Managing a Sea of Information:

Shipboard Command and Control in

the United States Navy, 1899-1945

Timothy Scott Wolters
B.A., Computer Applications/History, University of Notre Dame
M.A., American History, University of Maryland

Submitted to the Program in Science, Technology, and Society
in partial fulfillment of the requirements for the degree of:

Doctor of Philosophy
In the History of Science and Technology
Massachusetts Institute of Technology

September 2003

© Copyright Timothy Scott Wolters
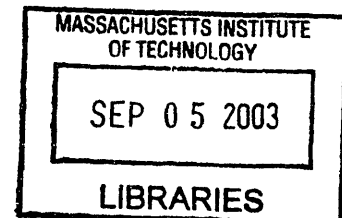
Signature of Author: _____

Program in the History and Social Study of Science and Technology
September 9th, 2003

Certified by: _____

David A. Mindell,
Associate Professor of the History of
Engineering and Manufacturing (MIT)

_____

Merritt Roe Smith, Professor of the
History of Technology (MIT)

_____

David Alan Rosenberg, Professor of
Maritime Strategy (Naval War College)

THIS PAGE INTENTIONALLY LEFT BLANK

Managing a Sea of Information:
Shipboard Command and Control in
the United States Navy, 1899-1945

by

Timothy S. Wolters

Abstract

This dissertation traces the history of shipboard command and
control systems in the United States Navy from 1899, when the
service first conducted experiments with wireless telegraphy,
through World War II, the conflict which witnessed the birth
of the modern shipboard information processing facility. It
argues that early-to-mid twentieth century naval officers'
development and employment of increasingly sophisticated ship-
board command and control systems fundamentally altered the
human experience of warfare at sea.

Based predominately on archival research, *Managing a Sea of
Information* follows a narrative format. It begins by examin-
ing the United States Navy's adoption of radio and challenges
the notion that a conservative officer corps failed to appre-
ciate the potential advantages of this new communications
technology. The bulk of the study explores the Navy's devel-
opment of shipboard command and control systems from World War
I through the beginning of World War II, focusing particularly
on the efforts of operational commanders to maximize their ca-
pabilities through the adoption of devices, methods, and pro-
cedures for the collection, processing, and dissemination of
information. These efforts gradually changed the nature of
command at sea, from an environment in which commanders could
make informed tactical decisions with relatively limited input
from subordinates, to one characterized by epistemic actions
and socially-distributed cognition. The dissertation con-
cludes with a brief analysis of shipboard command and control
systems during the Second World War, concentrating especially
on the United States Navy's creation of the Combat Information
Center (CIC).

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

To my grandfather,
C. W. Weaver

ACKNOWLEDGMENTS

One day shortly before this project began, I was walking past the STS reading room when I noticed a solitary figure sitting motionless, staring at a laptop. In the room was fellow student Greg Clancey, anxiously putting the finishing touches on his dissertation. In response to my query about his upcoming defense, Greg immediately offered me some unsolicited advice. "Whatever you do," he said, "as you go along make sure to record the name of everybody who assists you with your dissertation." Foolishly, I followed his advice only half-heartedly, and now it is my turn to gaze at a computer screen wondering how on earth to thank all those who have helped me in reaching this point.

Any words of gratitude rightfully should begin with my principal advisors, David Mindell and Merritt Roe Smith. David's first year as an assistant professor at MIT was also my first year as a graduate student in the STS Program, and from the very beginning he treated me more like a colleague than a pupil. His own work consistently served as an inspiration, and his insightful comments on earlier drafts of this study have, I believe, greatly improved the quality of this dissertation. No Ph.D. candidate could possibly hope to find a better teacher, critic, and friend.

To have the honor of working with one outstanding advisor is serendipitous; to have the privilege of working with two must be evidence of divine intervention. Roe Smith is a gifted scholar and a true gentleman, and I have benefited immensely from his tutelage. From nim I have learned much, not only about writing, research, and teaching, but also about life in academe. Our lengthy discussions about college football and basketball always served as a welcome distraction, and I look forward to many more to come.

Sincerest thanks must also go to the third member of my dissertation committee, David Alan Rosenberg. His unsurpassed knowledge of the twentieth century United States Navy has benefited me greatly in my struggles to understand certain aspects of shipboard command and control systems, and he graciously has introduced me to some very interesting historical work on American submarine operations. The lessons I have learned from this fine scholar will not soon be forgotten.

The Boston area has been a terrific place to attend graduate school, and with so many pleasant distractions I marvel that I am finishing at all. The Museum of Fine Arts, Boston Symphony Orchestra, and Boston Pops all have helped me to maintain my sanity in stressful times, as have those poster-children of eternal hope, the Boston Red Sox. And while I have delighted in heading over to Fenway Park to catch the power and grace of future hall-of-famers Nomar Garciaparra and Pedro Martinez, I always have identified more with guys like Brian Daubach, Darren Lewis, Trot Nixon, Lou Merloni, Jason Varitek, and Tim Wakefield. Take heart, Boston, for if someone like me can get a Ph.D. from MIT, then that elusive World Series championship must surely be just around the corner.

In the humanities, few dissertations are finished without some form of financial support, and mine is no exception. In this regard as in many others, I have been particularly fortunate. Twice the Dibner Institute for the History of Science and Technology gave me graduate fellowships, furnishing not only financial support but also a wonderful environment in which to read and write. The Naval Historical Center provided me with the Rear Admiral John D. Hayes Dissertation Fellowship for 2001-2002, and the Institute of Electronics and Electrical Engineers History Center awarded me the Life Members' Fellowship in Electrical History for 2002-2003. For travel expenses related to research, I was privileged to receive a grant from the National Science Foundation (SES-217532), and final revisions to this dissertation were applied while enjoying my tenure as the National Air & Space Museum's Ramsey Chair of Naval Aviation History for 2003-2004. I hope that my final product meets the high standards of these institutions, and even if it does this still makes for a small return on such generous assistance.

Lastly, I would like to thank the members of my family, who have always been there when I've needed them most. My parents, Dennis and Carol, have provided the kind of love and encouragement that only parents can. My siblings, Stephanie, Alison, and Jeffrey, have at different times and in their own ways supported and inspired me. Yet only my wife, Karen, and our daughter, Caroline, have had to tolerate the daily privations that go with having a husband and a father in graduate school. For their sacrifices and enduring love, I am eternally grateful.

LIST OF ABBREVIATIONS

Abbreviations used in notes for archival materials:

ADM	Admiralty
AIR	Air Ministry
ARFTF	Annual Reports of Fleets and Task Forces of the U.S. Navy, 1920-1941
ATF	Aviation Technical Files
BuEq	Bureau of Equipment
COMINCH	Commander-in-Chief, United States Fleet
DANWDP	Documentary Analysis of New-Weapon Development Programs
GB	General Board
HHR	Histories and Historical Records
IWM	Imperial War Museum
NACP	National Archives, College Park
NADC	National Archives, Washington DC
NAMC	National Archives Microfilm Collection
NASM	National Air and Space Museum
NOA	U.S. Navy Operational Archives
NRL-C	Naval Research Lab General Files (Confidential)
NRL-S	Naval Research Lab General Files (Secret)
NWC	Naval War College Archives
P46	Post-1946 Command File
PCL	Papers of Caleb Laning
PRC	Papers of Robert Church
PRO	Public Record Office
RG	Record Group
RRFP	Records Relating to United States Navy Fleet Problems I to XXII, 1923-1941

LIST OF ABBREVIATIONS (continued)

Abbreviations used in the narrative:

AGC	Amphibious Command Ship
CIC	Combat Information Center
CNO	Chief of Naval Operations
ECM	Electric Cipher Machine
HF	High Frequency
HMS	His Majesty's Ship
NRL	Naval Research Laboratory
OPNAV	Offices of the Chief of Naval Operations
OTC	Officer in Tactical Command
RCA	Radio Corporation of America
RDF	Radio Direction Finding
USS	United States Ship

A leader in planning a campaign or a battle thinks in terms of the limitations imposed by the ranges and arcs of train of his guns, of the speed of his ships, and the capacity of his bunkers. He must learn to think in terms of the limitations of his communications system too. These limitations are definite and any plans that overtax the system are destined to failure. He must know exactly what he can and cannot do.

Commander H. W. Boynton

Comments made during the
U.S. Navy's critique
of Fleet Problem VI
February 1926

THIS PAGE INTENTIONALLY LEFT BLANK

CHAPTER ONE
INTRODUCTION

Command and Control[1] Systems: Past and Present

On the morning of August 5th, 1864, Rear Admiral David
Glasgow Farragut led an eighteen-ship Union fleet into action
against the hardened Confederate defenses at Mobile Bay.   As
the battle commenced, Farragut climbed high into the rigging
aboard his flagship, *USS Hartford*.   For nearly the next four
hours the sixty-three year old admiral directed his forces from
this lofty perch, and when the smoke finally cleared the last
major Confederate port on the Gulf Coast was in Union hands.[2]
Linked forever with Farragut's famous order to "Damn the tor-
pedoes!" and proceed "Full steam ahead!" the Battle of Mobile

---

[1] The term "command and control" is a post-World War II construct, and
for this reason I have given serious consideration to its use in this
dissertation.   Ultimately I decided to do so because: (1) contemporary
understandings of command and control are entirely consistent with ear-
lier perceptions of "command," the term early-to-mid twentieth century
American naval officers would have used to describe what today is known
as command and control, (2) when used as a modifier before words such as
facility, system, or technology, "command" can be confusing (e.g., "com-
mand technology"), whereas "command and control" has a relatively unam-
biguous meaning, and (3) because the term is used commonly today, "com-
mand and control" simply sounds better to the modern reader.   I have en-
deavored to use the term judiciously and only at times when other words
are inadequate to capture succinctly the following basic concept: *the
exercise of authority and direction through an arrangement of personnel,
equipment, facilities, and procedures employed by a commander to plan,
direct, coordinate, and control forces and operations.*   For the United
States military's current definition of command and control, see Depart-
ment of Defense, *Joint Publication 1-02:   Dictionary of Military and As-
sociated Terms,* (2001), 100-101.   A brief discussion of how and why com-
mand and control came to be seen as a subset of command is available in
Thomas P. Coakley, *Command and Control for War and Peace* (1992), 34-38.
[2] For more on Farragut's role in the Battle of Mobile Bay, see Charles
Lee Lewis, *David Glasgow Farragut: Out First Admiral* (1943), 263-296,
and John C. Waugh, *Last Stand at Mobile* (2001), 13-60.   A new account
of the battle, *West Wind, Flood Tide: The Battle of Mobile Bay,* by

Bay remains one of the most celebrated events in American naval history (Figure 1-1).[3]

Thirty-four years later and half a world away, Commodore George Dewey placed himself in a similarly exposed position aboard his flagship, *USS Olympia*, as he led the U.S. Asiatic Squadron into action at Manila Bay. Like his former mentor,[4] Dewey achieved complete victory, destroying an overmatched Spanish fleet with relative ease. As with Farragut's words at Mobile Bay, Dewey's famous order, "You may fire when you are ready, Gridley,"[5] also has become a renowned part of American naval lore (Figure 1-2).[6]

Although a generation and a half separated Farragut and Dewey, their means for exercising command were strikingly similar. Both used a spyglass to assist in seeing the enemy. Both used signal flags to communicate with their forces. For issuing orders to subordinates, both men relied primarily on messengers or their own stentorian voices, although *Olympia* did possess a direct-line telephone between the pilot house and

---

John Friend, is scheduled for release by Naval Institute Press in November 2003.

[3] Farragut probably did not utter these exact words, although they certainly reflect his intentions. Lewis, *Our First Admiral*, 469-470.

[4] Dewey had served under Farragut during the Civil War. His admiration for the Union admiral was such that he later wrote: "Whenever I have been in a difficult situation, or in the midst of such a confusion of details that the simple and right thing to do seemed hazy, I have often asked myself, 'What would Farragut do?' . . . . Valuable as the training of Annapolis was, it was poor schooling beside that of serving under Farragut in time of war." George Dewey, *Autobiography of George Dewey: Admiral of the Navy* (1987 [1913]), 50, 52.

[5] Captain Charles V. Gridley was commanding officer of the *USS Olympia*. As an Acting Ensign, he had served under Farragut at Mobile Bay. For more on Gridley's career, see Maxwell P. Schoenfeld, *Charles Vernon Gridley: A Naval Career* (1983).

[6] Ronald Spector, *Admiral of the New Empire: The Life and Career of George Dewey* (1974), 40-63, David F. Trask, *The War with Spain in 1898* (1981), 95-107, George O'Toole, *The Spanish War: An American Epic, 1898* (1984), and John B. Hattendorf, "The Battle of Manila Bay," 175-197, in *Great American Naval Battles* (1998), ed. Jack Sweetman. Hattendorf, a well-respected maritime historian, suggests that Dewey's order remains

captain's stateroom. With very few exceptions, such as an engine-order telegraph and some nighttime visual signalling apparatus, the command and control systems available to Dewey were ones with which Farragut would have been completely familiar.[7] Yet Dewey's victory at Manila Bay clearly marked the end of an era, as larger fleets and improvements in propulsion, weapons, and communications technologies soon rendered it impossible for a naval commander to make informed tactical decisions on the basis of what he could see and hear unaided by devices, systems, and methods for dealing with the growing complexity of warfare at sea.[8]

★　　★　　★

Today, professional discussions about military and naval tactics, operations, and strategy consistently stress the importance of command and control. According to current United States Navy doctrine, "Command and control is the foundation upon which the planning and execution of naval operations are built. . . . It is the tool the naval commander uses to cope with the uncertainty of combat and to direct his forces to accomplish the assigned mission. . . . Command and control is an essential element of the art and science of naval warfare."[9] More recently, the Commander-in-Chief of the U.S. Seventh Fleet avowed that operational success only could be achieved by em-

---

"the most famous command in American naval history." Hattenforf, "Manila Bay," 189.

[7] For a virtual tour of *USS Olympia* that shows and/or discusses some of these systems, see http://www.spanamwar.com/olympiatourintro.htm, viewed July 25, 2003.

[8] I use the term "warfare at sea" in a broad sense, to include not only combat operations but also preparations for combat at sea.

[9] Department of the Navy, *Naval Doctrine Publication 6: Naval Command and Control* (1995), i-ii.

bracing command and control as a fundamental operational task, "with priority on schooling our commanders in what they must know, where to access that information, and how to act on it once they have it . . . Ultimately, command and control is the commander's contribution to winning the fight."[10]

Although these are recent observations, they reflect sentiments that would have resonated with naval officers of earlier eras, especially those in the United States Navy during the first half of the twentieth century. From 1899, when the U.S. Navy first conducted shipboard experiments with wireless telegraphy, through World War II, the conflict which witnessed the birth of the modern shipboard information processing facility, American naval officers consistently developed, tested and employed innovative systems for managing real-time, tactically-relevant information about enemy and own forces. Any attempt to understand technological development in the United States Navy must include an analysis of these systems, for they had a profound influence on operational decision-making.

Indeed, the primary argument of this dissertation is that early-to-mid twentieth century American naval officers' development and employment of increasingly sophisticated shipboard command and control systems fundamentally altered the human experience of warfare at sea. The officers of this era used new techniques and technologies to change the way information was acquired, displayed, and processed. This in turn created an environment in which successful leadership derived not only from a commander's audacity and innate mental aptitude, but also from his ability to master the cognitive skills critical

---

[10] Vice Admiral Robert F. Willard, "Rediscover the Art of Command and Control," *United States Naval Institute Proceedings*, vol. 128, no. 10 (2002), 54.

18

for processing large quantities of information. As a group,
these officers possessed an irrefutable consciousness of the
importance of command and control, displaying a level of under-
standing that undoubtedly would surprise those who today extol
the novelty of concepts such as "information superiority" and
"network-centric warfare."[11]

[11] For example, see Robert R. Tomes, "Boon or Threat? The Information
Revolution and U.S. National Security," Naval War College Review, vol.
53, no. 3 (2000), 39-59, David S. Alberts, John J. Garstka, and Freder-
ick P. Stein, Network Centric Warfare: Developing and Leveraging Infor-
mation Superiority (1999), and Vice Admiral Arthur K. Cebrowski and John
J. Garstka, "Network-Centric Warfare: Its Origin and Future," United
States Naval Institute Proceedings, vol. 124, no. 1 (1998), 28-35.

Part I:

THE COGNITIVE EXPERIENCE OF COMMAND AT SEA

During the Second World War, military strategist Bernard Brodie observed that "submarine warfare and the introduction of the airplane have been the two great naval revolutions of the twentieth century."[12] Literally and figuratively, aircraft and submarines added a new dimension to naval warfare. Along with the advent of steam-driven screw propulsion, mobile torpedoes, and long-range gunnery in the latter half of the nineteenth century, these technologies ensured that previous methods of command and control no longer would suffice. Never again could a naval commander hope to discern what was happening around him by relying exclusively on his own two eyes and ears.

Of the many technological innovations adopted and fostered by navies over the first four decades of the twentieth century, long-range gunnery, naval aviation, and underwater warfare have attracted the lion's share of scholarly attention.[13] Others, particularly those that deal with the coor-

---

[12] Bernard Brodie, *Sea Power in the Machine Age* (1943), 261. To this he should have added communications-electronics, the hardware that served as the backbone of naval command and control systems (about which more will be said later).

[13] See, for example, Elting E. Morison, "Gunfire at Sea," in *Men, Machines, and Modern Times* (1966), 17-44, Rodrigo Garcia y Robertson, "Failure of the Heavy Gun at Sea, 1898-1922," *Technology and Culture*, vol. 28, no. 3 (1987), 539-557, W. J. Jurens, "The Evolution of Battleship Gunnery in the U.S. Navy, 1920-1945," *Warship International*, vol. 28, no. 3, (1991), 240-271, Jon T. Sumida, *In Defence of Naval Supremacy: Finance, Technology, and British Naval Policy, 1889-1914*, 2nd edition (1993), and Idem, "The Quest for Reach: The Development of Long-Range Gunnery in the Royal Navy, 1901-1912," 49-96, in *Tooling for War: Military Transformation in the Industrial Age* (1996), ed. Stephen D. Chiabotti, Charles Melhorn, *Two Block Fox: The Rise of the Aircraft Carrier, 1911-1929* (1974), Geoffrey Till, *Air Power and the Royal Navy, 1914-1945: A Historical Survey* (1979), and Idem, "Adopting the Aircraft Carrier: The British, Japanese and American Case Studies," 191-226, in

dination of naval forces, have been examined much less exten-
sively.[14] Yet it was these coordinating technologies (and the
personnel who operated them) upon which naval commanders in-
creasingly relied for information about friendly and enemy
forces. As the Navy adopted more of these technologies, the
cognitive experience of naval command changed, from one in
which a commander focused mainly on direct actions to one in
which he had to expend as much if not more effort coping with
the growing amount of information available to him. In short,
naval warfare evolved into an extremely complex "thinking-man's
game."

Of course, even in the age of sail naval commanders
struggled with the need to make quick decisions in the face of
incomplete or misleading information.[15] On at least one level,

---

Military Innovation in the Interwar Period (1996), ed. Williamson Murray
and Allan R. Millet, Thomas C. Hone, Norman Friedman, and Mark D. Mande-
les, *American & British Aircraft Carrier Development, 1919-1941* (1999),
Mark R. Peattie, *Sunburst: The Rise of Japanese Naval Air Power, 1909-
1941* (2001), Ernest Andrade, "Submarine Policy in the United States
Navy, 1919-1941," *Military Affairs*, vol. 35, no. 2, (1971), 50-56, Gary
E. Weir, *Building American Submarines, 1914-1940* (1991), Norman Fried-
man, *U.S. Submarines Through 1945: An Illustrated Design History*
(1995), V. E. Tarrant, *The U-Boat Offensive, 1914-1945* (1989), John Ter-
raine, *The U-Boat Wars, 1916-1945* (1989), Arthur Hezlet, *The Submarine
and Sea Power* (1967), 16-240, Holger Herwig, "Innovation Ignored: The
Submarine Problem – Germany, Britain, and the United States, 1919-1939,"
in *Military Innovation in the Interwar Period*, Edwyn Gray, *The Devil's
Device: Robert Whitehead and the History of the Torpedo*, 2nd edition
(1991), 152-226, Michael Gannon, *Hellions of the Deep: The Development
of Torpedoes in World War II* (1996), Brodie, *Sea Power in the Machine
Age*, 171-448, and William M. McBride, *Technological Change and the
United States Navy, 1865-1945* (2000), 64-93, 111-156, 182-210. Addi-
tional works are cited in the bibliography.
[14] For more on this point, see Part II of this chapter.
[15] The importance of an education that would enable naval officers to
make the best possible decisions in such situations was first articu-
lated by famous American naval officer/historian Alfred Thayer Mahan.
As such, Mahan's writings provide numerous historical examples of naval
officer decision-making under conditions of uncertainty. See especially
Alfred T. Mahan, *The Influence of Sea Power Upon the French Revolution
and Empire, 1793-1812*, 2 vols. (1893), and Idem, *The Life of Nelson:
The Embodiment of the Sea Power of Great Britain*, 2 vols. (1897). For
more on Mahan's views regarding officer education, see Jon T. Sumida,
*Inventing Grand Strategy and Teaching Command: The Classic Works of
Alfred Thayer Mahan Reconsidered* (1997).

then, the nature of command at sea changed little with the industrialization of naval warfare. A commander still had to be prepared to lead his men into combat under demanding conditions in an unpredictable environment, with the full awareness that his actions might determine a military outcome and/or the difference between life and death. On another level, however, the nature of command at sea underwent a profound and fundamental change during the first half of the twentieth century, a change that revolved around the *cognitive experience* of naval commanders.

