. 78th Congress, Second Session. Pursuant to House Resolution 465, 1945.
6. Shortly after Conant's departure for England, German propagandists claimed that President Roosevelt had sent Conant to assist British development of a gas warfare capability.
7. Farago 1962, pp. 140-141.
8. Talk entitled "The Need for and Founding of an Operations Research Group," given by Rear Admiral Wilder D. Baker at OEG's tenth anniversary conference on operations research (sponsored by the Office of Naval Research) in May 1952.
9. Morse 1977, pp. 172-173.
10. Ibid., p. 15.
11. Ibid., pp. 66-67.
12. The other four activities that fell under the Columbia University contract were the U.S. Navy Underwater Sound Laboratory, the Airborne Instruments Laboratory, the Special Studies Group, and the Underwater Sound Reference Laboratories. It was felt that ASWORG's work would be compatible with—and, in fact, a big assist to—work performed by these other groups.
13. Captain Baker finally bowed out of the picture entirely on 15 December 1942 when he went to sea in command of the battleship *North Carolina.*
14. Lecture delivered by Philip M. Morse at the Center for Naval Analyses on 25 January 1977.
15. Morse 1977, pp. 204-205.
16. Farago 1962, p. 158.
17. Ibid., p. 166.
18. Lecture delivered by Philip M. Morse at the Center for Naval Analyses on 25 January 1977.
19. Lewin 1978, p. 20.
20. Ibid., p. 212.
21. Some people also include the independent Operational Training Command in this category. Under Rear Admiral Donald B. Beary, the command served as a school for antisubmarine training.
22. Tyson became director of the Operations Evaluation Group (OEG) in 1965, served until 1967, and was subsequently appointed senior scientist for all of the Center for Naval Analyses.
23. After a few months of working with this material, it was decided that IBM equipment should be obtained to make procedures more efficient. A card punch and verifier, together with a sorter, interpreter, and tabulator, were delivered in December 1942. The acquisition allowed extensive card files to be built up for various categories of operational data: a Ship Casualty file, World Wide Assessment file, Attacks on Enemy Submarines file, Air Operations file, and others.
24. Morse and Kimball 1946, pp. 137-138.
25. Turnbull 1961, p. 364.
26. In marked contrast to the operations research experience of the Allies, Nazi Germany failed to organize its vast pool of scientific talent for any comparable effort. Hitler's distrust of the "expert" and his propensity for the irrational precluded the rise of a German ORG. Albert Speer, Reichsminister for Armaments and War Production and later Joint Chairman of the Central Planning Office, was the only advisor to Hitler with a scientific background, but even he was seldom permitted to take the initiative.

## 2. A Period of Consolidation and Growth

1. This report, one of a series of three, covered the period from 1 March to 1 October 1945.
2. King 1946, p. 129.
3. Some years later, ONR held the position that such increases, though granted, might have violated the intent of the contract. Their interpretation of the original wording led them to believe that the forward-funding arrangements stipulated a fixed-dollar amount, not an amount that could vary. Nonetheless, the sum did increase modestly, until OEG was subsumed by the newly formed Center for Naval Analyses in 1962.
4. Morse 1977, p. 245.
5. The Format Committee for ORSA happened to consist of several other former ORG scientists: Jacinto Steinhardt, George E. Kimball, Robert F. Rinehart, Arthur A. Brown, John B. Lathrop, and William J. Horvath. A few of these then went on to be Council members.
6. Morse and Kimball 1951, p. 10b.
7. Koopman 1980, p. 9.
8. The Type XXI U-boat, a prefabricated submarine equipped with powerful electric motors and extra batteries, was designed for high submerged speed. About 120 of these U-boats were built just before Germany's capitulation; however, problems encountered during sea trials prevented the submarine from becoming operational before V-E Day.
9. The conference approach to broad study areas was used successfully by OEG on other occasions, too, as we shall shortly see.
10. The figures, typical for the entire war, were for coastal shipping during June 1943: Loss rate for convoys, 4 percent; loss rate for independents, 20 percent; increase in port time due to convoying, 20 percent; decrease in speed due to convoying, 11 percent.
11. Hartwell Project, *A Report on Security of Overseas Transport,* 21 September 1950.
12. It was in September 1949, after all, that the American public received the sobering news of a nuclear explosion in the Soviet Union.
13. Op-34H, Serial 808P-34, Establishment of Air Defense Committee. 22 July 1947.