The distinction between cognitive action carried out in order to bring one immediately closer to a desired end-state (e.g., deciding to man battle stations or ordering changes in course and speed) and cognitive action performed to make clearer information that is obscure or difficult to process mentally (e.g., directing large-scale fleet maneuvers or vectoring friendly aircraft to intercept hostile aircraft) increasingly has attracted the interest of brain and cognitive scientists, who generally refer to the former as *pragmatic* action and the latter as *epistemic* action.[16] As defined by David Kirsch and Paul Maglio, two leading scholars on the subject, pragmatic actions are those that directly bring an individual closer to his or her physical goal. Epistemic actions, on the other hand, are those performed by an individual so as to make a task or set of tasks more manageable (thus only indirectly bringing an individual closer to his or her final goal).[17] According to Kirsch and Maglio, epistemic actions generally are undertaken by individuals seeking to

---

[16] Andy Clark, "Embodied, Situated, and Distributed Cognition," 506-517, in *A Companion to Cognitive Science* (1998), ed. William Bechtel and George Graham.

22

simplify a problem-solving task, and are most likely to occur in situations where quick decision-making is essential. Specifically, Kirsch and Maglio define any action as epistemic if its ". . . primary function is to improve cognition by: (1) reducing the memory involved in mental computation, that is, space complexity; (2) reducing the number of steps involved in mental computation, that is, time complexity; [and/or] (3) reducing the probability of error in mental computation, that is, unreliability."[18]

For American naval commanders in the first half of the twentieth century, the cognitive experience of command at sea increasingly shifted from one of pragmatic actions to one of epistemic actions. In other words, naval commanders had to devote an ever greater amount of time and effort developing and employing systems whose *immediate* purpose was not to engage the enemy, but rather to simplify the decision-making process. Toward this end, the Navy promoted the creation and use of shipboard systems designed to improve the reliability of available information and to help senior officers better deal with the escalating complexity of warfare at sea.[19] Some of these efforts were more successful than others, but the overall trend was such that naval commanders had to rely increasingly on

[17] David Kirsch and Paul Maglio, "On Distinguishing Epistemic from Pragmatic Action," *Cognitive Science*, vol. 18, no. 4, (1994), 513-549.
[18] Ibid., 514. According to cognitive scientist Andy Clark, examples of simple epistemic actions include: "looking at a chessboard from different angles, organizing the spatial layout of a hand of cards so as to encode a record of known current high cards, laying out our mechanical parts in the order required for correct assembly, and so on. Epistemic actions, it should be clear, build designer environments – local structures that transform, reduce, or simplify the operations that fall to the biological brain in performance of a task." Clark, "Embodied, Situated, and Distributed Cognition," 511.
[19] This process was iterative, with sea-going commanders providing feedback to the Navy's material bureaus and vice versa.

their subordinates for the information necessary to make appropriate command decisions.

An important consequence of this development was that the decision-making process on board U.S. Navy warships became much more socially distributed. To be sure, ultimate authority continued to rest with a vessel's commanding officer or the officer in tactical command (OTC), but the extent to which a single individual could follow and dictate the course of events gradually declined.[20] Because naval commanders had to delegate unprecedented responsibility to their junior officers and enlisted personnel, successful exercise of command at sea increasingly required the employment of systems that could distribute problem-solving more evenly up and down the chain of command, a phenomenon anthropologist Edwin Hutchins refers to as "socially distributed cognition."[21]

The transition from an environment in which commanders could make informed tactical decisions with relatively limited input from subordinates, to one characterized by epistemic actions and socially distributed cognition, is an important yet unexplored aspect of American naval history. A thorough investigation of this transition leads to a better understanding of

---

[20] Several scholars have pointed to a similar trend in the evolution of land warfare. Historian John Keegan, for example, writes that the introduction of industrial communications technologies such as the telegraph "allowed intelligence to outpace the movement of armies, its volume [exceeding] the capacity of any one man to collect and digest it." John Keegan, *The Mask of Command* (1987), 326. Keegan's analysis draws heavily from Martin van Creveld, *Command in War* (1985).

[21] According to Hutchins, "organized groups may have cognitive properties that differ from those of the individuals who constitute the group. These differences arise from both the effects of interactions with technology and the effects of social distribution of cognitive labor. The system formed . . . can be thought of as a computational machine in which social organization is computational architecture. The members of the team are able to compensate for local breakdowns by going beyond the normative procedures to make sure that representational states propagate when and where they should." Edwin Hutchins, *Cognition in the Wild* (1995), 228.

the Navy's approach to technological innovation during the interwar period and beyond.

Rather than focus on the "battleship versus carrier" debate, as many previous authors have done,[22] this study examines how senior American naval officers addressed the difficulties inherent to the command of geographically-dispersed and dimensionally-diverse seaborne forces under simulated (or actual) conditions of battle. In so doing, it offers an alternative conceptual framework in which the locus of analysis shifts from progressive changes in warship types to the tactical integration of organized groups of vessels and aircraft. Such an approach reveals that the apparent technological conservatism of American naval officers had little to do with an irrational devotion to the battleship,[23] but instead had much to do with the inherent limitations of the fleet's command and control systems. Indeed, it was these very limitations that drove the U.S. Navy to pursue aggressively the adoption of command and control technologies, a propensity that further debunks the

---

[22] For example, see Vincent Davis, *The Admirals Lobby* (1967), Theodore Roscoe, *On the Seas and in the Skies: A History of the U.S. Navy's Air Power* (1970), 3-248, Waldo Heinrichs, "The Role of the United States Navy," 197-223, in *Pearl Harbor as History* (1973), ed. Dorothy Berg and Shumpei Okamoto, Melhorn, *Two Block Fox*, Thomas C. Hone, "Battleships vs. Aircraft Carriers: The Patterns of U.S. Navy Operating Expenditures, 1932-1941," *Military Affairs*, vol. 41, no. 3, (1977), Robert L. O'Connell, *Sacred Vessels: The Cult of the Battleship and the Rise of the U.S. Navy* (1991), 233-316, Clark G. Reynolds, *The Fast Carriers: The Forging of an Air Navy*, 2nd edition (1992), Hone, Friedman, and Mandeles, *American & British Aircraft Carrier Development*, and McBride, *Technological Change and the United States Navy*, 111-241.

[23] A number of authors have condemned the U.S. Navy's senior leadership for failing to recognize the potential of carrier aviation prior to the United States' entry into the Second World War. The enduring popularity of this interpretation is attested to by the fact that the phrase "battleship admiral" remains an epithet for an excessively conservative senior naval officer. Works that either support or accept this view include: Davis, *The Admirals Lobby*, Roscoe, *On the Seas and in the Skies*, Heinrichs, "The Role of the United States Navy," O'Connell, *Sacred Vessels*, Reynolds, *The Fast Carriers*, and McBride, *Technological Change and the United States Navy*.

myth of a pre-World War II naval officer corps ardently resis-
tant to technological change. By the end of World War II, the
sophisticated systems created by the Navy for the command and
control of naval forces had become a defining characteristic of
warfare at sea.

Part II:

BLACK BOX AS PARADOX

On October 14th, 2000, the United States Navy commissioned a new guided-missile destroyer, the *USS Roosevelt*. In an official statement released several days prior to the commissioning ceremony, the Navy lauded its newest warship's lethal *Tomahawk* cruise missiles, powerful gas-turbine engines, anti-submarine helicopter capabilities, and "space-age communication, radar and weapons technologies."[24] With a length equal to nearly two football fields, a displacement of over 8,000 tons, and a maximum speed in excess of thirty knots, the Navy's newest class of destroyer provides a twenty-first century exemplar of what one author refers to as the "American technological sublime."[25]

Conspicuously absent from the Navy's description of *Roosevelt* is mention of the location from which her officers exercise command and control, a place known as the Combat Information Center, or CIC. Without the CIC, however, a warship's sophisticated sensors and weapons are essentially useless. To use a metaphor frequently invoked by American naval officers, CICs function as the brains of modern warships. Within them, officers and enlisted personnel collect, organize, process, evaluate, and disseminate vast quantities of information using automated, semi-automated, and manual techniques. Senior per-

---

[24] Public Affairs Release, October 12, 2000, "Navy to Commission AEGIS Guided Missile Destroyer ROOSEVELT (DDG 80) in Mayport, Fla.," available at the Navy Office of Information, Pentagon, Room 4A686, Washington, DC.
[25] David E. Nye, *American Technological Sublime* (1994). Interestingly, Nye omits military and naval technologies from his analysis, writing, "The national anthem evokes 'the rockets' red glare and bombs bursting in air,' a reminder that the most powerful experiences of technology for many have long been encountered in warfare. This subject merits a study of its own." Nye, xvi.

sonnel make important tactical decisions on the basis of this information.[26]

Given the critical importance of a warship's command and control facilities, why does the Navy rarely mention them in its public statements? To begin, few people outside the defense industry have much interest in military command and control systems. These systems, composed as they are of internal and external communications networks, trained personnel, formalized procedures, computer systems, and other artifacts, are difficult to explain in a press release. Furthermore, security restrictions preclude the Navy from providing more than a basic overview of tactical operations. Most significantly, however, the physical appearance of command and control facilities is not particularly impressive. They do not go fast, make loud noises, or blow things up, and therefore do not contribute to the glamorous image sought by the Navy in its public relations.

For similar reasons, the origins and development of shipboard command and control systems in the United States Navy has remained a topic little explored by historians. Classification restrictions provide a partial explanation for this lack of attention, but archival records pertaining to command and control technologies rarely fall into categories that contain sensitive information, such as war planning, clandestine operations, or naval intelligence. In fact, the U.S. Navy has declassified

---

[26] Two American warships on which this decision-making recently went tragically wrong include the *USS Stark*, which was hit by an Iraqi missile on 17 May 1987, and the *USS Vincennes*, which accidentally shot down a passenger airliner on 3 July 1988. The *Stark* incident is covered in Jeffrey L. Levinson and Randy L. Edwards, *Missile Inbound: The Attack on the* Stark *in the Persian Gulf* (1997). A biased yet first-hand account of the *Vincennes* incident (written by the ship's commanding officer and his wife) is found in Will Rogers, Sharon Rogers, and Gene Gregston, *Storm Center: The* USS Vincennes *and Iran Air Flight 655 - A Personal Account of Tragedy and Terrorism* (1992). Rogers begins his account with a description of events inside the CIC.

substantial archival material pertaining to shipboard command and control systems, including nearly all records through the end of World War II. Still, other issues present a challenge. Understanding how command and control facilities functioned in exercises or combat is a formidable task. Command and control technologies possess different (and often disparate) archival filing designators, making research rather time-consuming. Finally, shipboard command and control systems lack the glamour so often present in naval historiography, from grand strategy and famous battles to daring personalities and awe-inspiring technologies.

These difficulties nevertheless fail to provide a sufficient explanation as to why the development of shipboard command and control systems remains unexplored, since many other difficult and ostensibly unglamorous subjects have been studied, albeit not to the extent or degree several knowledgeable historians believe is necessary.[27] This dissertation posits that the early history of shipboard command and control systems has been overlooked primarily because it presents scholars with a paradox. On the one hand, when compared to numerous military and naval technologies of the early-to-mid twentieth century – such as airplanes, submarines, rockets, tanks, battleships, and of course, the atomic bomb – naval command and control systems appear relatively unsophisticated.[28] On the other hand, the

---

[27] John Hattendorf, ed., *Doing Naval History: Essays Toward Improvement* (1995). See especially the essays by John Hattendorf, James Goldrick, Jon Sumida and David Rosenberg, Nicholas Rodger, and Dennis Showalter.
[28] There are some interesting discussions of the relationship between "low-" and "high-tech" military devices, including why the former often are neglected in the scholarly literature. In particular, see Irving B. Holley, "Technology and Strategy: A Historical Overview," 15–41, in *Technology, Strategy, and National Security* (1985), ed. Franklin D. Margiotta and Ralph Sanders, Jerry E. Strahan, *Andrew Jackson Higgins and the Boats that Won World War II* (1994), and Timothy Moy, *War Machines: Transforming Technologies in the U.S. Military, 1920-1940* (2001), 9–11, 101–177.

creators of these systems were seeking to solve one of the most difficult problems of their time: managing information in a difficult environment where even the briefest of delays could mean the difference between life or death, victory or defeat, honor or disgrace. Confronted with this paradox, historians have been content to locate shipboard command and control systems inside a "black box," taking their design, construction, and use as axiomatic.[29] Why this has occurred poses an intriguing question.

<p style="text-align:center">*   *   *</p>

A useful starting point for investigating this question is found in the work of historians Jon Sumida and David Rosenberg. In a recent essay, they divide the field of naval history into three basic groups: core, ancillary, and cognate. According to Sumida and Rosenberg, *core* naval history generally focuses on naval policy and operations. While practitioners of

---

[29] Believed to have originated in Britain during World War II, the term "black box" is used to denote an automatic apparatus that performs intricate functions. The concept allows scientists and engineers to concentrate on inputs and outputs without worrying about what occurs inside the box. In the past two decades, scholars in disciplines from anthropology to zoology have adopted the metaphor of the black box to describe an artifact that performs its function(s) without an understanding of its internal workings. For example, see Nathan Rosenberg, *Inside the Black Box: Technology and Economics* [economics] (1982), and Idem, *Exploring the Black Box: Technology, Economics, and History* [economic history] (1994), Bruno Latour, *Science in Action: How to Follow Scientists and Engineers through Society* [philosophy of science] (1987), Donald MacKenzie, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance* [sociology] (1990), D. W. Hamlyn, *In and Out of the Black Box: On the Philosophy of Cognition* [philosophy/cognitive psychology] (1990), Langdon Winner, "Upon Opening the Black Box and Finding It Empty: Social Constructivism and the Philosophy of Technology," *Science, Technology, & Human Values*, vol. 18, no. 3 (1993), 362-378 [science and technology studies] , Michael Behe, *Darwin's Black Box: The Biochemical Challenge to Evolution* [biochemistry/evolutionary biology] (1996), and David A. Mindell, *War, Technology, and Experience aboard the USS Monitor* [history] (2000). For more on the origins of the term, see *Oxford English Dictionary*, on-line ed., s.v. "black box."

this genre sometimes acknowledge the influence of technical, economic, administrative, and financial factors, they do not investigate these matters rigorously in their own terms. *Ancillary* naval history consists of works dealing primarily with naval machines, individuals, manufacturing, and management. Sumida and Rosenberg argue that these studies usually accept the core histories as given or disregard them altogether, and that their findings rarely address larger policy or operational issues. Finally, *cognate* naval history consists of works concerned with navies in the past, but written mainly from the standpoint of fields distinct from naval history, including but not limited to social, economic, political, diplomatic, intellectual, cultural, and technical history; or even different disciplines such as political science, sociology, and security studies. Cognate naval history differs from ancillary naval history by engaging larger questions and employing the methodologies characteristic of its respective fields or disciplines.[30]

For different reasons, practitioners in each of these three groups have located shipboard command and control systems within a black box. Unable to conduct detailed research into all matters, writers of core naval history occasionally mention such systems, but more often than not ignore them altogether.[31]

---

[30] Jon T. Sumida and David A. Rosenberg, "Machines, Men, Manufacturing, Management, and Money: The Studies of Navies as Complex Organizations and the Transformation of Twentieth Century Naval History," 25-39, in *Doing Naval History: Essays Toward Improvement* (1995), ed. John Hattendorf.

[31] Recent core histories sometimes acknowledge the importance of shipboard command and control systems, but then make little effort to explain how these facilities functioned. For example: "High above the flight decks, carrier superstructures sprouted the antennas of new and improved radar which sent 'blips' down to the Combat Information Centers, to be evaluated as friend or foe – and if foe, promptly dealt with by fighters vectored out by the CIC." Nathan Miller, *War at Sea: A Naval History of World War II* (1995), 393. Another example is found in

These historians tend to describe command and control activi-
ties in terms of outcome rather than process. Samuel Eliot
Morison's recounting of events at the start of the Battle of
the Philippine Sea (19-20 June 1944) provides a typical exam-
ple:

> As early as 0530 bogeys [unidentified aircraft]
> appeared on radar screens in the direction of
> Guam; a Hellcat from *Monterey* tallyhoed [visu-
> ally sighted] two Judys in that direction and
> destroyed one, and about half an hour later a
> Val was shot down by destroyers of the battle
> line. The first phase of the action was on.[32]

This simple description belies the complexity of these events,
reminding one of the battle piece narratives John Keegan would
criticize so soundly a generation later.[33] Morison never ex-
plains to his readers just how electronic images, appearing on
small screens in dark rooms deep inside U.S. Navy ships, led
to the destruction of fast-moving Japanese aircraft dozens of
miles away.

One might consider such criticism unfair since writers of
core naval history seek a level of analysis inconsistent with
that degree of detail. After all, historians continually ex-
ercise selective judgment in their work, forever seeking to

Pacific War Encyclopedia, where the authors write: "The US Navy had de-
veloped the CIC (Combat Information Center). Because of the wide use of
radios in aircraft, and powerful shipboard radars, the admiral in the
CIC (on his flagship) could thus control hundreds of aircraft at once
and coordinate them against large Japanese attacks. The Japanese had
nothing quite as effective as the CIC, and suffered much from the effi-
cient American CICs." James F. Dunnigan and Albert A. Nofi, *Pacific War
Encyclopedia* (1998), 251. CICs are not further discussed in either of
these two books.

[32] Samuel Eliot Morison, *History of United States Naval Operations in
World War II: New Guinea and the Marianas, March 1944 – August 1944*,
Vol. VIII (1953), 260.

[33] John Keegan, *The Face of Battle: A Study of Agincourt, Waterloo, and
the Somme* (1976), 35-45.

strike a balance between inordinate detail and the sins of omission. As several prominent historians have argued, "history-writing implicitly begins by concentrating on those aspects of an event deemed most relevant to the inquiry."[34] One may conclude that for Morison, what occurred inside a warship's command and control center was not particularly relevant. Other core naval histories of World War II basically have accepted this premise,[35] with the author of one well-known synthesis even going so far as to claim that the tactical coordination of naval forces was accomplished simply "by good sense and the seat of the pants."[36]

In general, historians place complex processes into black boxes for one of two reasons. In the first case, they assume that a detailed examination of the box is superfluous to their broader arguments. As typified by Morison, this line of reasoning helps explain why command and control systems are absent from most core naval histories. In the second instance, historians utilize black boxes when they believe that the contents of those boxes have been examined adequately elsewhere. Yet this is a category into which shipboard command and control systems do not fall, since writers of ancillary naval history,

[34] Joyce Appleby, Lynn Hunt, and Margaret Jacob, *Telling the Truth About History* (1994), 253.

[35] Specific examples include: Dudley W. Knox, *A History of the United States Navy,* 2nd edition (1948), 435-625, John Costello, *The Pacific War, 1941-1945* (1981), E. B. Potter, ed., *Sea Power: A Naval History,* 2nd edition (1981), 254-353, Richard Hough, *The Longest Battle: The War at Sea, 1939-1945* (1986), Kenneth J Hagan, *This People's Navy: The Making of American Sea Power* (1992), 292-332, Robert W. Love, *History of the U.S. Navy, 1942-1991,* vol. 2 (1992), 1-273, Frank Uhlig, *How Navies Fight: The U.S. Navy and Its Allies* (1994), 101-284, George W. Baer, *One Hundred Years of Sea Power: The U.S. Navy, 1890-1990* (1994), 181-272, Miller, *War at Sea,* and Dunnigan and Nofi, *Pacific War Encyclopedia.* See also Samuel Eliot Morison, *The Two Ocean War: A Short History of the United States Navy in the Second World War* (1963).

[36] Edward L. Beach, *The United States Navy: 200 Years* (1986), 484.

like practitioners of core naval history, also have neglected to study this topic. What are the reasons for this neglect?

In searching for answers, one must begin by looking at the historiography of naval technology, perhaps the most popular form of ancillary naval history. Not surprisingly, the study of late nineteenth and twentieth century naval technology has centered on innovations in warship design: the introduction of the ironclad, the dreadnought revolution, the rise of the aircraft carrier, the ascension of the nuclear-powered submarine. Following very much in the tradition of Whig history, the theme of progress is an underlying aspect of many works in the history of naval technology.[37] Widespread acceptance of this theme in turn has led practitioners to concentrate on the most sublime naval technologies – battleships, submarines, and aircraft carriers (and naval aircraft) – and the progressive changes in their relationships to one another.

Certainly these technologies are an important part of modern naval history, but by concentrating on dominant warship forms scholars have placed undue emphasis on technological competition. Unfortunately, this emphasis has contributed to the characterization of naval technologies as either winners or losers, an artificial black/white dichotomy frequently leading to oversimplified historical interpretation.[38] In addition, such an approach tends to overlook issues that appear unrelated to the development of the sublime naval technologies; in par-

---

[37] See Herbert Butterfield, *The Whig Interpretation of History* (1950 [1931]), Edward Hallett Carr, *What Is History?* (1961), Peter Novick, *That Noble Dream: The "Objectivity Question" and the American Historical Profession* (1988), and Appleby, et al., *Telling the Truth About History* (1994). For more on the myth of technological progress, see John M. Staudenmaier, *Technology's Storytellers: Reweaving the Human Fabric* (1985), particularly 162-201.
[38] Recent work on the dreadnought revolution illustrates the dangers of such an approach. See especially Nicholas A. Lambert, *Sir John Fisher's Naval Revolution* (1999), and Sumida, *In Defence of Naval Supremacy*.

34

ticular, those technologies that coordinate naval operations, either between naval forces (of all warship types), or between forces at sea and forces ashore.[39] These technologies include visual and sound signalling techniques, the telegraph, continuous wave radio, communications intelligence, the radio-telephone, radar, data-link systems, and satellite communications.[40] During the first half of the twentieth century, shipboard command and control centers became the seaborne locations from which naval personnel integrated coordinating naval technologies.

In summary, then, core naval histories have dismissed shipboard command and control systems as unimportant artifacts, incidental to broader historical themes, while ancillary naval histories have ignored them because they fall outside the dominant paradigm established by historians interested in naval technology. There are, however, two fields of cognate naval history that one might expect to have explored the origins and development of naval command and control systems: social history and the history of technology. In neither case does such an examination exist, but again the reasons for this are revealing.[41]

---

[39] A notable exception is Arthur Hezlet, *Electronics and Sea Power* (1975). Unfortunately, Hezlet's work is poorly documented and fails to examine the integration of the technologies he discusses.

[40] Of these technologies, communications intelligence and radar have attracted the most scholarly interest. An informative historiographic essay on World War II communications intelligence is W. J. R. Gardner, "Intelligence Test: Evaluating Ultra in the Battle of the Atlantic," 280-297, in *New Interpretations in Naval History: Selected Papers from the Fourteenth Naval History Symposium* (2001), ed. Randy Carol Balano and Craig L. Symonds. The historiography of naval radar is discussed later in this chapter.

[41] One political scientist currently is exploring the development of naval CICs. Personal communication to the author from Paul Nagy, via e-mail, 14 December 2000. See also Paul Nagy, "Network-Centric Warfare

*   *   *

Scholarly study of the social aspects of navies dates back over half a century to the pioneering books of Michael Lewis, who explored the lives of British sailors and officers in the age of sail.[42] More recent work on the Royal Navy includes some outstanding scholarship, most notably Nicholas Rodger's remarkable treatise on the Georgian Navy.[43] On the western side of the Atlantic, probably the most renowned social naval historian is Harold Langley, a scholar whose work on the United States Navy does not quite match Rodger's level of detail but which remains valuable nonetheless.[44] In the past decade a number of informative books in U.S. social naval history have appeared,[45]

Isn't New," *United States Naval Institute Proceedings*, vol. 127, no. 10 (2001), 44-46.

[42] Michael Lewis, *England's Sea-Officers: The Story of the Naval Profession* (1939), Idem, *The Ships and Seamen of Britain* (1946), 39-56, Idem, *The Navy of Britain: A Historical Portrait* (1948), Idem, *A Social History of the Navy, 1793-1815* (1960), and Idem, *The Navy in Transition, 1814-1864: A Social History* (1965). Early works by others include Christopher Lloyd, *The British Seaman, 1200-1860: A Social Survey* (1968), Peter Kemp, *The British Sailor: A Social History of the Lower Deck, 1850-1880* (1970), and Eugene L. Rasor, *Reform in the Royal Navy: A Social History of the Lower Deck* (1976). Unfortunately, only Rasor's book contains thorough documentation. Also of note is the pioneering treatise *Three Rows of Tape.* A. Trystan Edwards, *Three Rows of Tape: A Social Study of the Lower Deck* (1929).

[43] N. A. M. Rodger, *The Wooden World: An Anatomy of the Georgian Navy* (1986). Among naval historians, Rodger's work is widely regarded as an exemplar in the field. Other recent social histories of the Royal Navy include John Wells, *The Royal Navy: An Illustrated Social History, 1870-1982* (1994), and Suzanne J. Stark, *Female Tars: Women Aboard Ship in the Age of Sail* (1996).

[44] Harold D. Langley, *Social Reform in the United States Navy, 1798-1862* (1967), and Idem, *A History of Medicine in the Early U.S. Navy* (1995).

[45] David Valuska, *The African American in the Union Navy: 1861-1865* (1993), Mary Pat Kelly, *Proudly We Served: The Men of the USS Mason* (1995), William Marvel, *The Alabama and the Kearsarge: The Sailor's Civil War* (1996), Dennis J. Ringle, *Life in Mr. Lincoln's Navy* (1998), Ronald H. Spector, *At War, At Sea: Sailors and Naval Warfare in the Twentieth Century* (2001), and Steven J. Ramold, *Slaves, Sailors, Citizens: African Americans in the Union Navy* (2002). Spector's book is only partly about the U.S. Navy, covering the navies of other nations as well. Also important is Peter Karsten's *Naval Aristocracy*, which

and authors in other fields have produced important works that borrow from the basic methodologies of social history.[46]

While recent scholarship therefore indicates a general interest in social naval history, work that explores the experiences of sailors and officers in twentieth century navies remains rare.[47] Several factors contribute to this peculiarity. First, much of the relevant primary source material has not yet made its way into official depositories.[48] Second, the recent trend in mainstream social history has been to focus on identity politics – in particular issues of gender, race, and ethnicity[49] – themes that are at times difficult to discern in the seemingly homogeneous world of military institutions.[50]

---

despite its age remains an influential work in the field. Peter Karsten, *The Naval Aristocracy: The Golden Age of Annapolis and the Emergence of Modern American Navalism* (1972).

[46] See especially Mindell, *War, Technology, and Experience*, and Jim Ring, *We Come Unseen: The Story of Britain's Cold War Submariners* (2001). Ring's book is actually a prosopography, but the extreme secrecy that surrounded Cold War submarine operations makes a wider social history nearly impossible. Also important are two recent ethnographies: Edwin Hutchins, *Cognition in the Wild* (1995), and Serge DuFoulon, *Les gars de la marine: Ethnologie d'un navire de guerre* (1998).

[47] Ronald Spector's recent book is a notable exception. Spector, *At War, At Sea*.

[48] For evidence of this, see Dean C. Allard, Martha L. Crawley, and Mary W. Edminson, eds., *U.S. Naval History Sources in the United States* (1979). Of course, more material is available now than was the case when this guide was published, but still not nearly as much as scholars (especially those who concentrate on the Cold War) would like to see.

[49] Recent monographs exemplifying this trend include W. Jeffrey Bolster, *Black Jacks: African American Seamen in the Age of Sail* (1997), Christopher B. Booker, *"I Will Wear No Chain!": A Social History of African American Males* (2000), Barbara Young Welke, *Recasting American Liberty: Gender, Race, Law, and the Railroad Revolution, 1865-1920* (2001), and Venus Green, *Race on the Line: Gender, Labor, and Technology in the Bell System, 1880-1980* (2001). Edited volumes include Sally M. Miller, ed., *Race, Ethnicity, and Gender in Early Twentieth Century American Socialism* (1996), Margaret S. Creighton and Lisa Norling, eds., *Iron Men, Wooden Women: Gender and Seafaring in the Atlantic World, 1700-1920* (1996), and Roger Horowitz and Arwen Mohun, eds., *His and Hers: Gender, Consumption, and Technology* (1998). For an explicit discussion of gender as a category of historical analysis, see Joan Wallach Scott, *Gender and the Politics of History* (1988).

[50] A discussion of general opinions within the American historical profession toward the study of military institutions is found in Alex Roland, "Science, Technology, and War," *Technology and Culture*, vol.

Finally, twentieth century navies were extremely technical. While exploration into the relationship between technological innovation and social adaptation began a generation ago,[51] many historians still steer clear of subjects that require a thorough understanding of sophisticated technologies. This avoidance is unfortunate, for as Elting Morison and others have demonstrated, an understanding of the modern human condition requires an exploration of man's relationship with the machine.[52]

For these reasons, social historians rarely have focused upon human experience in the complex environment of an industrial warship. Studies of this kind more likely would be conducted by historians of technology, a field whose practitioners increasingly have endeavored to formulate analytic syntheses between technical factors and social context.[53] Yet historians of technology also have neglected to investigate the black box of naval command and control.

No doubt this neglect stems partly from the relatively small number of scholars who study the history of technology,

---

S36, no. 2 (1994), 83-99. For an historiographic review of the relationship between society and the military, see Barton C. Hacker, "Military Institutions, Weapons, and Social Change: Toward a New History of Military Technology," *Technology and Culture*, vol. 35, no. 4 (1993), 768-834.

[51] See Merritt Roe Smith, *Harpers Ferry Armory and the New Technology: The Challenge of Change* (1977). Of Smith's work, John Staudenmaier writes that its publication "was taken as indicative of a breakthrough of the scholarly acceptance of technology in social history." Staudenmaier, *Technology's Storytellers*, 187.

[52] Morison writes that technology creates "its own environment and own set of conditions. Put even more simply, as the mechanism steadily increases in power and scale, the tendency is to fit men into the machinery rather than to fit the machinery into the contours of a human situation." Elting E. Morison, *Men, Machines, and Modern Times* (1966), 211. See also Lewis Mumford, *Technics and Civilization* (1934), and Siegfried Giedion, *Mechanization Takes Command: A Contribution to Anonymous History* (1948).

[53] According to an analysis of articles published in *Technology and Culture*, the journal of the Society for the History of Technology, the presence of such "contextualist" approaches increased by nearly fifty percent from the late 1950s to the early 1980s. Staudenmaier, *Technology's Storytellers*, 208.

and the even smaller number of historians of technology inter-ested in things military.[54] Nevertheless, individuals in four sub-fields within the history of technology concentrate on sub-jects related directly to naval command and control systems: (1) historians of military and naval technologies,[55] (2) histo-rians of communications technologies, (3) historians of comput-ing, and (4) historians of electronics and electrical technolo-gies.[56]

While a full review of the canonical literature in each of these sub-fields is beyond the scope of this dissertation, a few observations are germane. For reasons previously ad-dressed, historians interested in naval technology have con-centrated primarily on innovations in warship design. An archetypal example of this is William McBride's recent book, *Technological Change and the United States Navy, 1865-1945.*[57] The book's title suggests a work that traces the development of technology in the U.S. Navy, yet McBride chooses not to discuss fire control, radio, or radar. Without an examination

---

[54] Here I borrow the expression "things military" from Alex Roland, "Sci-ence, Technology, and War," 84.

[55] One would not expect scholars interested in land-based military op-erations to have studied *naval* command and control systems. As a gen-eral rule, however, military historians have demonstrated a greater interest in command and control than have their counterparts in naval history. For example, see Kenneth Allard, "History, Technology and the Structure of Command," *Military Review*, vol. 61 (1981), 3-9, Martin van Creveld, *Command in War* (1985), Martin Samuels, *Command or Control? Command, Training and Tactics in the British and German Armies, 1888-1918* (1998), and M. A. Ramsay, *Command and Cohesion: The Citizen-Sol-dier and Minor Tactics in the British Army, 1870-1918* (2002). Nuclear command and control also has its own body of literature; see especially Paul J. Bracken, *The Command and Control of Nuclear Forces* (1983), and Bruce G. Blair, *Strategic Command and Control: Redefining the Nuclear Threat* (1985).

[56] The Society for the History of Technology has special interest groups for each of these sub-fields. See http://shot.press.jhu.edu/special.htm, viewed May 1, 2003. Although the distinctions between sub-fields provide a useful heuristic, in practice such boundaries are rather fluid.

[57] McBride, *Technological Change and the United States Navy*. See also the discussion of sea warfare from 1830 to 1945 in Martin van Creveld, *Technology and War: From 2000 B.C. to the Present* (1989), 199-216.

of these technologies, exploration of naval command and control systems simply is not possible.

Communications historians study a vast array of technologies, and scholars in this genre have produced some valuable work over the past several decades. This work includes syntheses that place communications systems within a global context,[58] as well as monographs that examine the histories of telecommunications companies or specific communications technologies, such as the telegraph, the telephone, the radio, and the internet.[59] Radio is the most important communications technology with respect to naval command and control, but relatively few studies explore the Navy's development of radio communications.[60] This tendency is understandable given the tremendous success and rapid growth of the commercial radio indus-

---

[58] Daniel Headrick, *The Invisible Weapon: Telecommunications and International Politics, 1851-1945* (1991), Peter J. Hugill, *Global Communications since 1844: Geopolitics and Technology* (1999), and Debora L. Spar, *Ruling the Waves: Cycles of Discovery, Chaos, and Wealth from the Compass to the Internet* (2001). See also Eugene B. Skolnikoff, *The Elusive Transformation: Science, Technology, and the Evolution of International Politics* (1993), 93-174.

[59] George David Smith, *The Anatomy of a Business Strategy: Bell, Western Electric, and the Origins of the American Telephone Industry* (1986), Kenneth Lipartito, *The Bell System and Regional Business: The Bell System in the South, 1877-1920* (1989), Stephen B. Adams and Orville R. Butler, *Manufacturing the Future: A History of Western Electric* (1999), Paul Israel, *From Machine Shop to Industrial Laboratory: Telegraphy and the Changing Context of American Invention, 1830-1920* (1992), John Brooks, *Telephone: The First Hundred Years* (1976), Claude S. Fischer, *America Calling: A Social History of the Telephone to 1940* (1992), Hugh G. J. Aitken, *Syntony and Spark: The Origins of Radio* (1976), and Idem, *The Continuous Wave: Technology and American Radio, 1900-1932* (1985), Susan J. Douglas, *Inventing American Broadcasting, 1899-1922* (1987), and Idem, *Listening In: Radio and the American Imagination, from Amos 'n' Andy and Edward R. Murrow to Wolfman Jack and Howard Stern* (1999), Sungook Hong, *Wireless: From Marconi's Black-Box to the Audion* (2001), Janet Abbate, *Inventing the Internet* (1999), and James Gillies and Robert Cailliau, *How the Web Was Born: The Story of the World Wide Web* (2000).

[60] The most thorough work to date is by Susan J. Douglas. See Douglas, *Inventing American Broadcasting*, 102-143, 260-291, 319, and Idem, "Technological Innovation and Organizational Change: The Navy's Adoption of Radio, 1899-1919," 117-173, in *Military Enterprise and Technological Change: Perspectives on the American Experience* (1985), ed. Merritt Roe Smith.

try; nevertheless, the role of radio in the U.S. Navy deserves more attention than it has received. Unfortunately, the most important book on the subject is forty years old and its author, a former naval communications officer, sought mainly to provide his readers with technical detail.[61] While this study furnishes a valuable reference source, an analysis of naval command and control systems requires that radio's development be placed into broader historical context.

Turning next to the historiography of computing, early naval command and control systems occasionally are portrayed as precursors to digital electronics systems,[62] but more often than not they are disregarded.[63] Such disregard is not unique to the U.S. Navy – as one author sardonically described the history of computing prior to 1945: "Nobody had computers to play with. Nothing happened."[64] Fortunately, recent scholarship has focused greater attention on the so-called pre-history of computing, with substantial work having been accomplished on mechanical calculating machines, automata, punched-card machinery, and early data-processing equipment.[65] While studies like these are certainly important, they tend to emphasize devices,

[61] Linwood S. Howeth, *History of Communications-Electronics in the United States Navy* (1963). See also Louis A. Gebhard, *Evolution of Naval Radio-Electronics and Contributions of the Naval Research Laboratory* (1979), 1-26, 43-167.

[62] David L. Boslaugh, *When Computers Went to Sea: The Digitization of the United States Navy* (1999).

[63] For example, see Herman H. Goldstine, *The Computer from Pascal to von Neumann* (1972), and Nathan Weinberg, *Computers in the Information Society* (1990), 19-38.

[64] Gregory Rawlins, *Slaves of the Machine: The Quickening of Computer Technology* (1997), 58.

[65] William Aspray, ed., *Computing Before Computers* (1990), James W. Cortada, *Before the Computer: IBM, NCR, Burroughs, and Remington Rand and the Industry they Created, 1865-1956* (1993), Martin Campbell-Kelly and William Aspray, *Computer: A History of the Information Machine* (1996), 9-76, and Michael R. Williams, *A History of Computing Technology*, 2nd edition (1997), 1-208. An important book that specifically examines the pre-history of the electronic digital computer is Paul E. Ceruzzi, *Reck-*

programming, and business applications, or more broadly put, the *products* of the "Computer Revolution."[66] Historians have shown considerably less interest in the *processes* of computing, particularly in cases where the distinctions between human and machine become blurred.[67] For this reason, the artifacts in which humans perform computations usually are viewed as distinct from, and perhaps even unrelated to, the artifacts that perform computations for humans.

Historians of electronics and electrical technologies constitute the final group that focus on subjects related to naval command and control systems. Like those who study communications history, scholars in this sub-field explore a wide variety of topics, ranging from specific technologies, such as electric lights and automobiles, to broader trends, such as the electrification of society.[68] In general, however, authors who have written about the role of electronics in military history devote little or no attention to warfare at sea.[69]

This tendency is unfortunate, as four different electrical technologies – radio, radar, sonar, and interior communica-

---

oners: *The Prehistory of the Digital Computer, from Relays to the Stored Program Concept, 1935-1945* (1983).

[66] As noted computer historian/bibliographer James Cortada writes, "the majority of the technical histories of the computer business center around descriptions of machines and how they came into being." James W. Cortada, *The Computer in the United States: From Laboratory to Market, 1930 to 1960* (1993), 4.

[67] A notable exception is David A. Mindell, *Between Human and Machine: Feedback, Control, and Computing Before Cybernetics* (2002).

[68] Robert Friedel and Paul Israel, *Edison's Electric Light: Biography of an Invention* (1987), Michael Schiffer, *Taking Charge: The Electric Automobile in America* (1994), David A. Kirsch, *The Electric Vehicle and the Burden of History* (2000), Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (1983), and David E. Nye, *Electrifying America: Social Meanings of a New Technology* (1990).

[69] See Alfred Price, *The History of U.S. Electronic Warfare: The Years of Innovation – Beginnings to 1946* (1984), Martin van Creveld, *Technology and War: From 2000 B.C. to the Present* (1985), 265-283, and Tony Devereux, *Messenger Gods of Battle: Radio, Radar, Sonar – The Story of Electronics in War* (1991). Hezlet is again the exception that proves the rule (see note 39).

tions – were integral to the development of early-to-mid twentieth century command and control systems. As previously addressed, few writings explore the U.S. Navy's development of radio communications, and the best of this work does not extend past the end of World War I. A majority of the literature on the history of sonar is technically oriented and fails to place that technology within its broader cultural and institutional context,[70] and no work at all exists on the history of naval interior communications systems.[71]

The history of radar, on the other hand, has attracted considerable scholarly interest. For naval radar specifically, scholars have recounted its origins and development in all major naval powers of the Second World War.[72] Most of these

---

[70] Marvin Lasky, "Review of World War I Acoustic Technology," *Journal of Underwater Acoustics*, vol. 24, no. 3 (1973), 363-385, Idem, "A Historical Review of Underwater Acoustic Technology, 1916-1939, With Emphasis on Undersea Warfare," *Journal of Underwater Acoustics*, vol. 24, no. 4 (1974), 597-624, Idem, "Review of Scientific Effort for Undersea Warfare, 1939-1945," *Journal of Underwater Acoustics*, vol. 25, no. 3 (1975), 567-584, Idem, "Historical Review of Underwater Acoustic Technology, 1939-1945, With Emphasis on Undersea Warfare," Journal of Underwater Acoustics, vol. 25, no. 4 (1975), 885-918, and Howeth, *History of Communications-Electronics*, 297-312, 471-478. The scholarly literature covers British sonar developments more thoroughly. See Willem Dirk Hackmann, *Seek & Strike: Sonar, Anti-Submarine Warfare, and the Royal Navy, 1914-1954* (1984). Hackmann discusses developments in the United States when relevant to the British experience.