## 3. A Decade of Change for OEG: from Korea to a New Strategic Balance

1. Cagle and Manson 1957, pp. 27-28.
2. Refer back to Figure 3-3 for the location of towns mentioned throughout the rest of the discussion on the Korean Conflict.
3. Lecture delivered by Jacinto Steinhardt at the Center for Naval Analyses on 22 February 1977.
4. Talk entitled "Evolution of the Operations Evaluation Group Since World War II," given by Joseph H. Engel at OEG's twentieth anniversary conference on operations research (sponsored by the Office of Naval Research) in May 1962.
5. Other missions that could be checked off on the Gunfire Support Cards, but which accounted for a too small part of the effort to be addressed separately by the study, were illumination and "counterbattery" (that is, firing against shore-based guns).
6. It should be noted that the navy and air force held different philosophies about what constituted the appropriate use of air power. Specifically, the navy recognized the value of tactical strikes in or immediately close to the battlefield; the air force, on the other hand, gave priority to strategic bombing of the enemy's war-making potential and tended to regard close air support as secondary.
7. The distance from the frontline at which such air attacks occurred point to yet another difference between navy and air force operations. The navy (as did the Marine Corps) delivered its ordnance much nearer to friendly forces than did the air force–often within a few hundred yards. The air force generally provided

what should more accurately be called "deep" rather than "close" air support, delivering their ordnance several thousand yards back.

8. Cagle and Manson 1957, p. 293.
9. Several other nations contributed to the blockade, although on a much smaller scale. These included Australia, Canada, France, the Netherlands, New Zealand, Columbia, and Thailand.
10. This and all the following quotations in our discussion of OEG's tenth anniversary conference come from the proceedings, *The Operations Evaluation Group Decennial Conference on Operations Research.*
11. Refer back to the Introduction for further discussion of E. C. Williams and the Bawdsey Research Station.
12. ORG's deputy director for administration, Charles M. Stearns, also happened to be an OEG employee, as was its head of personnel, Roy F. Ash, Jr.
13. In 1946, the air force persuaded Douglas Aircraft Company to manage Project Rand (the name is an abbrevation for "research and development"), for the purpose of conducting studies that would help the air force make strategic policy decisions. The original staff assembled to work on the project was culled from both industry and academia, much as ASWORG's staff had been four years earlier. Then, in 1948, Project Rand–which by that time had gained considerable respect in the military and operations research communities–became an independent, nonprofit organization called Rand Corporation. Rand subsequently moved from Douglas Aircraft to its own facilities in Santa Monica, California, where it remains today as a Federal Contract Research Center (FCRC). It has traditionally emphasized long-range, broad-based strategic issues.
14. Letter from the Vice Chief of Naval Operations, Admiral D. B. Duncan, to the president of MIT, James R. Killian, Jr., 17 October 1955.
15. Letter from the vice president of MIT, E. L. Cochrane, to the Vice Chief of Naval Operations, Admiral D. B. Duncan, 8 November 1955.
16. It was important not to obscure the distinction between deterrence and retaliation. Deterrent power was meaningful only in relation to an enemy's perception of the situation. Retaliatory power, on the other hand, had absolute meaning in that there was a real capability to achieve revenge.
17. George and Smoke 1974, pp. 451-452.
18. Secretary McNamara's tenure had a further effect on OEG's operations when in April 1961 he issued a Defense Department directive requiring *all* study groups under contract to the services to submit a copy of their reports to the secretary's office, as well as to the service for which the work was performed. The purpose was to gain increased oversight, so that sensitive information–for example, of a Defense Department or JCS level of policy making–could not be inadvertently released by any of the groups. It was the general consensus among the services and research organizations, however, that this was a rather draconian measure that would inhibit the honest and objective analysis needed by the services to avoid glossing over controversial or difficult problems. The requirement was rescinded in October 1966, as much due to its impracticality (because of the hundreds of reports that would have to cross the secretary's desk) as anything else.
19. Engel was later to serve as director of OEG, between 1962 and 1965.

## 4. OEG and the New Center for Naval Analyses

1. Address delivered by Alain C. Enthoven before the American Economic Association, Pittsburgh, Pennsylvania, on 29 December 1962.
2. McNamara 1968, p. 87.
3. Ibid., p. 95.
4. Tucker 1966, p. 131.
5. The MIT faculty committee comprised Professor Philip M. Morse (Physics), who served as chairman; MIT Vice President Major General James McCormack, Jr. (USAF, Ret.); and Professors Jerome B. Wiesner (Research Laboratory of Electronics), Albert G. Hill (Physics), Martin A. Abkowitz (Marine Engineering),

George P. Wadsworth (Mathematics), Raymond L. Bisplinghoff (Aeronautical Engineering), and Robert M. Solow (Economics).

6. The size of the navy's study effort at that time—insofar as OEG, NAVWAG, ASD, and INS were concerned—was as follows:

| | *Scientists* | *Support* | *Funds for FY 62* |
|---|---|---|---|
| OEG | 56[a] | 42 | $1,625,000 |
| NAVWAG | 10 | 3 | 221,500 |
| ASD | 12 | 6 | 800,000 |
| INS | 43[b] | 14 | 1,500,000 |
| | 121 | 65 | $4,146,500 |

[a]Thirty-eight in Washington, eighteen in the field.
[b]Forty-two in Cambridge, one in Newport.