[71] Sadly, a majority of the archival records pertaining to U.S. Navy interior communications, those of the Interior Communications Board, are missing from the National Archives.

[72] For details on radar development in the United States Navy, the best available sources are David Kite Allison, *New Eye for the Navy: The Origin of Radar at the Naval Research Laboratory* (1981), and Gebhard, *Evolution of Naval Radio-Electronics*, 169-221. For the British Navy, see F. A. Kingsley, ed., *The Development of Radar Equipments for the Royal Navy, 1935-1945* (1995), Derek Howse, *Radar at Sea: The Royal Navy in World War 2* (1993), Alastair Mitchell, "The Development of Radar in the Royal Navy, 1935-1945: Part I," *Warship*, no. 13 (1980), 2-14, and Idem, "The Development of Radar in the Royal Navy, 1935-1945: Part II," *Warship*, no. 14 (1980), 117-134. For English-language accounts of radar development in Germany and Japan, see David Pritchard, *The Radar War: Germany's Pioneering Achievement, 1904-1945* (1989), Harry von Kroge, *GEMA: Birthplace of German Radar and Sonar* (2000), Yasuzo Nakagawa, *Japanese Radar and Related Weapons of World War II* (1997), and Morris F. Low, "The Useful War: Radar and the Mobilization of Science and Industry in Japan," 291-301 in *Science and the Pacific War: Science and Sur-*

studies, however, concentrate on scientific and technical developments rather than operational practices.[73] Unquestionably, engineers and scientists played a critical role in making radar a successful weapon of war.[74] Yet theirs is only half the story. Equally important was the employment of radar technology. For the U.S. Navy, such efforts included the operation of both fire control and search radars, neither of which could have been employed as successfully as they were without adequate command and control systems.[75]

For a variety of reasons, then, little effort has been made to explore the black box of shipboard command and control. As artifacts, naval command and control systems traverse the boundaries of several different historical fields and sub-fields, yet they remain unstudied. By examining the United States Navy's creation and development of shipboard command and control systems prior to and during the Second World War, this dissertation helps to remedy such neglect. It adopts a cognate approach to naval history, bringing together the methodologies of social history and the history of technology in order to ex-

vival in the Pacific, 1939-1945, ed. Roy M. MacLeod (2000). See also applicable sections in Louis Brown, *A Radar History of World War II: Technical and Military Imperatives* (1999), Russell Burns, ed., *Radar Development to 1945* (1988), Oskar Blumtritt, Hartmut Petzold, and William Aspray, eds., *Tracking the History of Radar* (1994), and Sean S. Swords, *Technical History of the Beginnings of Radar* (1986), especially 42-173. For a journalistic account of radar development in Britain and the United States, see Robert Buderi, *The Invention that Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution* (1996).

[73] Exceptions include David Zimmerman, *Britain's Shield: Radar and the Defeat of the Luftwaffe* (2001), and Henry E. Guerlac, *Radar in World War II* (1987 [1947]). Guerlac's voluminous account covers both operational practices and scientific/technical developments.

[74] This story is told succinctly in Daniel J. Kevles, *The Physicists: The History of a Scientific Community in Modern America* (1978), 289-291, 302-323.

[75] For the history of fire control in the United States Navy prior to and during World War II, see Mindell, *Between Human and Machine*, 19-68, 216-223, 260-275.

plain better the operations of American naval forces during the first four and a half decades of the twentieth century.

Dissertation Overview

The study is divided into six chapters and follows a narrative format, although several of the chapters are themselves organized thematically. The chapter immediately following the introduction explores the United States Navy's adoption of radio and challenges the notion that a conservative officer corps failed to appreciate the potential advantages of this new communications technology. The next chapter looks at the early development of shipboard command and control systems, paying particular attention to the facilities from which officers exercised command. Chapter Four examines the fleet's employment of new command and control technologies during the late interwar period, focusing on the efforts of operational commanders to maximize their capabilities through development of devices, methods, and procedures for the collection, processing, and dissemination of information. How the Navy integrated radar into warfare at sea is the subject of the fifth chapter. Specifically, it looks at how the service created command and control facilities to integrate, evaluate, and disseminate the tactical information obtained through radar. The final chapter explores the development of these facilities during the Second World War, concluding with a broader look at the relationship between information, technology, and human decision-making.
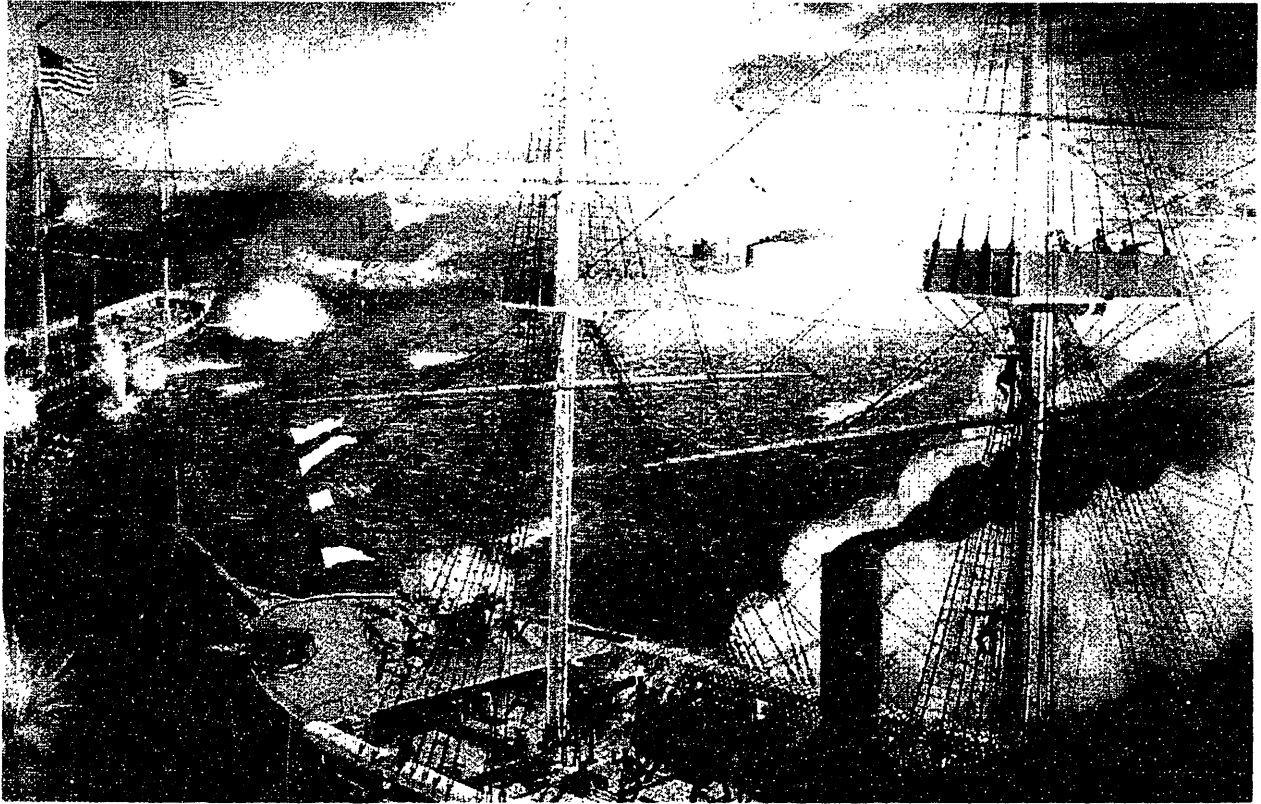
FIGURE 1-1

Civil War hero David Glasgow Farragut, located high
in the rigging of *USS Hartford*, directs his forces
during the Battle of Mobile Bay.
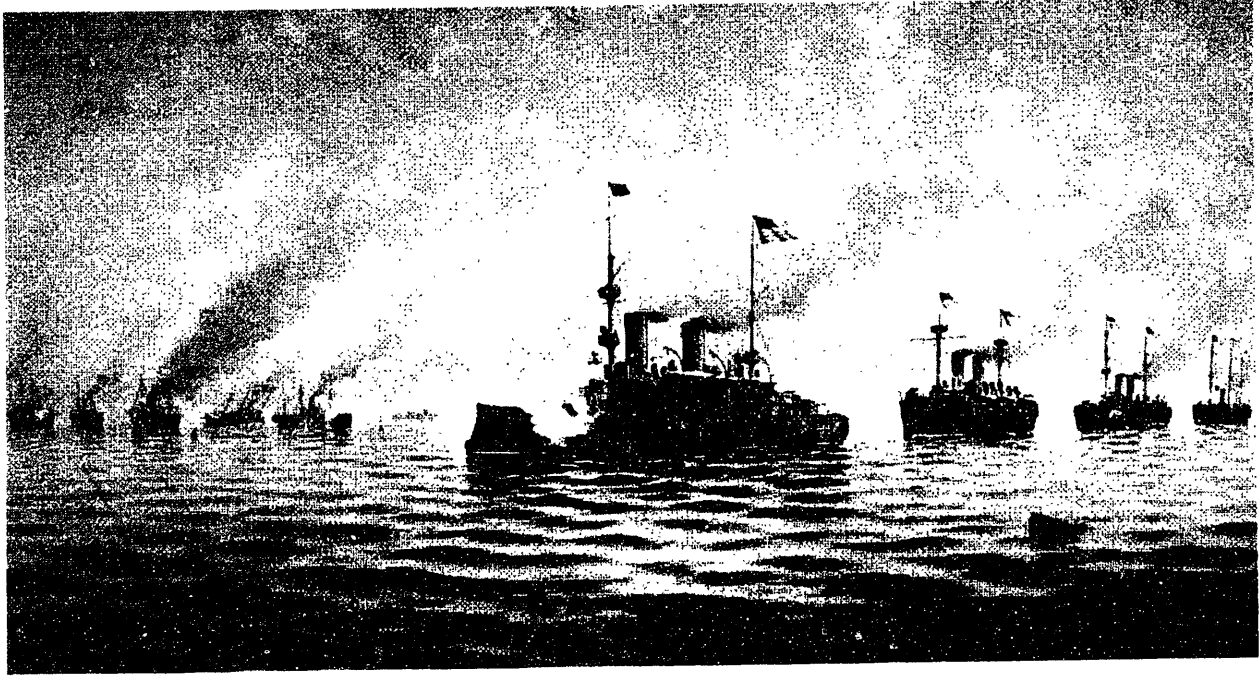
FIGURE 1-2

At the Battle of Manila Bay, Commodore George Dewey led his forces from *USS Olympia* with command and control systems strikingly similar to those that had been employed by Farragut more than a generation earlier.

Citations for Figures

Figure 1-1: Depiction of the Battle of Mobile Bay, by Dean
             Mosher. Courtesy of the Mobile Museum of Art.

Figure 1-2: Depiction of the Battle of Manila Bay, by Alfonso
             Sanz. Courtesy of the Naval Historical Center.

CHAPTER TWO
SPARKS AND ARCS:
THE NAVY ADOPTS RADIO

Prior to the final decades of the nineteenth century, shipboard command and control systems consisted almost exclusively of face-to-face communications and visual signalling techniques, the latter of which were effective only during daylight hours. This situation started to change with the electrification of warships, as navies adopted electrical systems for interior communications and nighttime visual signalling. Yet only after navies developed practical systems of wireless communication at the beginning of the twentieth century did the human experience of warfare at sea begin to shift toward epistemic actions and socially distributed cognition.[1] Radio was the first technology to provide seaborne commanders with access to tactically-relevant, real-time information from beyond the horizon. Because the availability of such information increased the complexity of naval operations, officers and enlisted personnel began to develop devices, methods, and procedures to assist in managing that complexity.

Previous work on the United States Navy's adoption of radio has focused primarily on hardware, devoting little attention to radio's place as a component in the fleet's system of wartime tactical signalling. This propensity has led some historians to conflate officers' opinions about strategic and tactical radio, which in turn has contributed to perceptions

---

[1] A detailed discussion of epistemic action and socially distributed cognition may be found in Part I of Chapter One. For a brief discussion of the meaning of the term "warfare at sea," see note 8 in Chapter One.

that the turn-of-the century American Navy was a hidebound bureaucracy full of conservative officers resistant to technological change. More often than not, however, in their efforts to improve the fleet's overall system of ship-to-ship communications American naval personnel aggressively pursued the adoption of radio technology.

Initial Tests: Jackson, Marconi, and the U.S. Navy

In January 1895, Commander Henry B. Jackson, a torpedo and electrical specialist, assumed command of *HMS Defiance*, the Royal Navy's sea-going torpedo school. Jackson, a dedicated and intelligent naval officer who two decades later would become Britain's First Sea Lord, long had held an interest in what were known at the time as Hertzian waves.[2] As early as 1892, only a few years after Heinrich Hertz had validated the electro-magnetic equations of James Clerk Maxwell,[3] Jackson investigated the possibilities of a system that would employ "radio"[4] waves to distinguish friendly from enemy

---

[2] Alan Rawles, "Jackson of the *Defiance*," *Journal of the Institution of Electrical Engineers*, vol. 1, no. 12, (1955), 743-745, and Barrie Kent, *Signal! A History of Signalling in the Royal Navy* (1993), 25-27. For more on Jackson's career, see Malcolm H. Murfett, "Admiral Sir Henry Bradwardine Jackson (1915-1916)," 91-100, in *The First Sea Lords: From Fisher to Mountbatten* (1995), ed. Malcolm H. Murfett.
[3] See Heinrich Hertz, *Electric Waves: Being Researches on the Propagation of Electric Action with Finite Velocity Through Space* (1962 [1893]), trans. D. E. Jones. An overview of the papers in this volume and a brief analysis of their significance is found in Charles Süsskind, "The Early History of Electronics: The Experiments of Hertz," *IEEE Spectrum*, vol. 5, no. 12, (1968), 57-60. For a more detailed discussion of Hertz and his experiments on electric waves, see Jed Z. Buchwald, *The Creation of Scientific Effects: Heinrich Hertz and Electric Waves* (1994).
[4] The word "radio" is an anachronism in this context, since it did not appear in the English language until after the turn of the century. According to one expert, the word came into common usage in the United States sometime between 1906 and 1912. Susan J. Douglas, *Inventing American Broadcasting, 1899-1922* (1987), xxviii-xxix. Prior to that

vessels during a night attack.[5] In the short run nothing came
of these efforts, but once the Royal Navy's torpedo school was
under his command, Jackson possessed both the inclination and
the authority to undertake further experiments. In the summer
of 1896, he carried out tests in which *Defiance* successfully
maintained radio communications with another British ship,[6]
and in September of that year Jackson, now sporting the four
stripes of a captain, met with Anglo-Irish-Italian inventor
and entrepreneur Guglielmo Marconi.[7]

The meeting between the two men was the first encounter
in what was to become a long but often contentious relation-
ship between Marconi (and the company he later would found)
and the Royal Navy. In 1899, at the Admiralty's request
Marconi fitted three Royal Navy warships with radio equipment

---

time, radio generally was referred to as "wireless," a truncated ver-
sion of the retronym "wireless telegraphy." Here I use the terms radio
and wireless interchangeably.

[5] Arthur Hezlet, *Electronics and Sea Power* (1975), 27.

[6] In what is widely regarded as one of the authoritative works on the
early history of radio, Hugh G. J. Aitken states that the Royal Navy in
1896 under Jackson's supervision succeeded in maintaining radio commu-
nications between *Defiance* and the gunboat *HMS Scourge* at a distance of
over 3 1/2 miles. Hugh G. J. Aitken, *Syntony and Spark: The Origins
of Radio* (1976), 286. Recent work by Sungook Hong, however, reveals
Jackson did not succeed in transmitting signals more than a third of a
mile until April 1897. Hong cites a May 1897 report, written by Jack-
son himself, which reads in part: "Comparing my experiments with those
of Mr. Marconi, I would observe that before I heard of his results, I
had succeeded with the instruments at my disposal in transmitting Morse
signals with my apparatus about 100 yards, which I gradually increased
to one-third of a mile, but could not improve upon till I obtained a
more powerful induction coil last month, with which I have obtained my
present results." "Report of Captain Jackson," 22 May 1897, Public Re-
cord Office, Kew, Richmond, Surrey (PRO), "Board of Admiralty, Record
Office, circa 1809-1964," (ADM 116), File No. 523. Quoted in Sungook
Hong, *Wireless: From Marconi's Black Box to the Audion* (2001), 17.
Sadly, this report is no longer accessible, as someone apparently pur-
loined it (along with all of ADM 116/523) from the Public Record Office
in early 2002.

[7] Marconi's mother was born Annie Jameson, whose Scottish father, Andrew
Jameson, co-founded the Irish distillery that produces a whiskey still
bearing the family name. Orrin L. Dunlap, *Marconi: The Man and his
Wireless* (1938), 6, and Degna Marconi, *My Father, Marconi* (1962), 7.

for the fleet's annual maneuvers.[8] During the maneuvers, wireless telegraphy was used to transmit tactical information between the radio-equipped ships, in one instance at a distance of nearly seventy-five nautical miles.[9] Impressed with the performance of Marconi's equipment, the Admiralty inquired about purchasing a number of sets, but the two sides could not agree on terms of sale. Due to apparent restrictions in British patent law, the Admiralty could not oblige Marconi's insistence upon the payment of royalties, and Marconi was unwilling to sacrifice this form of remuneration.[10] Seeking a resolution to the royalty issue, in February 1900 the Admiralty concluded that "the extreme importance of this invention [wireless telegraphy] for H.M. Navy in war" warranted considering it "altogether apart from that of the general adoption by H.M. Government for peace purposes."[11] This justification appears to have raised no objections, and in May the Admiralty agreed to purchase thirty-two sets from Marconi's Wireless Telegraph Company for £100 per set and to

---

[8] The torpedo school originally was to have provided these sets; however, after Jackson rotated to a new billet in 1897 (he became the British naval attaché in Paris) the torpedo school encountered a number of manufacturing problems with their radio equipment. Hezlet, *Electronics and Sea Power*, 31. A layman's description of the 1899 maneuvers is found in W. P. Jolly, *Marconi* (1972), 62-67.

[9] Linwood S. Howeth, *History of Communications-Electronics in the United States Navy* (1963), 22. Hezlet places the maximum distance at which the ships communicated at sixty nautical miles. Hezlet, *Electronics and Sea Power*, 33.

[10] Secretary of the Admiralty [Sir Evan Macgregor] to The Wireless and Telegraph Signal Company, 7 December 1899, Managing Director, The Wireless and Telegraph Signal Company [Major Flood Page], 11 December 1899, and minutes from a meeting between Major Flood Page and the Controller of the Navy and Director of Navy Contracts on 14 December 1899 (dated 15 Decmber 1899), all in PRO, ADM 116/567.

[11] Secretary of the Admiralty to Postmaster-General, 26 February 1900, PRO, ADM 116/567.

pay annual royalties of the same amount (i.e., £3,200 per an-
num) for fourteen consecutive years.[12]

Unlike the Royal Navy, the United States Navy prior to
1899 had not conducted sustained tests with radio communica-
tions.[13] As such, reports filed by the American naval atta-
ché in London detailing the performance of the Marconi equip-
ment generated considerable interest within the service. At
the direction of the Secretary of the Navy, the Bureau of
Equipment arranged for four officers to observe firsthand
Marconi's radio reporting of the America's Cup for the *New
York Herald*.[14] Marconi permitted the officers to observe the
wireless sets in operation, but refused to provide detailed
technical information about the equipment for fear of reveal-
ing proprietary secrets.[15] Despite this limitation, the ob-
servers reported to the Secretary of the Navy that the new
technology would be of potential benefit to the fleet.[16] In

---

[12] Secretary of the Admiralty to Marconi's Wireless Telegraph Company,
8 May 1900, and Secretary, Marconi's Wireless Telegraph Company [Henry
Allen] to Secretary of the Admiralty, 12 May 1900, both in PRO, ADM
116/527. Hugh Aitken mistakenly lists the price of *each* set at £3,200.
Aitken, *Syntony and Spark*, 232. The two parties signed the final con-
tract in February 1901. "Contract for Supply of Apparatus and Payment
of Royalty" between Marconi's Wireless Telegraph Company, Limited, and
The Admiralty, 20 February 1901, PRO, ADM 116/527.
[13] In the late 1880s, one U.S. Navy ship, the cruiser *USS Atlanta*, ex-
perimented with induction telegraphy. Nothing tangible came out of
these efforts. Bradley A. Fiske, *From Midshipman to Rear-Admiral*
(1919), 96-101.
[14] In *Inventing American Broadcasting*, Douglas provides a detailed de-
scription of Marconi's reporting of the 1899 America's Cup. Douglas,
Inventing American Broadcasting, 19-28.
[15] Howeth, *History of Communications-Electronics*, 25-28.
[16] Lieutenant Commander John T. Newton, "Reports on System of Wireless
Telegraphy during International Yacht Races between COLUMBIA and SHAM-
ROCK, from October 3rd to October 20th, 1899," 9 November 1899, Na-
tional Archives, Washington, DC (NADC), Record Group 19 - Bureau of
Ships, (RG 19), Bureau of Equipment General Correspondence, 1899-1910
(BuEq), Box No. 83. Newton's report was a compilation of the individ-
ual reports of the observers, of which it appears that only three out
of four have survived. Also extant is a report based on observations
during the period September 25th to October 4th. Lieutenant John B.
Blish, "Report on Trial of Marconi Wireless Telegraph during the Yacht
Races," 13 November 1899, NADC, RG 19, BuEq, Box No. 83.

commenting to a *Herald* reporter, one officer exuberantly stated: "If we could only have had this last year, what a great thing it would have been. When we landed marines in Guantanamo [Cuba] , the ships were unable to lend assistance, for the reason that the enemy could not be located, and firing at random would have placed our forces in danger. With the aid of the Marconi system, the men ashore would have directed the fire."[17]

Encouraged by initial reports from these observers, the Navy Department asked Marconi if tests could be carried out on one or more warships after his commitments to the *Herald* were finished. Marconi agreed, but only after cautioning that his most modern equipment remained in Britain.[18] The Navy acknowledged Marconi's concerns, and quickly installed antennas on the battleship *USS Massachusetts* and the armored cruiser *USS New York*. Upon completion of the America's Cup, Marconi transferred his apparatus to these two vessels (Figure 2-1). A lighthouse in New Jersey also received a set of the Marconi equipment, so that both ship-to-ship and ship-to-shore communications could be tested. Trials commenced on October 26th and continued for more than a week, during which time the United States Navy transmitted its first official radio message. Although more tests were planned, in early November the British government requested that Marconi return

---

[17] Lieutenant Commander Edward F. Qualtrough made these comments. Quoted in Howeth, *History of Communications-Electronics*, 27.
[18] Susan J. Douglas, "Technological Innovation and Organizational Change: The Navy's Adoption of Radio, 1899-1919," 126-127, in *Military Enterprise and Technological Change: Perspectives on the American Experience* (1985), ed. Merritt Roe Smith. Howeth comments that the time between the dates of the agreement to conduct tests and the start of the tests "was more than enough to have permitted shipping of the equipment from England." Howeth, *History of Communications-Electronics*, 33. Possibly Marconi was hesitant to ship equipment after a bad experience in which some of his apparatus had been lost upon his arrival in the United States. Jolly, *Marconi*, 74-75.

home to provide the War Office with technical assistance in support of the Boer War. Further trials were cancelled, and Marconi departed for England soon thereafter.[19]

From the Navy's perspective, the 1899 tests failed to provide definitive results (Figure 2-2). They did, however, showcase the potential of radio communications. The *Massachusetts* received signals from *New York* at ranges in excess of forty-five nautical miles, and operators successfully transmitted and received messages at speeds of up to twelve words per minute.[20] In a remarkably prescient statement, several officers noted that if the Navy were to install Marconi equipment on its ships, "the best location of the instruments would be below, well protected, in easy communication with the Commanding Officer."[21]

Still, obvious problems existed, the most critical of which was the problem of interference. Unlike a modern radio, where multiple channels are available and tuning is automatic, all of Marconi's equipment radiated at approximately the same wavelength. In practice, this meant that when two or more ships transmitted simultaneously, none of the messages sent could be read. The naval officers assigned to comment on the trials, known collectively as the Marconi Board, described the problem of interference as follows:

---

[19] Howeth, *History of Communications-Electronics*, 28-33, Douglas, "The Navy's Adoption of Radio," 127-128, and Idem, *Inventing American Broadcasting*, 110-111.

[20] Marconi's equipment, not the operators, limited the maximum transmission rate to twelve words per minute. Lieutenant John B. Blish, "Notes on the Marconi Wireless Telegraph," *United States Naval Institute Proceedings*, vol. 25, no. 4, (1899), 857-864.

[21] Lieutenant Commander John T. Newton, Lieutenant John B. Blish, and Lieutenant Frank K. Hill to Chief, Bureau of Equipment, "Report of Board on Marconi System of Wireless Telegraphy," 13 November 1899, NADC, RG 19, BuEq, Box No. 83.

When two transmitters are sending at the same
time all the receiving wires within range re-
ceive the impulses from transmitters, and the
tapes, although unreadable, show unmistakably
that such double sending is taking place. In
every case, under a great number of varied
conditions, the attempted interference was
complete. Mr. Marconi, although he stated to
the Board, before these attempts were made,
that he could prevent interference, never
explained how nor made any attempt to demon-
strate that it could be done.[22]

Shortly after the suspension of testing, the Marconi
Board submitted a formal report to the Navy's Bureau of
Equipment, recommending that the service give the new tech-
nology a full trial.[23] On December 1st, 1899, the Bureau
Chief wrote the Secretary of the Navy concurring with this
recommendation, and expressed his opinion that wireless
promised "to be very useful in the future of the naval serv-
ice."[24] Despite this favorable endorsement, the Navy chose
not to acquire any Marconi equipment, a decision which in
hindsight appears to support the commonly-held view that the
Navy of this period was a conservative organization resistant
to technological change.[25]

---

[22] Ibid. Hong's work shows that at the time these tests, Marconi's ap-
paratus could not have prevented interference. Marconi may have been
misquoted, although a more likely explanation is that he simply made
exaggerated claims. As early as 1898 Marconi and his assistants had
been working on the interference problem, but even five years and sev-
eral patents later they had not yet solved the problem, as revealed by
the infamous Maskelyne Affair. Hong, *Wireless*, 89-118. For more on
the Maskelyne Affair, see also Sungook Hong, "Syntony and Credibility:
John Ambrose Fleming, Guglielmo Marconi, and the Maskelyne Affair,"
157-176, in *Scientific Credibility and Technical Standards in 19th and
Early 20th Century Germany and Britain* (1996), ed. Jed Z. Buchwald.
[23] Newton, Blish, and Hill, "Report of Board on Marconi System of Wire-
less Telegraphy."
[24] Chief, Bureau of Equipment to Secretary of the Navy, 1 December 1899,
NADC, RG 19, BuEq, Box No. 83.
[25] Harold and Margaret Sprout, *The Rise of American Naval Power, 1776-
1918* (1990 [1939]), 282-287, Elting E. Morison, *Admiral Sims and the*

In actuality, multiple factors contributed to the United States Navy's decision not to acquire Marconi's apparatus. Like the Royal Navy before them, the U.S. Navy objected to Marconi's insistence upon the payment of annual royalties. Consistent with typical military acquisition practices of the late nineteenth and early twentieth centuries, the Navy preferred to purchase outright all radio equipment for its ships and shore stations.[26] Furthermore, even if the Bureau of Equipment had agreed in principle to Marconi's terms, they were constrained by law from obligating funds beyond the current fiscal year.[27]

For his part, Marconi believed that annual royalties were justified by the high development costs he already had incurred.[28] The inventor-entrepreneur and his associates apparently failed to comprehend fully the financial and political constraints faced by the organization to which they

---

Modern American Navy (1942), 61-259, and Idem, "Gunfire at Sea," in *Men, Machines, and Modern Times* (1966), 17-44, Daniel R. Headrick, "The Sources of Technological Innovation in the Armed Forces: The Case of the U.S. Navy, 1865-1915," 282-289, in *Critical Problems and Research Frontiers in History of Science and History of Technology* (1991), and Robert L. O'Connell, *Sacred Vessels: The Cult of the Battleship and the Rise of the U.S. Navy* (1991), 9-152.

[26] Marconi's proposal, which essentially amounted to a leasing arrangement, was rather unusual for its time. Prior to the twentieth century, civilian inventors generally assumed the financial risks associated with military innovations. Witness, for example the tribulations faced by Robert Fulton, and later Samuel Colt, in efforts to develop weapons for underwater warfare, or the financial burdens assumed by the partners of the *Monitor* project. Alex Roland, *Underwater Warfare in the Age of Sail* (1978), 89-119, 134-149, and James Phinney Baxter, *The Introduction of the Ironclad Warship* (1968 [1933]), 253-268. See also William McNeill's discussion of the subject in William H. McNeill, *The Pursuit of Power: Technology, Armed Force, and Society since A.D. 1000* (1982), 185-306.

[27] Secretary of the Navy to Marconi Wireless Telegraph Company, 25 September 1903, NADC, RG 19, BuEq, Box No. 85.

[28] For more on the early financial situation of the company founded by Marconi, The Wireless Telegraph and Signal Company, Ltd., and its successor, Marconi's Wireless Telegraph Company, Ltd., see W. J. Baker, *A History of the Marconi Company* (1970), 35-51, and H. E. Hancock, *Wireless at Sea: The First Fifty Years* (1950), 23-27.

were trying to sell their product. As Susan Douglas asserts in her ground-breaking work on the subject, Marconi's company and the United States Navy approached each other from two strong but opposite cultural traditions – one greatly concerned with raising money for future experimentation, the other on spending it wisely. According to Douglas, "contrasting pecuniary orientations, coupled with widely divergent socializations, induced the members of each group to view the other with suspicion and, occasionally, contempt . . . these conflicting traditions, cultures, and attitudes played a salient part in contract disputes."[29]

Yet the most significant reason the U.S. Navy decided not to purchase any of Marconi's equipment at century's turn was that contemporary radio technology did not provide the fleet with improved tactical capabilities. Douglas overlooks this vital point when she argues that the Navy ". . . was not the sort of organization in which technical sponsorship, especially of an invention that threatened autonomy and decentralization, was either desired or possible."[30] In 1900 – and for several years thereafter – radio simply did not offer superior capabilities over existing methods of ship-to-ship communications, which consisted primarily of flag signals and the Ardois/Telephotos light system.[31] To be sure, these

---

[29] Douglas, "The Navy's Adoption of Radio," 132, and Idem, *Inventing American Broadcasting*, 113.

[30] Douglas, "The Navy's Adoption of Radio," 126, and Idem, *Inventing American Broadcasting*, 109.

[31] Howeth, *History of Communications-Electronics*, 10-11. The issue of shore-to-ship/ship-to-shore communications was a different matter, although this represented a strategic, not a tactical, concern. Unlike ship-to-ship communications, which could be accomplished rapidly and efficiently by methods other than radio, communications between shore commands and ships at sea still required the use of dispatch vessels, unless, of course, a ship was in port and could connect to a telegraph cable. Many nations, including the United States, disliked Great Britain's near monopoly in worldwide submarine telegraph cables, and saw wireless telegraphy as a potential alternative to British dominance.

technologies possessed their own limitations, the most
critical of which were poor performance in conditions of
restricted visibility, such as fog or smoke, and a maximum
theoretical range determined by line-of-sight.[32] Neverthe-
less, in comparison to turn-of-the-century radio technology,
visual and light signalling systems were more reliable, espe-
cially under the anticipated conditions of battle. Reflect-
ing such concerns, Lieutenant Commander Bradley A. Fiske, an
officer widely regarded for his technical foresight and ex-
pertise, noted that "for nine-tenths of our purposes the
present system of signals are perfectly adequate,"[33] and de-
clared that wireless telegraphy, "while it will be extremely
convenient for all the ordinary purposes of fleet work . . .
possesses the inherent defect that, if used in the presence
of the enemy, the enemy can interfere with its indications by
sending out Hertzian waves themselves."[34]

(Nearly two-thirds of the world's submarine cables were under British
control in 1901). Still, nothing from the 1899 tests indicated Mar-
coni's equipment could remedy this geo-political situation, and when
later tests revealed that long-distance radio communications were pos-
sible, the Navy aggressively pursued such possibilities. For more on
Great Britain's imperial telecommunications network and its geo-politi-
cal significance, including resentment of the British, see Paul M. Ken-
nedy, "Imperial Cable Communications and Strategy," 75-98, in *The War
Plans of the Great Powers, 1880-1914* (1979), ed. Paul M Kennedy, Daniel
R. Headrick, *The Tentacles of Progress: Technology Transfer in the Age
of Imperialism, 1850-1940* (1988), 97-144, Idem, *The Invisible Weapon:
Telecommunications and International Politics, 1851-1945* (1991), 28-
115, and Peter J. Hugill, *Global Communications since 1844: Geopoli-
tics and Technology* (1999), 25-51. The statistic listed above in pa-
rentheses is from Headrick, *Tentacles of Progress*, 106.

[32] The *theoretical* maximum distance at which visual signals can be ob-
served is determined by the equation $d = 2.08 (\sqrt{h_1} + \sqrt{h_2})$, where d is
distance in nautical miles, and h_1 and h_2 are the respective heights
above water of the signalling device and the observer, in meters. In
practice, existing systems never came close to achieving this theoreti-
cal maximum.

[33] Lieutenant Commander Bradley A. Fiske, from a letter published in
United States Naval Institute Proceedings, vol. 28, no. 4, (1902), 939.

[34] Ibid., 941.

Douglas and others have pointed to statements made by Fiske as indicative of the Navy's institutional conservatism toward radio communications, asserting that even one of the service's most innovative officers opposed adoption of this promising new technology.[35] According to Douglas, Fiske held that "radio had 'no military usefulness whatsoever.'"[36] Yet the principal concern for Fiske, as for many other U.S. naval officers, was wartime tactical signalling. These men did not oppose the adoption of radio *per se*; rather, they believed tactical radio communications would be operationally ineffective under conditions of battle. According to Fiske, wireless telegraphy supplemented and improved existing methods of ship-to-ship communication, but only when an enemy was not present.[37] Interestingly, Fiske not only recognized that an opposing fleet could use intentional interference (i.e., "jamming") to disrupt ship-to-ship communications, he also anticipated the emergence of efforts to collect intelligence from radio signals, asking rhetorically: "[W]hat admiral is going to fill the ether with Hertzian waves, and make a present to the enemy of the information that he is near?"[38]

The point here is not to suggest that Fiske was a visionary who mistakenly has been characterized as some sort of reactionary, although clearly his thoughts on radio were not as backward-looking as they previously have been portrayed. Rather, Fiske offers a point of departure for reconsidering

---

[35] In addition to Douglas's article, "The Navy's Adoption of Radio," other works that stress the Navy's conservative attitude toward wireless include Headrick, "Technological Innovation in the Armed Forces: The Case of the U.S. Navy," 285-289, Douglas, *Inventing American Broadcasting*, 102-119, 134-137, and Howeth, *History of Communications-Electronics*, 65-66, 263-264.

[36] Douglas, "The Navy's Adoption of Radio," 119.

[37] Commander Bradley A. Fiske, "War Signals," *United States Naval Institute Proceedings*, vol. 29, no. 4, (1903), 931-934.

[38] Ibid., 932.

the standard interpretation, based largely on anecdotal evidence, that the U.S. Navy resisted the adoption of a promising new communications technology in the early 1900s due to individual and institutional conservatism.[39] A closer examination of the Navy's work with radio during the first decade of the twentieth century exposes not a hidebound bureaucracy, but a technically-oriented organization operating under budgetary constraints. In fact, the Bureau of Equipment aggressively pursued the acquisition of radio technology. While Douglas and others are correct to point out that line officers often resented – and sometimes resisted – receiving orders while at sea, they overlook that this opposition centered on ship-to-shore communications. If technological conservatism truly was the basis for such resistance, then one would expect to find similar opposition with respect to ship-to-ship communications. Yet the available evidence suggests otherwise. Not only did officers and enlisted men support the Navy's efforts to improve existing methods of tactical communication, they also developed a number of innovative new ways to employ radio technology.

---

[39] To cite one such anecdote, Douglas recounts the story of a flag lieutenant who "didn't give a damn about wireless" and moved the antenna wires on his ship because he objected to their "unsymmetrical appearance." Douglas, "The Navy's Adoption of Radio," 148-149, and Idem, *Inventing American Broadcasting*, 135. What Douglas fails to mention is that the flag lieutenant's boss quickly countermanded this order and had the ship's crew move the antenna wires back to their original (and functioning) location. Howeth, *History of Communications-Electronics*, 64-65.

Successes and Failures: The First Fifteen Years

The turn of the new century witnessed no improvement in
relations between the Marconi Company and the United States
Navy. Marconi continued to investigate the interference
problem, and in April 1900 the British government granted him
a patent for a syntonic transmitter (Patent No. 7,777).[40]
The heart of this "four sevens" patent was an oscillation
transformer, designated the jigger, which Marconi used to
connect the transmitter's discharge circuit with its antenna.
In a design he had patented two years previously,[41] Marconi
connected the coherer circuit to the receiving antenna in a
similar manner.[42] The end result of these changes was to
create a four-circuit tuning system, in which two closed
circuits (the discharge and coherer circuits) were induc-
tively coupled to two open circuits (the transmitting and
receiving antennas, respectively) with the jigger serving as
the necessary link between them. Because the radiated energy
in this system could be confined to a narrower range of fre-
quencies (i.e., the radio waves were less damped), Marconi
obtained two practical benefits: (1) the ability to distin-
guish one set of signals from another, and (2) a stronger

---

[40] Aitken, *Syntony and Spark*, 250.
[41] For further details on this patent, see Hong, *Wireless*, 93-96.
[42] Marconi and other early radio pioneers used a device called a coherer
to detect transmitted radio waves. Typically, the coherer consisted of
an evacuated glass tube filled with a mixture of metal filings. These
filings evidenced very high resistance at low voltages, but changed to
a state of extremely low resistance when a high voltage was applied.
In this way the coherer acted as a switch. Normally the coherer was in
the "off" position, but it switched to "on" after receiving a radiated
signal above a certain voltage threshold. To return a coherer to its
decohered state, an operator had to tap or shake the device. Eventu-
ally, automatic tappers were developed. Blish, "Notes on the Marconi
Wireless Telegraph," 857-859, Aitken, *Syntony and Spark*, 102-107, and
Hong, *Wireless*, 31.

response to feeble signals. In theory, at least, Marconi's four sevens patent provided the means both to prevent interference and to increase range.[43]

Like many new inventions, however, Marconi's syntonic system did not always work as designed. Keeping the transmitter and receiver in tune required frequent calibration, and skilled operators were a necessity. Furthermore, Marconi's system was quite vulnerable to interference from any transmitter generating highly damped waves.[44] This difficulty was highlighted by the international yacht races of 1901, when the Marconi Company and two other wireless concerns – the American Wireless Telephone & Telegraph Company and the Wireless Telegraph Company of America[45] – attempted to report the results of these races. During the contest, the shore stations of the Wireless Telegraph Company and the Marconi Company were unable to read any of the signals transmitted by their shipboard colleagues, because the American Wireless Telephone & Telegraph Company intentionally jammed their transmissions.[46] This incident quite naturally embarrassed the Marconi Company (as well as the Wireless Telegraph Company of America) and did not go unnoticed by the U.S. Navy.[47]

---

[43] Aitken, *Syntony and Spark*, 70-76, 247-254, and Hong, *Wireless*, 62-64, 90-100.

[44] Hong, *Wireless*, 117-118.

[45] The former company, organized in 1899, was not related to the American Telephone & Telegraph Company (AT&T). The Wireless Telegraph Company of America, established in 1901, was founded by Lee De Forest, who later achieved fame for his pioneering work with the audion. Howeth, *History of Communications-Electronics*, 37-39, and Hong, *Wireless*, 169-189. For more on De Forest, see James Hijiya, *Lee De Forest and the Fatherhood of Radio* (1992).

[46] Alfred Price, *The History of U.S. Electronic Warfare: The Years of Innovation – Beginnings to 1946* (1984), 4.

[47] Howeth, *History of Communications-Electronics*, 38-39.