7. SecNav Instruction 5000.14, 29 March 1962.
8. Both contract Nonr-3732(00) and SecNav Instruction 5000.14 called the new enterprise the Center *of* Naval Analyses, which remained in effect until close to the end of the year, when "of" was replaced with "for."
9. LePage's choice for executive director, Charles M. Mottley, was not announced until March 1963.
10. SecNav Instruction 5420.150, 13 December 1962.
11. The CNA Policy Council comprised the following: the Assistant Secretary of the Navy for Research and Development, serving as chairman; the Deputy CNO for Fleet Operations and Readiness; the Deputy CNO for Development; the Deputy Chief of Staff for Research and Development, U.S. Marine Corps; the Chief of Naval Research; the director of the Long-Range Objectives Group, serving as executive secretary; and the president and executive vice president of the Franklin Institute. A new member, the Deputy CNO for Plans and Programs, was added in May 1963.
12. This and all the following quotations in our discussion of OEG's twentieth anniversary conference come from the proceedings, *The Operations Evaluation Group Twentieth Conference on Operations Research.*
13. It cost as much, for example, to operate a wing of B-52s for five years as it did to procure the planes for that wing, and it cost more to operate an infantry division for one year than it did to equip it initially. Also, because it may be desirable to limit our immediate commitment solely to development, as was the case with the B-70, research and development costs should be known apart from procurement costs.
14. Morse and Kimball 1951, p. 1.
15. The messages originated and received by CinCLant and CinCLantFlt were quite different, even though the two commands had the same commander and shared much of the same staff.
16. Shortly thereafter, NAVWAG was itself supported by the new and administratively subordinate Naval Objectives Analysis Group (NOAG).
17. Marine Corps Order 5400.7, 17 February 1965.
18. The sixth group, called the Program Analysis Group (Op-961), was mostly responsible for ensuring the smooth running of Op-96's own operations.
19. This matter was of special concern because CNA's NAVWAG was conducting an extremely important study called "War at Sea II," with the aim of exploring the military, political, and economic implications of wars at sea between the United States and Soviet Union in the 1975 time frame.
20. Letter from Chancellor W. Allen Wallis of the University of Rochester to Secretary of the Navy Paul Nitze, 8 May 1967.

21. Letter from Secretary of the Navy Nitze to President Wynn L. LePage of the Franklin Institute, 27 June 1967.
22. The distribution list for CNA reports has grown to include more than three hundred navy recipients and about another seventy-five outside the navy: the secretary of defense, the Joint Chiefs of Staff, the other services, the Central Intelligence Agency, the Department of State, CNA's sister analytical organizations, and others.

## 5. New Wartime Responsibilities and the Emergence of Today's OEG

1. Although U.S. Marines would normally have been used in such an amphibious assault role, they were already fully committed to fighting in I Corps.
2. This area came under heaviest attack in December 1972, when navy A-6s, in coordination with B-52s of the Strategic Air Command and F-111s of the air force, took part in a massive eleven-day bombing operation called Linebacker II.
3. Cagle 1972, p. 106.
4. OpNav Notice 03300, 13 September 1967.
5. Admiral Zumwalt, who formerly had command of American naval forces in South Vietnam, replaced Admiral Thomas H. Moorer as CNO on 1 July 1970.
6. The heavy B-52 raids on Hanoi and Haiphong and associated strikes in other parts of North Vietnam during December became known as Linebacker II; hence, the period of air operations covered by OEG's study was frequently referred to as Linebacker I.
7. In fact, there had been three earlier attempts by the navy to have CNA/OEG take over the contract. The first attempt, in 1966, failed because of a lack of agreement about how much control over the contract OEG's management would retain. The second two attempts, in late 1968 and again in 1969, fell through because of a funding ceiling.
8. David B. Kassing was appointed president of CNA in 1973, replacing Charles DiBona, who took a leave of absence to become special consultant on energy matters to President Richard M. Nixon.
9. In 1977, CNA merged SEG into the Naval Warfare Analysis Group (NAVWAG), to strengthen the center's ability to analyze the cost and effectiveness of future naval systems. Then, in October 1981, CNA merged NAVWAG and the Institute of Naval Studies (INS) into an entirely new division, the Naval Studies Group (NSG), with the aim of expanding the center's activities in such areas as strategic studies, the application of advanced technology, long-term force planning, naval warfare, resource management, and manpower, support, and readiness. Today, CNA consists of OEG, NSG, and the Marine Corps Operations Analysis Group (MCOAG).
10. In February 1982, Admiral McKee was chosen to replace the retiring Admiral Hyman G. Rickover as director of the Naval Nuclear Propulsion Program. Rear Admiral William R. Smedberg took over as acting director of naval warfare, until the present director, Vice Admiral Lee Baggett, was appointed in August 1982.

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The following works provided useful background information on many of the topics covered in this history of OEG. By far the main sources of information, however, were the following: the extensive records kept by OEG and CNA (internal memorandums, correspondence, administrative documents, and other official papers); the reports documenting ASWORG's and OEG's analyses; and the recollection of past OEG members whom I interviewed.


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