Nevertheless, in late 1901 the Navy's Bureau of Equipment decided to re-investigate radio equipment and methods of operation.[48] Partly because the Marconi Company held steadfast to its leasing policy, the Bureau appointed retired naval officer and expatriate Francis M. Barber to study the existing state of radio telegraphy in Europe. As Susan Douglas has shown, Barber was not necessarily the ideal person for such an assignment. Although the former naval officer possessed technical expertise and linguistic proficiency in French and German, he also held inventors in low esteem and at times displayed an attitude bordering on the xenophobic.[49] Barber especially disliked Marconi, at one point expressing his hope that the Navy eventually would "drive the American Marconi Co. out of business."[50]

Barber's foibles aside, in January 1902 Rear Admiral Royal B. Bradford, the Chief of the Bureau of Equipment, approved his envoy's recommendation to purchase several sets of European-manufactured radio equipment.[51] Bradford asked his counterpart at the Bureau of Construction and Repair to provide all ships under construction "with masts suitable for the use of wireless telegraphy apparatus,"[52] and authorized Barber to purchase two sets each from three different Euro-

[48] Acting Chief, Bureau of Equipment to Chief, Bureau of Navigation, 13 September 1901, NADC, RG 19, BuEq, Box No. 83.

[49] Douglas, "The Navy's Adoption of Radio," 132-135, and Idem, *Inventing American Broadcasting*, 114-115.

[50] Francis M. Barber to Chief, Bureau of Equipment, 11 February 1907, NADC, RG 19, BuEq, Box No. 89.

[51] Barber made this recommendation in early December. Francis M. Barber to Chief, Bureau of Equipment, 6 December 1901, NADC, RG 19, BuEq, Box No. 85.

[52] Chief, Bureau of Equipment, "Memorandum for the Bureau of Construction and Repair," 4 January 1902, NADC, RG 19, BuEq, Box No. 23. Bradford exempted four single-turret monitors from his request.

pean companies: Slaby-Arco, Ducretet, and Rochefort.[53] In addition, Bradford requested that one officer and two enlisted personnel be sent abroad to study recent developments in European wireless telegraphy.[54] The Bureau of Navigation, which at the time was responsible for issuing orders to naval personnel, assigned an engineering officer, Lieutenant John Hudgins, and two chief electrician's mates, James Bell and William Bean, to perform this duty.[55] Hudgins and his two assistants arrived in Paris on May 8th, met with Barber, and soon thereafter began their study of the Ducretet and Rochefort apparatus. In June, the trio moved to Berlin to learn about the Slaby-Arco equipment, as well as that of another company, Braun-Siemens. Finally, in July the group traveled to England, where it spent ten days examining the devices of Marconi and several other British firms.[56]

After completing their assignment, in early August 1902 Hudgins, Bell, and Bean submitted a formal report to the Bureau of Equipment. Their report, submitted under Hudgins's name, concluded that none of the equipment they had examined worked in an entirely satisfactory manner, "[t]here being always interference, lack of adjustment, or some fault either

---

[53] Chief, Bureau of Equipment to Francis M. Barber, 13 January 1902, NADC, RG 19, BuEq, Box No. 84. Slaby-Arco was a German company; the other two were French.

[54] Letters from Chief, Bureau of Equipment to Secretary of the Navy, 10 January 1902, 12 February 1902, and 15 March 1902. The first letter is in NADC, Record Group 80 – General Records of the Department of the Navy (RG 80), General Correspondence of the Secretary of the Navy, 1897-1915, Box No. 531; the later two letters are in NADC, RG 19, BuEq, Box No. 89.

[55] According to Howeth, the Navy selected these three men for their technical competence and ability to teach others. Hudgins later became the head of the Bureau of Equipment's Radio Division, while Bell and Bean helped establish the Navy's radio training program. Howeth, *History of Communications-Electronics*, 43.

[56] Letters from Francis M. Barber to Chief, Bureau of Equipment, 7 May 1902, 9 May 1902, 17 June 1902, and 11 July 1902, all in NADC, RG 19, BuEq. The first two letters are in Box No. 88; the latter two are in Box. No. 85.

in the transmitter or receiver which rendered accurate reception of a message difficult or doubtful. Important messages, cipher, proper names, or any sentence in which the context would not assist in deciphering, having to be repeated back and forth frequently four or five times . . . ."[57] The report also stated that published reports of European radio equipment were willfully misleading, since companies refused to disclose anything but their best results. In addition to pointing out deficiencies, Hudgins's report endeavored to provide the Navy with practical information that would help it to determine which radio apparatus was the best available. For example, the report noted that the French-manufactured equipment could not be tuned, and that although the Braun-Siemens sets had sharper tuning than those of Marconi or Slaby-Arco, this advantage was negated by the fact that the frequency could be changed easily in neither transmitter nor receiver. After careful consideration, Hudgins listed, in order, Marconi, Braun-Siemens, Slaby-Arco, Rochefort, and Ducretet as manufacturers of the sets most suited for adaptability to naval service.[58]

Within two weeks of Hudgins submitting his report, the Navy commenced tests on the European-manufactured equipment it had purchased. These tests, carried out under the direction of a specially-convened Wireless Telegraph Board,[59] lasted over a year and eventually were expanded to include

[57] Lieutenant John M. Hudgins to Chief, Bureau of Equipment, 7 August 1902, NADC, RG 19, BuEq, Box No. 62.
[58] Ibid.
[59] Acting Secretary of the Navy [Charles H. Darling] to Commander Conway H. Arnold, 14 August 1902, and Darling to Arnold, 16 August 1902, both in NADC, RG 19, BuEq, Box No. 61, and Chief, Bureau of Equipment to Senior Member, Wireless Telegraph Board [Arnold], 18 August 1902, NADC, RG 19, BuEq, Box No. 85.

one British and two U.S. manufacturers.[60] In August 1903, the Board submitted its final report, recommending the Slaby-Arco apparatus as the one "best adapted to naval use among all the various systems tried, not only on account of its greater range, but also on account of its reliability, freedom from interference, adjustability, and ease of manipulation by unskilled or poorly trained operators."[61] Based on this and previous recommendations submitted by the Wireless Telegraph Board, the Navy ordered forty-five sets of Slaby-Arco equipment.[62]

Even before the Wireless Telegraph Board put forward its final report, however, one American company already was protesting the Navy's willingness to purchase foreign-made radio apparatus. Reginald Fessenden of the National Electric Signaling company informed the Secretary of the Navy that he had received no notice of service trials for wireless equipment, and suggested that prior to making large purchases from foreign firms his system – which had been developed by Americans – should be given a chance. Tests eventually revealed Fessenden's system to be inferior to that of Slaby-Arco, but after the outbreak of hostilities between Russia and Japan in February 1904 the Navy did de-

---

[60] Lodge-Muirhead was the British manufacturer. Chief, Bureau of Equipment to Chief, Bureau of Supplies and Accounts, NADC, RG 19, BuEq, Box No. 22. The two U.S. concerns were Reginald Fessenden's National Electric Signaling Company and Lee De Forest's Wireless Telegraph Company. For more on Lodge-Muirhead, see Aitken, *Syntony and Spark*, 124-168. For more on the careers and contributions of De Forest and Fessenden, see Hugh G. J. Aitken, *The Continuous Wave: Technology and American Radio, 1900-1932* (1985), 28-86, 162-249.
[61] "Report of the Wireless Telegraph Board," 28 August 1903. Quoted in Howeth, *History of Communications-Electronics*, 55.
[62] Chief, Bureau of Equipment to Francis M. Barber, 17 March 1903, NADC, RG 19, BuEq, Box No. 87, and Chief, Bureau of Equipment to Francis M. Barber, 9 September 1903, NADC, RG 19, BuEq, Box No. 88.

cide that a reliance on foreign equipment seemed rather imprudent.[63]

In an effort to determine the feasibility of acquiring American-manufactured radio equipment, on April 2nd the Navy reconstituted the Wireless Telegraph Board, a body that for all practical purposes had disbanded the previous September. For the second time in as many years, the Board coordinated and supervised a series of comparative tests, once again concluding that the German-manufactured sets were the best available.[64] Significantly, however, the Board also noted that several U.S. companies manufactured radio apparatus suitable for naval service, a finding which in light of the international situation practically guaranteed these manufacturers a lion's share of all new contracts.[65] Indeed, within three years less than fifty percent of the Navy's radios were of German origin, and most of the original forty-five Slaby-Arco sets had been modified to conform to the newer American equipment.[66]

While the Wireless Telegraph Board occupied itself with this second round of comparative tests, half a world away the Japanese and Russian fleets engaged one another at the Battle

---

[63] Howeth, *History of Communications-Electronics*, 55-59. At the start of the Russo-Japanese War, President Theodore Roosevelt apparently warned both Germany and France that if Russia were defeated he would intervene as necessary to prevent them from interfering with Japanese interests in the Pacific. Elting E. Morison, ed., *The Letters of Theodore Roosevelt*, vol. 4 (1951), 1284.

[64] Chief, Bureau of Equipment to Secretary of the Navy, 16 December 1904, NADC, RG 19, BuEq, Box No. 32. By this time the German firms Slaby-Arco and Braun-Siemens had merged to form a new company, Gesellschaft für Drathtlose Telegraphie, usually referred to as Telefunken.

[65] Howeth, *History of Communications-Electronics*, 85-105.

[66] The Slaby-Arco transmitters were modified to operate at a higher frequency, and the receiving coherers were replaced with electrolytic or magnetic detectors. In many instances, the trial-and-error tinkering of U.S. Navy personnel led to substantial improvements in the performance and reliability of the Navy's radio equipment. Ibid., 105-106.

of Tsushima. In an encounter the eminent naval historian Sir
Julian Corbett later described as "perhaps the most decisive
and complete naval victory in history,"[67] the Japanese Com-
bined Fleet annihilated their Russian counterparts.[68] During
the peace that followed, members of the world's navies inves-
tigated numerous facets of the Russo-Japanese War, including
radio's implications for warfare at sea. Most contemporary
observers believed that the Japanese Navy used wireless far
more judiciously than the Russian Navy, especially at Tsu-
shima, where Japanese warships used radio communications both
to report the enemy's location and to provide essential tac-
tical directions.[69] One enthusiastic U.S. naval officer even

---

[67] Julian Corbett, *Maritime Operations in the Russo-Japanese War, 1904-
1905*, vol. 2 (1994 [1914]), 332-333. This work first appeared in Janu-
ary 1914 as a confidential publication of the Intelligence Division of
the British Admiralty's War Staff. Published commercially for the
first time on the eightieth anniversary of its initial appearance, Cor-
bett's work remains the most thorough account of naval operations dur-
ing the Russo-Japanese War.
[68] Of thirty-eight warships in the Russian fleet, thirty-four were sunk,
scuttled, captured, or interned, and the ratio of Russian to Japanese
casualties was an astounding 48:1. David C. Evans and Mark R. Peattie,
*Kaigun: Strategy, Tactics, and Technology in the Imperial Japanese
Navy, 1887-1941* (1997), 124, and Ronald H. Spector, *At War, At Sea:
Sailors and Naval Combat in the Twentieth Century* (2001), 31.
[69] Captain Seaton Schroeder, "Gleanings from the Sea of Japan," *United
States Naval Institute Proceedings*, vol. 32, no. 1, (1906) 47-93, Cor-
bett, *Maritime Operations in the Russo-Japanese War*, vol. 2, 217-311,
and Hezlet, *Electronics and Sea Power*, 43-49. Criticism of the Russian
Navy usually centered on the fleet commander's decision not to jam the
transmissions of the Japanese ship that first sighted the Russian fleet.
See President, Naval War College to President, General Board, 21 Febru-
ary 1912, NADC, RG 80, Records of the General Board (GB), Subject File
419, Box No. 49. A detailed discussion of this debate is contained in
Tony Devereux, *Messenger Gods of Battle: Radio, Radar, Sonar - The
Story of Electronics in War* (1991), 51-58. For further perspectives on
contemporary thinking, see Schroeder, Corbett, and Newton A. McCully,
The McCully Report: The Russo-Japanese War, 1904-1905 (1977 [1906]),
Nicolas Klado, *The Battle of the Sea of Japan* (1906), trans. J. H.
Dickinson and F. P. Marchant, Alekse Novikoff-Priboy, *Tsushima* (1937),
trans. Eden and Cedar Paul, and J. N. Westwood, *Witnesses of Tsushima*
(1970).

went so far as to proclaim: "The battle of the Japan Sea
[Tsushima] was won by the wireless telegraph."[70]

In the aftermath of Tsushima, the United States Navy
placed an even greater emphasis on the development of radio.
Strategically, the Navy sought to expedite the construction
of Caribbean wireless stations to provide reliable communi-
cations with the newly acquired Panama Canal Zone.[71] Tacti-
cally, the Navy increased efforts to assimilate radio into
fleet operations. In January 1906, Robley D. Evans, Com-
mander-in-Chief of the U.S. Atlantic Fleet, took advantage of
a scheduled transit from Norfolk to the Caribbean to run a
simple exercise designed to test the efficacy of the Navy's
wireless equipment. Evans attempted to maintain contact be-
tween his scouting line and his main body through radio com-
munications, but achieved only sporadic success. Reporting
on the exercise to the Secretary of the Navy, Evans stated
that ship-to-ship wireless communications still could not be
used with certainty and called on the shore establishment to
provide better-trained operators and an improved understand-
ing of atmospheric effects.[72]

Evans's comments accurately reflected the three main
difficulties faced by the Navy with respect to radio in the
middle of the first decade of the twentieth century. To be-
gin, naval commanders still could not depend on wireless for
reliable ship-to-ship communications. To a large extent,
this deficiency derived from the existing state of radio
technology. Spark transmitters produced damped waves which
rendered precise tuning and wireless telephony impossible,

---

[70] Schroeder, "Gleanings from the Sea of Japan," 82-83.
[71] Hezlet, *Electronics and Sea Power*, 59-61, and Howeth, *History of Com-
munications-Electronics*, 93-99.
[72] Hezlet, *Electronics and Sea Power*, 65, and Howeth, *History of Commu-
nications-Electronics*, 110-113.

and even though electrolytic detectors had begun to replace coherers, receivers remained temperamental and prone to failure under the harsh conditions of shipboard use.[73] Exacerbating these technical limitations was a pool of operators generally lacking in the skills required to derive maximum performance out of the Navy's radio equipment. Existing programs for the training of naval electricians failed to provide adequate instruction on the maintenance and repair of wireless sets, and most officers received no formal training in radio communications.[74] Finally, the new methods of industrial research, organization, management, and finance then being adopted by many American firms had only just begun to be embraced by the U.S. Navy.[75] In practice, this meant that the Navy did not possess effective institutional mechanisms for addressing the formidable engineering problems associated with the adoption of a complex technology such as radio.[76]

Nowhere were these weaknesses more evident than in the U.S. Navy's initial efforts to adopt wireless telephony. Searching for a system that would be tactically superior to

[73] Hong, *Wireless*, 165-169, and Louis A. Gebhard, *Evolution of Naval Radio-Electronics and Contributions of the Naval Research Laboratory* (1979), 11-12.

[74] Douglas, "The Navy's Adoption of Radio," 149-150, 155-158, Hezlet, *Electronics and Sea Power*, 65, and Howeth, *History of Communications-Electronics*, 52, 110.

[75] This transformation is documented most thoroughly by the eminent business historian Alfred Chandler. Alfred D. Chandler, *The Visible Hand: The Managerial Revolution in American Business* (1977), and Idem, *Strategy and Structure: Chapters in the History of the American Industrial Enterprise* (1962). See also Harold C. Passer, *The Electrical Manufacturers, 1875-1900* (1953), David F. Noble, *America by Design: Science, Technology, and the Rise of Corporate Capitalism* (1977), Leonard S. Reich, *The Making of American Industrial Research: Science and Business at GE and Bell, 1876-1926* (1985), George Wise, *Willis R. Whitney, General Electric, and the Origins of U.S. Industrial Research* (1985), Paul Israel, *From Machine Shop to Industrial Laboratory: Telegraphy and the Changing Context of American Invention, 1830-1920* (1992), and Glenn Porter, *The Rise of Big Business, 1860-1920*, 2nd edition (1992).

[76] On this point, see especially Douglas, "The Navy's Adoption of Radio," 147-154, 170-173, and Idem, *Inventing American Broadcasting*, 134-137.

the radio equipment used by Evans the previous year, in September 1907 the Bureau of Equipment tested some arc radio-telephone apparatus developed by the newly-formed De Forest Radio Telephone Company.[77] The De Forest system seemed to offer tremendous promise, especially when considered from a tactical perspective, and after successful tests on two American battleships the Bureau of Equipment ordered twenty-six sets.[78]

Unfortunately for both the Navy and De Forest,[79] the new radio-telephone devices were manufactured and installed hastily in order to be available for the world cruise of Theodore Roosevelt's "Great White Fleet."[80] The Navy gave De Forest's company only forty days to manufacture all twenty-six sets, and because there was insufficient time to install all of these prior to sailing, the Navy had to ship some of the sets to Rio de Janeiro for installation by ships' personnel. In many ways the arc transmitters represented an improvement over older spark sets; however, as with most new technologies unanticipated difficulties soon appeared. The arc, which was generated in a hydrogen atmosphere between carbon-copper

[77] De Forest established this firm in early 1907 after leaving the American De Forest Wireless Telegraph Company. Aitken, *The Continuous Wave,* 224, and Hijiya, *Lee De Forest and the Fatherhood of Radio,* 70.

[78] Gebhard, *Evolution of Naval Radio-Electronics,* 6-9. Voice communications were possible with De Forest's radio-telephone sets because they utilized arc transmitters to generate undamped continuous waves. For more on the transition from spark to continuous wave transmitters, see Aitken, *The Continuous Wave.*

[79] Due to poor management and business practices of questionable legality, the company founded by De Forest went bankrupt in 1911. De Forest himself very nearly was convicted of fraud. Hijiya, *Lee De Forest and the Fatherhood of Radio,* 87-89, and Robert H. Marriott and Haraden Pratt, "Radio Ancestors: An Autobiography by Robert H. Marriott," *IEEE Spectrum,* vol. 5, no. 6, (1968), 59.

[80] For more on the Great White Fleet's around-the-world cruise, see James R. Reckner, *Teddy Roosevelt's Great White Fleet* (2001 [1988]), and Kenneth Wimmel, *Theodore Roosevelt and the Great White Fleet: American Sea Power Comes of Age* (1998). Also still informative is Thomas A. Bailey, "The World Cruise of the American Battleship Fleet, 1907-1909," *Pacific Historical Review,* vol. 1 no. 4, (1932), 389-423.

electrodes, needed frequent adjustment. Operators familiar with spark transmitters often failed to understand the intricacies of the new system, and the Navy made little effort to provide an appropriate level of training. The Navy did not acquire (and De Forest failed to provide) an adequate supply of spare parts for a fleet that would be circumnavigating the globe. Finally, because De Forest had designed his system to operate at approximately the same frequency as all other shipboard radio equipment, it could not be used simultaneously with any of the older equipment.[81]

As frequently happens when a military organization confronts failure, the Great White Fleet's experience with De Forest's radio-telephone system had significant institutional repercussions.[82] The Navy Department concluded that the debacle was due in part to the absence of an internal organization with scientific and engineering expertise in radio technology, and sought to establish a research laboratory dedicated specifically to the investigation of problems in wireless telegraphy. This sentiment eventually led to the creation of the United States Naval Radio Telegraphic Labora-

---

[81] Howeth, *History of Communications-Electronics*, 169-172. Douglas points to the Great White Fleet's radio-telephone debacle as further evidence of line officers' recalcitrance toward radio technology, arguing that "officers on shore could not compel officers at sea to adopt the invention." Douglas, "The Navy's Adoption of Radio," 149. I arrive at a different conclusion; namely, that officers at sea did not embrace the De Forest system because officers on shore provided them with an unreliable system which failed to improve operational capabilities even marginally. For evidence that supports this interpretation, see Chief, Bureau of Equipment to Commander in Chief, Atlantic Fleet, 8 July 1909, and Commander in Chief, Atlantic Fleet to Chief, Bureau of Equipment, 18 July 1909, both in NADC, RG 19, BuEq, Box No. 88. While the Navy's experience with the De Forest radio-telephone offers a textbook example of how *not* to integrate a new technology into a military organization, that experience does not provide *prima facie* evidence of conservatism as a causal factor.

[82] For more on the ramifications of failure in military organizations, see Eliot A. Cohen and John Gooch, *Military Misfortunes: The Anatomy of Failure in War* (1990).

tory, which opened in September 1908 under the direction of a
civilian physicist who reported directly to the Bureau of
Equipment.[83] Fittingly, the first work undertaken by the new
laboratory was an examination of some Danish wireless tele-
phones that had been purchased by the Navy the previous
year.[84] After running a series of tests, the lab concluded
that the sets "required more skilled attention than would be
easily available on shipboard, and that . . . it would take
up too much space to be used as an auxiliary in the ordinary
wireless room."[85]

Of course, prior to 1908 either the Bureau of Equipment
or specially-convened wireless telegraph boards had conducted
tests of all new radio equipment acquired by the Navy.[86] The
Naval Radio Telegraphic Laboratory differed from these bodies
in that it also sought to provide solutions to technical and
scientific problems previously viewed as the responsibility
of civilian manufacturers. After concluding that the radio-
telephone sets were unsuited for naval service, the Lab
launched an investigation into various aspects of wireless
telephony, focusing especially on ways to increase receiver
sensitivity. The Lab's research in this and several other
areas later benefited the Navy considerably in its efforts to
integrate radio into fleet operations.[87]

---

[83] Louis W. Austin, "The Work of the U.S. Naval Radio-Telegraphic Labora-
tory," *Journal of the American Society of Naval Engineers*, vol. 24, no.
1, (1912), 122-127. Austin was the Naval Radio Telegraphic Laboratory's
first director.
[84] Howeth, *History of Communications-Electronics*, 173.
[85] Austin, "The Work of the U.S. Naval Radio-Telegraphic Laboratory," 124.
[86] By the end of 1905, the Navy Department had determined that special
boards could not provide the continuity necessary for a thorough evalua-
tion of radio technology. Accordingly, no further wireless telegraph
boards were convened, and the Radio Division of the Bureau of Equipment,
which had been established in 1903, assumed all responsibilities regard-
ing the acquisition of wireless equipment. Howeth, *History of Communi-
cations-Electronics*, 92, 520.
[87] Ibid., 124-141.

Other important organizational changes also improved the Navy's ability to integrate radio technology into the fleet. In 1906, the Navy transferred all battleships from the European and South Atlantic stations to the North Atlantic Squadron, shortly thereafter establishing the U.S. Atlantic Fleet.[88] For the first time, the United States Navy possessed a permanent peacetime fleet, one in which vessels could operate and train together on a regular basis as a single organized group.[89] In early 1909, newly-appointed and reform-minded Secretary of the Navy George Von L. Meyer began implementing a series of reforms designed to increase efficiency and improve economy. Meyer thought the Navy had grown too big for effective control under its existing organizational form, and believed the most serious defect he faced was "the lack of a branch dealing directly with the military use of the fleet and the lack of responsible expert advisers to aid the Secretary."[90] Meyer divided the Navy Department into four sections – fleet operations, personnel, material, and inspections – and placed the existing bureaus under these sections according to functional responsibility. Each section was headed by a line officer, who advised the Secretary on technical issues within his jurisdiction. Meyer also re-

---

[88] George W. Baer, *One Hundred Years of Sea Power: The U.S. Navy, 1890-1990* (1994), 40-41.

[89] During most of the nineteenth century, the squadron was the largest group of U.S. warships. In general, the Navy made little effort to train squadrons as a whole, since it considered individual ship training to be entirely sufficient. This began to change in the 1880s, when the Navy created the Squadron of Evolution to conduct exercises and fleet maneuvers, including gunnery practices, landing drills, and torpedo attacks. With naval expansion and the writings of Alfred Thayer Mahan came calls for the creation of a permanent fleet in being. Not coincidentally, this vision came to fruition during the presidency of the ardent navalist Theodore Roosevelt. Marie B. Allen, *Annual Reports of Fleets and Task Forces of the U.S. Navy, 1920-1941* (1974), 1-2, and Sprout and Sprout, *Rise of American Naval Power*, 310-326.

[90] George Von L. Meyer, *Annual Report of the Secretary of the Navy, 1909*, 5.

organized the Navy yards, established a postgraduate engi-
neering curriculum at the Naval Academy to enhance technical
education opportunities for officers, and adopted many of the
latest practices in business management.[91]

One of Secretary Meyer's most important organizational
changes took place in 1910 when he abolished the Bureau of
Equipment and assigned its duties to the Bureau of Navigation
and the remaining three material bureaus.[92] The Bureau of
Steam Engineering, which was responsible for the design, con-
struction, maintenance, and repair of machinery aboard naval
vessels, acquired the Bureau of Equipment's Radio Division.
Although division personnel remained in their billets and
retained their responsibilities, the head of the Division
reported to a new chief.[93] Significantly, disestablishment
of the Bureau of Equipment created a more appropriate orga-
nizational home for the Radio Division, as the Bureau of
Steam Engineering possessed both a larger budget and a
stronger technical tradition.[94] The net result of the Navy's
reorganization and reform efforts during this period was to

[91] Paolo E. Coletta, "George Von Lengerke Meyer," 495-522, in *American
Secretaries of the Navy, 1775-1972*, vol. 1 (1980), ed. Paolo E. Coletta,
Sprout and Sprout, *Rise of American Naval Power*, 338-341, and Charles O.
Paullin, *Paullin's History of Naval Administration, 1775-1911: A Col-
lection of Articles from the U.S. Naval Institute Proceedings* (1968),
442, 479-480.
[92] These three bureaus were Construction & Repair, Ordnance, and Steam
Engineering. Meyers also sought to consolidate the Bureau of Steam En-
gineering and the Bureau of Construction & Repair, but he attempted to
do so without Congressional approval and was rebuffed soundly. This
consolidation eventually took place in June 1940. Paul J. Strayer and
Edward J. Pope, *An Administrative History of the Bureau of Ships During
World War II*, vol. 1 (1947), 1-48, and Julius A. Furer, *Administration
of the Navy Department in World War II* (1959), 217-222.
[93] The head of the Radio Division at the time of the reorganization was
Lieutenant David W. Todd. His new boss was Rear Admiral Hutch I. Cone.
Howeth, *History of Communications-Electronics*, 161-162.
[94] The Bureau of Steam Engineering's appropriated funds for fiscal year
1910 (the Bureau of Equipment's last year in existence) were 71 percent
greater those of the Bureau of Equipment ($6.85 million as compared to
$4.00 million). George Von L. Meyer, *Annual Report of the Secretary of
the Navy, 1909*, 45, 53-54.

create an environment in which new technologies like radio could more easily be acquired, evaluated, and employed.[95]

Developments in radio technology proceeded apace as the Navy underwent and adjusted to these organizational changes. As previously discussed, the development of arc transmitters made possible the generation of undamped continuous waves. Nevertheless, spark gap transmitters remained the dominant technological paradigm, and wireless concerns strove to improve these devices. In 1906, the German firm Telefunken produced a quenched spark gap transmitter, and the following year Marconi unveiled a timed spark gap transmitter, more commonly known as a disc discharger.[96] In the United States, the National Electric Signaling Company developed a rotary quenched spark gap transmitter, of which the Navy purchased approximately fifty between 1909 and 1911.[97] Each of these devices represented an attempt by their inventors to generate continuous waves, and although none succeeded entirely, all produced relatively undamped waves (Figure 2-3). Such waves greatly reduced the problem of interference, a characteristic that enabled the U.S. Navy to issue its first official frequency plan in 1911. The issuance of this plan was an important step toward the successful tactical employment of radio by fleet commanders.[98]

Advances in transmitter technology were paralleled by improvements in wireless receivers. Marconi began to replace the coherer with the magnetic detector in his receiving cir-

---

[95] Douglas makes a simil . argument. Douglas, "The Navy's Adoption of Radio," 147-154, 170-173.

[96] Aitken, *The Continuous Wave*, 128, and Howeth, *History of Communications-Electronics*, 521. For more on Marconi's disc discharger and its historical significance, see Aitken, *Syntony and Spark*, 276-282.

[97] The Navy purchased two different models: a 10 kilowatt version for shipboard use, and a 100 kilowatt behemoth for shore installations. Howeth, *History of Communications-Electronics*, 137-142.

[98] Ibid., 182.

cuits as early as 1902, but the strained relationship between the U.S. Navy and Marconi precluded the former from taking advantage of this development.[99] The Navy utilized the coherer until 1906, at which time the Bureau of Equipment replaced it with the electrolytic detector, a device patented by Reginald Fessenden three years earlier.[100] Even before the Navy completed the transition to electrolytic detectors, however, a new device, the crystal detector, became available. Although not as rugged as the Bureau of Equipment would have preferred, the crystal detector was easier to maintain and less expensive than its electrolytic counterpart.[101] By the eve of the First World War, the new detector had become standard in virtually all Navy receivers.[102]

Like its magnetic and electrolytic counterparts, the crystal detector enabled radio operators to listen for dots and dashes while they transcribed messages by hand, instead of receiving them in printed form on a paper tape. This shift from paper tapes to transcribed messages had significant implications for naval radio. Accuracy improved because operators could better discriminate between signals and ran-

---

[99] Marconi's magnetic detector, more commonly known by the soubriquet "Maggie," permitted the operator to use headphones for detecting signals. Baker, *A History of the Marconi Company*, 74-76, and Hezlet, *Electronics and Sea Power*, 39-40.

[100] Gleason L. Archer, *History of Radio to 1926* (1938), 68. Demonstrating blatant disregard for Fessenden's patent, the Navy in order to save money purchased most of its electrolytic detectors from the De Forest Company. Aitken, *The Continuous Wave*, 56-57.

[101] Archer, *History of Radio*, 90-91. For a brief description of detectors of the era, see Samuel S. Robison, *Manual of Wireless Telegraphy for the Use of Naval Electricians*, 2nd edition (1911), 128-136, Ellery W. Stone, *Elements of Radiotelegraphy* (1919), 209-222, and George G. Blake, *History of Radio Telegraphy and Telephony* (1928), 58-98.

[102] The IP-76 crystal-detector receiver, manufactured by the Wireless Specialty Apparatus Company, became the *de facto* Navy standard. One reason for the IP-76's effectiveness was the "cat whisker," a fine metal point maintained in light contact with the crystal. Notably, the cat whisker was developed by an enlisted naval electrician. Howeth, *History of Communications-Electronics*, 148-149, 173-174.

dom noise, and transmission rates nearly tripled, from twelve to thirty-five words per minute.[103] These benefits were partially offset, however, by the need to rely on the ears of a single individual. Although a paper tape could be double-checked, an audible signal once received was gone forever, save for the scribbles of an operator who might be inexperienced, indifferent, incompetent, or distracted at the time of message receipt. For fleet commanders, any viable system of tactical ship-to-ship communications had to minimize the likelihood that such transgressions would occur.

While civilian manufacturers produced new types of transmitters and receivers, the Navy continued in its efforts to obtain suitable equipment and effective procedures for tactical ship-to-ship communications. In 1908, the Bureau of Equipment acquired several small spark sets from the National Electric Signaling Company and supplied them to the Atlantic Fleet.[104] Prior to testing these sets the fleet's signal officer, Lieutenant D. W. Wurtsbaugh, thoroughly investigated the Navy's previous attempts to use radio for tactical signalling. He determined that earlier efforts had neglected to explore the potential benefits of differing equipment configurations for strategic and tactical communications, and concluded that existing shipboard arrangements made the wartime tactical employment of radio a risky proposition. Transmitters, receivers, and antennas were located in positions that left them vulnerable to enemy fire, and no one could say for sure that a radio operator would be able to hear and receive messages through the loud

---

[103] Aitken, *The Continuous Wave*, 189-191.

[104] Acquisition of this equipment evidenced the Navy's changing attitude toward civilian manufacturers, as the Bureau of Equipment's Radio Division worked closely with the National Electric Supply Company in designing and constructing these sets. Howeth, *History of Communications-Electronics*, 174.

discharges of a warship's main battery.[105] One possible so-
lution to these difficulties was the creation of a "battle
wireless room," to be installed at a central location below
a vessel's protective deck and linked to the conning tower
via voice tubes and telephones.[106]

In early 1909, the Atlantic Fleet tested these concepts.
A series of experiments, supervised by Wurtsbaugh, indicated
that wireless communications were possible at ranges up to
twenty nautical miles under simulated battle conditions.[107]
After learning of these results, the Navy's General Board en-
couraged further experimentation,[108] and in March the Bureau
of Equipment requested that the Bureau of Construction and
Repair construct a protected radio room aboard the battleship
USS Michigan.[109]

The following year testing continued, this time under
the watchful eye of Lieutenant George C. Sweet, an officer
recently detached from the Bureau of Equipment's Radio Divi-
sion. Because Sweet was an acknowledged expert in naval ra-
dio, his superiors gave him wide latitude in running these
tests. Sweet's first objective was to determine experimen-
tally the most favorable arrangements for a battle antenna.
After several months of testing, in August 1910 he recom-
mended use of a single, flexible, insulated cable suspended
from an optimal height of eighty feet. According to Sweet,
such an antenna had two advantages: (1) it could be quickly

---

[105] Ibid., 175 and Lieutenant D. W. Wurtsbaugh to Commander in Chief,
U.S. Atlantic Fleet, 7 January 1909, NADC, RG 19, BuEq, Box No. 75.
[106] Commander in Chief, U.S. Atlantic Fleet to Secretary of the Navy, 10
January 1909, NADC, RG 19, BuEq, Box No. 75.
[107] Lieutenant D. W. Wurtsbaugh to Commander in Chief, U.S. Atlantic
Fleet, 7 January 1909, NADC, RG 19, BuEq, Box No. 75.
[108] President, General Board [George Dewey] to Secretary of the Navy, 24
February 1909, NADC, RG 80, GB, Subject File 419, Box No. 49.
[109] Chief, Bureau of Equipment, "Memorandum for Bureau of Construction
and Repair," 2 March 1909, NADC, RG 19, Box No. 75.

replaced if destroyed, and (2) it helped eliminate the interference problems associated with longer antennas. Like Wurtsbaugh, Sweet believed transmitters and receivers should be located in a protected area, but he proposed placing these devices in the conning tower, since this would permit face-to-face communications between a ship's commanding officer and his radio operator.[110] Apparently, Sweet failed to share Wurtsbaugh's faith in the reliability and effectiveness of shipboard interior communications systems.[111]

Even as the Navy was considering whether or not to implement Sweet's recommendations, it continued to search for ways to improve tactical ship-to-ship communications. Prior to the autumn battle practice of 1911, the Bureau of Navigation tasked several officers to analyze and report on the fleet's ability to employ radio for tactical signalling.[112] The three men assigned to perform this task - Ensign Charles H. Maddox, Lieutenant Stanford C. Hooper, and Lieutenant Commander Todd T. Craven - all had extensive experience with U.S. Navy radio equipment and communications procedures.[113]

As instructed, the three officers assessed the fleet's operational capabilities with regard to wireless telegraphy.

---

[110] Howeth, *History of Communications-Electronics*, 175-176. See also Lillian C. White, *Pioneer and Patriot: George Cook Sweet, Commander USN, 1877-1953* (1963), 43-49, 61-67.

[111] These conflicting opinions concerning the appropriate location for shipboard radio offer an early episode in what became a prolonged debate over how best to provide a commanding officer with information obtained from electrical or electronic equipment.

[112] Howeth, *History of Communications-Electronics*, 193-194.

[113] Craven, assigned to the Bureau of Navigation's Division of Operations, apparently initiated this effort. Although Maddox was relatively junior, he had a strong relationship with the director of the Naval Radio-Telegraphic Laboratory, under whom he had served in 1910. Hooper's experiences with naval radio dated back more than half a decade, when as a passed midshipman on the *USS Chicago* he helped to reestablish communications between San Francisco and the rest of the nation in the days immediately after the infamous San Francisco earthquake of 1906. For complete biographical sketches of Hooper and Maddox, see Howeth, *History of Communications-Electronics*, 113-114, 189.

Craven, Hooper, and Maddox identified several technical deficiencies, but posited that the Navy's principal problem was organizational in nature. Specifically, they pointed to a dearth of highly-proficient operators and a lack of adequate supervision by officer personnel, arguing that these deficiencies could best be solved by increasing the level of technical specialization among the enlisted ratings and by establishing better officer and enlisted radio training programs. They also suggested the creation of a radio officer's billet on the staff of the Atlantic Fleet Commander-in-Chief, since this would provide a dedicated expert to oversee further efforts for integrating wireless communications into fleet operations.[114]

After submitting these recommendations one of the officers, Hooper, likely wished he had taken heed of the old aphorism "be careful what you wish for," as the Navy quickly determined that he was an excellent choice to fill the billet of Atlantic Fleet Radio Officer.[115] Pleased with his current assignment as an instructor in the Electrical Department at the U.S. Naval Academy, Hooper was reticent to acquiesce in the early termination of his first shore-tour after recently completing seven consecutive years of sea-duty. Nevertheless, the young officer eventually accepted the position of Atlantic Fleet Radio Officer, assuming his official duties on August 16th, 1912 (Figure 2-4).[116]

The creation of this specialized billet on the staff of the Commander-in-Chief of the Atlantic Fleet was an important institutional development, as it signified the Navy's recog-

---

[114] Douglas, "The Navy's Adoption of Radio," 156-157, Idem, *Inventing American Broadcasting*, 262-263, and Howeth, *History of Communications-Electronics*, 193-195.
[115] Apparently, Maddox was the one who recommended Hooper for the position. Howeth, *History of Communications-Electronics*, 194.
[116] Ibid., 194-195.

nition that efficient radio communications were essential for tactical proficiency. Hooper, by nearly all accounts a diligent and capable naval officer, tried hard to correct the deficiencies he and his colleagues had identified in their previous assessments. Over time, he gained the confidence of the Atlantic Fleet Commander-in-Chief, who became evermore inclined to implement suggestions put forth by his new staff officer.[117] For example, in September 1912, Hooper convinced his boss to issue an order requiring all ships to appoint a radio officer.[118] This policy had beneficial consequences, not only because it distributed expertise throughout the fleet, but also because it created a large cadre of young officers knowledgeable about the capabilities and limitations of radio communications. Years later many of these same officers would rise to hold command positions on the Navy's battleships, cruisers, and destroyers.

Other changes recommended by Hooper and implemented by the Commander-in-Chief of the Atlantic Fleet further increased the fleet's operational proficiency in tactical signalling. In late 1912, the Navy instituted competitions to determine which enlisted operators were the most adept at sending and receiving messages, with the winners receiving promotions as prizes.[119] The following year, the Commander-in-Chief introduced further reforms. In particular, he standardized the number of operators per ship, initiated addi-

---

[117] Rear Admiral Hugo Osterhaus was the Commander-in-Chief of the Atlantic Fleet when Hooper assumed his duties as Fleet Radio Officer. Osterhaus was relieved in 1913 by Rear Admiral Charles J. Badger, who a decade earlier had served on the Navy's Wireless Telegraph Board. Captain Conway H. Arnold, et al., to Chief, Bureau of Equipment, 13 December 1902, NADC, RG 19, BuEq, Box No. 85.
[118] On larger vessels and flagships, officers were required not only to supervise radio operations, but also to "become proficient in operating and in procedure." Howeth, *History of Communications-Electronics*, 195.
[119] Ibid., 196.

tional testing on the simultaneous use of multiple frequencies, and ordered commanding officers to parallel all visual signals by radio.[120] Hooper also convinced his boss to consider the still unresolved issue of where best to locate shipboard radio equipment. Earlier suggestions to transfer wireless apparatus from topside areas to armor-protected locations had never been implemented, in part because such a move would have required longer lengths of electrical cabling, a feature that introduced noticeable resistance losses between a ship's antennas and the corresponding transmitters and receivers. Hooper believed that the reduced sensitivity created by longer cable lengths was insufficiently detrimental to justify the placement of shipboard radio apparatus in unprotected areas, and he persuaded the Atlantic Fleet Commander-in-Chief that the situation should be remedied. Accordingly, the Commander-in-Chief arranged for the reinstallation of radio equipment below-decks on all Atlantic Fleet vessels.[121] World events would soon reveal this to be a prudent decision.

<p style="text-align:center">★   ★   ★</p>

By the eve of the First World War, the United States Navy earnestly had committed to integrating wireless telegraphy into fleet operations. Technical improvements, several of which had been developed under Navy auspices, resulted in more reliable ship-to-ship communications, and organizational realignment fostered an environment in which

---

[120] Douglas, "The Navy's Adoption of Radio," 162, and Idem, *Inventing American Broadcasting*, 265.
[121] Douglas, "The Navy's Adoption of Radio," 162-163.

the research, development, testing, and evaluation of radio technology could be accomplished more easily and efficiently.

Nevertheless, numerous difficulties had not yet been resolved. The Navy still could not operate effectively on several frequencies in the same vicinity at the same time, did not possess a dependable technique for minimizing the effects of intentional interference by an adversary, and had only just begun to develop methods and procedures for encoding messages.[122] Compounding these dilemmas was the continued lack of adequate training programs for enlisted personnel. Although the Atlantic Fleet Commander-in-Chief had initiated efforts to improve operator proficiency, not until January 1917 did the Bureau of Navigation's Division of Enlisted Personnel establish a basic radio school.[123] Finally, tactical signalling by wireless served only as a complement to, and not as a replacement for, traditional visual signalling techniques. Despite its many advantages, radio telegraphy remained slower than flag signalling, and therefore was not as effective for time-critical warship maneuvers.[124]

Despite these issues, in 1914 the United States Navy clearly possessed a better system of tactical communications than it had fifteen years previously. To be sure, the story

---

[122] Howeth, *History of Communications-Electronics*, 200-202. The Navy Department first issued a "Battle Signal Book" on 12 May 1913.

[123] Michael D. Besch, *A Navy Second to None: The History of U.S. Naval Training in World War I* (2002), 82-83. This school was located at the Great Lakes Naval Training Station in Great Lakes, Illinois.

[124] While I have not uncovered specific figures for the U.S. Navy, for the Royal Navy in 1914 the typical time to send and receive radio-telegraphic signals, transcribe them into plain language, and present them to a ship's commanding officer was between ten and fifteen minutes. By comparison, the same amount of information could be conveyed in about three minutes when flag signals were utilized. Almost certainly, these times were comparable with those of the American Navy. Jon T. Sumida, "British Battle Fleet Tactical Communications in the Era of the World Wars, 1900-1945," paper presented 18 October 2002 at the annual meeting of the Society for the History of Technology, 4. See also, Kent, *Signal!*, 44, and Hezlet, *Electronics and Sea Power*, 93.

was not one of uninterrupted progress. The installation of radio-telephones on the warships of the Great White Fleet, for example, had been a colossal failure. Yet this debacle led to reforms that resulted directly in improved radio equipment. Even as the fleet acquired better apparatus, however, commanders were discovering that improved means did not necessarily make their ends easier to achieve. American naval officers soon would discover, albeit vicariously at first, just how difficult a task it was to coordinate geo-graphically-dispersed seaborne forces under conditions of battle.

FIGURE 2-1

Guglielmo Marconi and his wireless apparatus
aboard "U" Massachusetts in the fall of 1899.
With nearly identical equipment, Marconi
transmitted the Navy's first official radio
message from "U" New York on November 2nd,
1899.
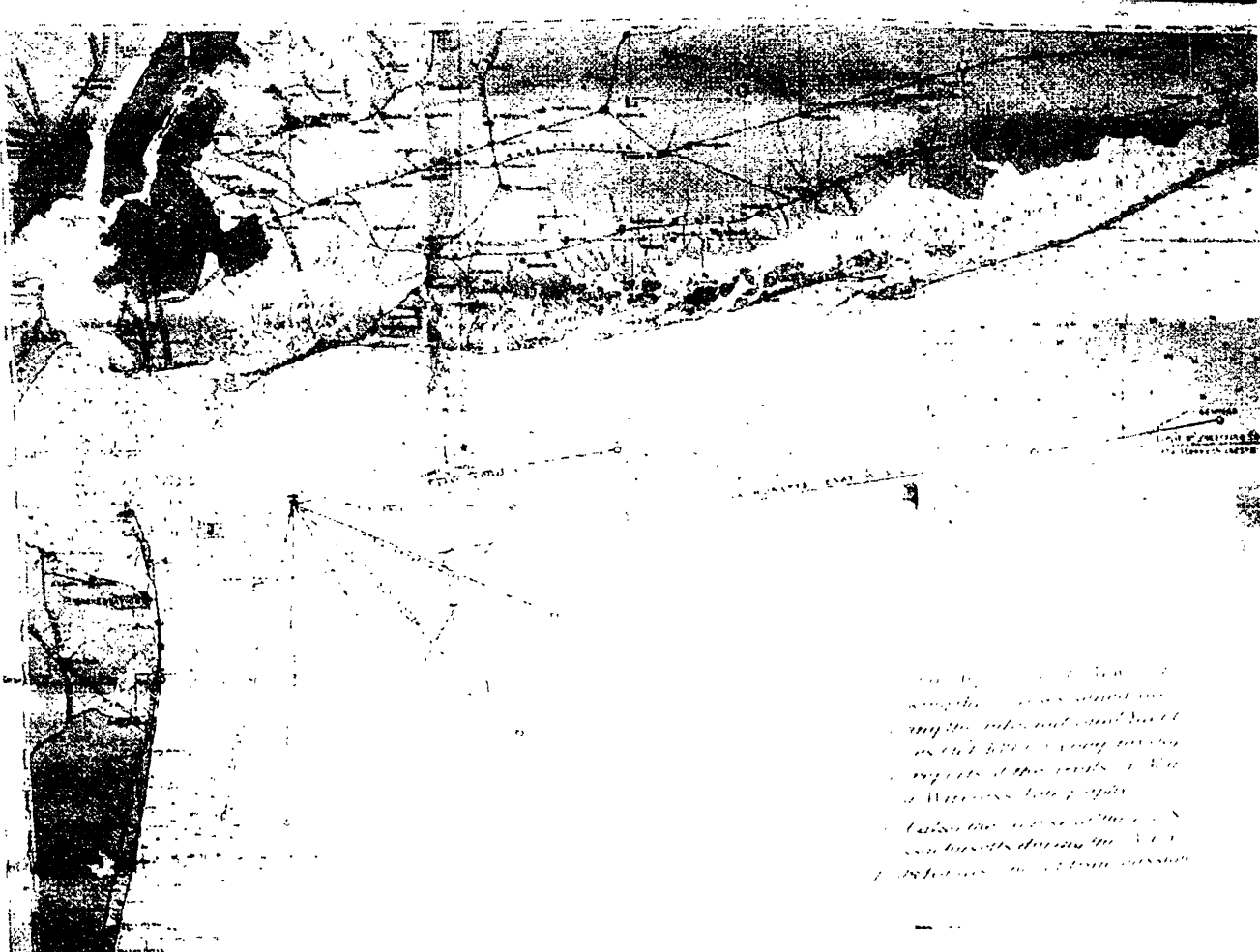
FIGURE 2-2

SPARK GAPS

SYNCHRONOUS ROTATING SPARK GAP
FIG 52

NON-SYNCHRONOUS ROTATING SPARK GAP
FIG. 53

AIR

FIG 54

FIG. 55

AIR BLAST GAP

PARALLEL GAP

MARCONI DISC DISCHARGER
FIG 56

QUENCHED SPARK GAP
FIG. 57

FIG. 58   TELEFUNKEN
(Now Obsolete)

FIG. 59   STONE
(Now Obsolete)

MASSIE GAP FOR COMPRESSED AIR
FIG. 60
(Now Obsolete)

FESSENDEN-DE FOREST
FIG. 61
(Now Obsolete)
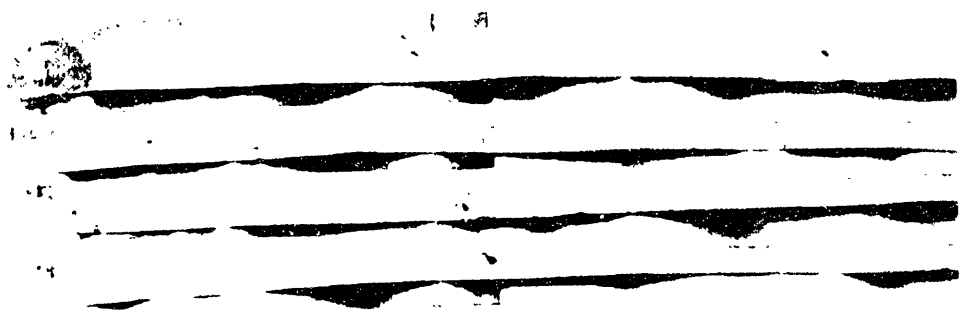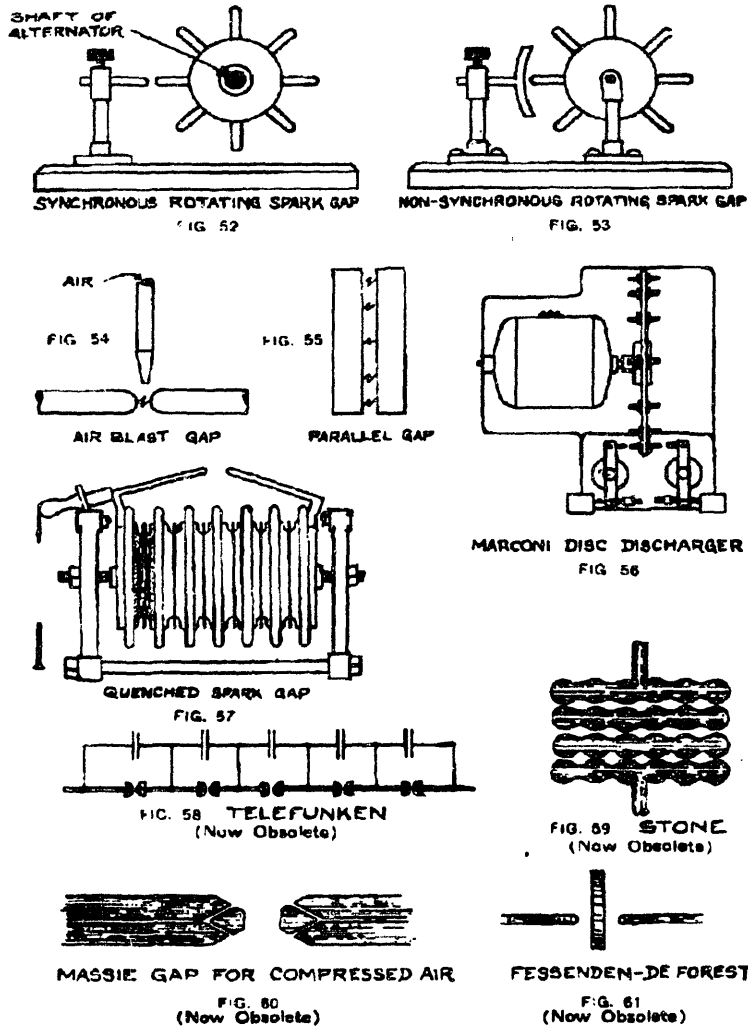
FIGURE 2-3

This sketch of various types of transmitters is taken from a U.S. Navy radio instruction manual published in 1911. Note how many of the devices are considered obsolete only twelve years after the initial Marconi tests.
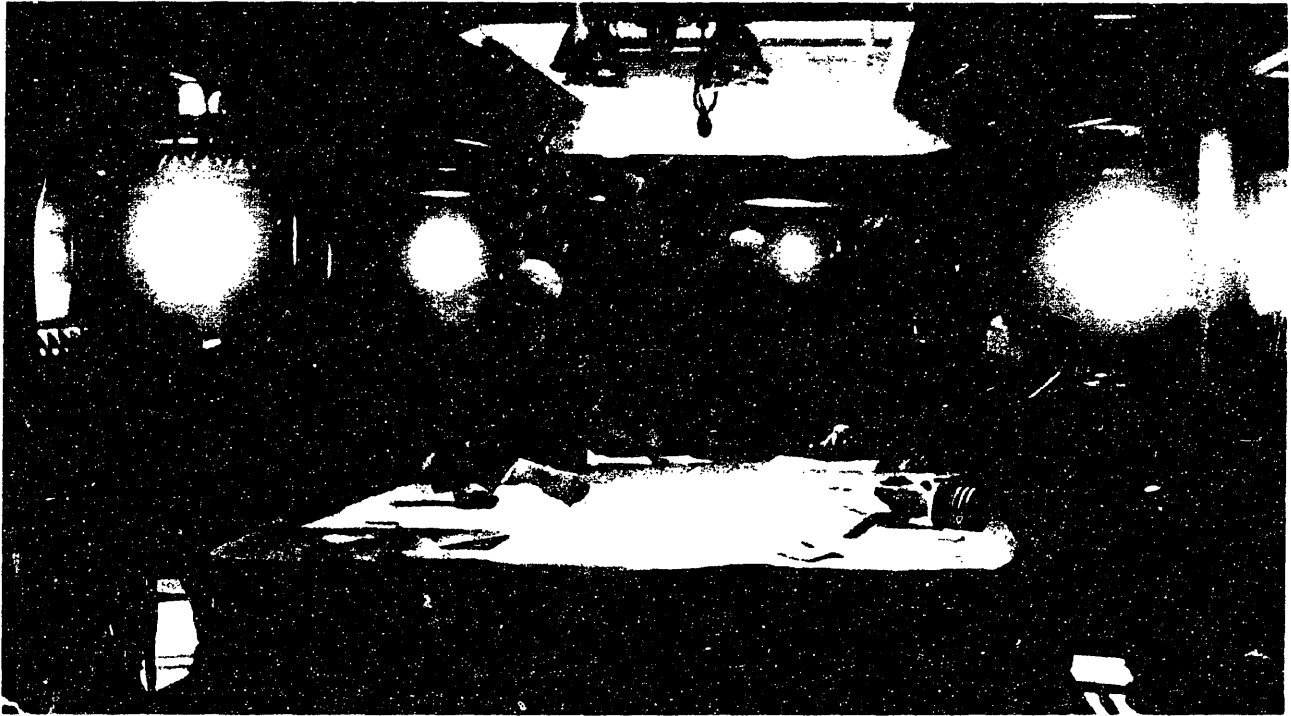
FIGURE 2-4

The creation of a permanent fleet radio officer
billet indicated that the U.S. Navy recognized
the important relationship between wireless
communications and tactical proficiency. This
photo, taken in 1913, shows the staff of
Atlantic Fleet Commander-in-Chief Charles J.
Badger aboard USS Wyoming. Badger's Radio
Officer, Lieutenant Stanford C. Hooper, is
fourth from the left.

Citations for Figures

Figure 2-1: Courtesy of the Naval Historical Center.

Figure 2-2: Chart and paper tapes included with "Report of
             Board on Marconi System of Wireless Telegraphy,"
             13 November 1899.

Figure 2-3: Samuel S. Robison, *Manual of Wireless Telegraphy
             for the Use of Naval Electricians*, 2nd edition,
             105.

Figure 2-4: Courtesy of the Naval Historical Center.

THIS PAGE INTENTIONALLY LEFT BLANK

CHAPTER THREE
IN WAR AND PEACE:
THE COORDINATION OF NAVAL FORCES

Like Hell Let Loose

On the afternoon of May 31st, 1916, Admiral John Jellicoe stood impatiently on his flagship, *HMS Iron Duke*, while awaiting information from his battle cruiser fleet. Nearly an hour had passed since he last had received any word on the location, course, and speed of the German fleet opposing him. Finally, at about 5:40 PM, *Iron Duke* came into contact with the British battle cruisers. Twice Jellicoe signalled to inquire: "Where is the enemy?"[1] Approximately fifteen minutes later, the commander of the battle cruiser fleet replied at last with a report that the main German fleet was less than seven miles away.[2]

Frustration over the British Grand Fleet's ability to communicate during this naval battle, known to posterity as Jutland,[3] was not limited to the fleet's highest ranking offi-

---

[1] According to *Iron Duke's* commanding officer, Jellicoe's full inquiry was: "Where is the enemy battle fleet?" Frederic C. Dreyer, *The Sea Heritage: A Study of Maritime Warfare* (1955), 126-127.

[2] My depiction of Jellicoe draws chiefly from Dreyer, *The Sea Heritage,* 115-132, A. Temple Patterson, *Jellicoe: A Biography,* 115-119, Ronald H. Spector, *At War, At Sea: Sailors and Naval Combat in the Twentieth Century* (2001), 86-91, and Nigel Steel and Peter Hart, *Jutland, 1916: Death in the Grey Wastes* (2003), 166-177.

[3] As with the Battle of Tsushima, a comprehensive discussion of events at Jutland is beyond the scope of this dissertation. For more on this famous naval conflict, in addition to the works cited above the reader is invited to consult Holloway H. Frost, *The Battle of Jutland* (1936), Donald Macintyre, *Jutland* (1957), Geoffrey M. Bennett, *The Battle of Jutland* (1964), Arthur J. Marder, *From the Dreadnought to Scapa Flow: The Royal Navy in the Fisher Era, 1904-1919 - Jutland and After (May 1916 - December 1916),* 2nd edition, vol. 3 (1978), 3-259, V. E. Tarrant, *Jutland: The German Perspective - A New View of the Great Bat-*

cers. Aboard *HMS Galatea*, leading telegraphist Percy Burgess also was having a devil of a time. As he later described the situation:

> I shall never forget what it was like with those earphones on. Pandemonium let loose. I had to report naturally every signal received. The Germans' wireless transmitters were by TELEFUNKEN, which all had a very high frequency note. It sounded as though all the Germans were transmitting at the same time. Also were all our own ships transmitting enemy reports dozens of times. At the same time the IRON DUKE was making MANOEUVERING messages every minute to the fleet. It was like hell let loose.[4]

These vignettes provide just two illustrations of the command and control problems encountered by British naval personnel during the Battle of Jutland. Of the methods then available for tactical communication - signal flags, searchlights, semaphores, and wireless telegraphy - only wireless permitted communications beyond the horizon, and neither German nor Royal Navy personnel possessed effective systems for managing the information obtained through radio. In the case of the Royal Navy, for example, inaccurate or incomplete information severely handicapped the Commander-in-Chief of the

tle, 31 May 1916 (1995), Andrew Gordon, *The Rules of the Game: Jutland and British Naval Command* (1996), John Campbell, *Jutland: An Analysis of the Fighting* (2000 [1986]), and Keith Yates, *Flawed Victory: Jutland, 1916* (2000). An informative historiographic analysis of the battle is available in Eugene L. Rasor, *The Battle of Jutland: A Bibliography* (1992). Two recent articles which call into question some longstanding assumptions about Jutland are Nicholas A. Lambert, "'Our Bloody Ships' or 'Our Bloody System'? Jutland and the Loss of the Battle Cruisers, 1916," *The Journal of Military History*, vol. 62, no. 1, (1998), 29-55, and Jon T. Sumida, "A Matter of Timing: The Royal Navy and the Tactics of Decisive Battle, 1912-1916," *The Journal of Military History*, vol. 67, no. 1, (2003), 85-136.
[4] Percy Leonard Herbert Burgess to Robert Church, undated but likely written in 1972, Imperial War Museum (IWM), "Papers of Robert Church" (PRC), Burgess Folder, Box No. 1.

Grand Fleet (Jellicoe) on several occasions.[5] One naval historian has argued persuasively that many of the Grand Fleet's communications problems derived from a system of command that stressed obedience over initiative,[6] but additional factors were at work as well.[7] At Jutland, Jellicoe had to coordinate the actions of over one hundred vessels from a flagship that lacked adequate physical facilities for such a task (Figure 3-1).[8] Other British warships had facilities that were no better, leaving Jellicoe and his subordinate commanders without the means to attain a common tactical picture during the battle.

The inability of British naval commanders to arrive at a common tactical picture and the pervasiveness of a command system that discouraged individual initiative led to a classic "catch-22" situation at Jutland. On the one hand, lower-ranking commanders and individual commanding officers often hesitated to take independent action for fear their superiors knew something they did not (or had intentions of which they were unaware). On the other hand, senior commanders frequently possessed no more tactically relevant information

---

[5] See especially Marder, *From Dreadnought to Scapa Flow*, vol. 3, 45-55, 93-110, 151-186, 215-224.

[6] Andrew Gordon, *Rules of the Game*.

[7] Most British warships still used spark transmitters, so there was tremendous mutual interference during the battle. One of the wireless telegraphers on Jellicoe's flagship (*Iron Duke*) estimated that sixty-five different ships possessed transmitters that operated on the same general wavelength. Arthur John Brister, "W/T Apparatus and Organization," attached to Arthur John Brister to Robert Church, 23 July 1972, IWM, PRC, Brister Folder, Box No. 1. According to Andrew Gordon, one high-ranking Royal Navy officer later alleged that during daylight action at Jutland the British battle fleet attempted to send, on average, one signal every sixty-seven seconds. Gordon, *Rules of the Game*, 506.

[8] Jellicoe's plotting organization consisted of only two staff officers, who were responsible for plotting (by hand) own-ship's position and the reports received from all other vessels. Keep in mind that by 1916 every major warship in the Grand Fleet was equipped with wireless, and that Jellicoe's forces were geographically dispersed over hundreds of square miles. Jellicoe's plotting organization is described in Arthur Hezlet, *Electronics and Sea Power* (1975), 127.

than their subordinates. In some instances, naval commanders failed to receive critical information;[9] in others, battle damage significantly inhibited ship-to-ship communications.[10] The extent to which senior British officers anticipated these problems remains a matter of debate,[11] but there is no doubt that the "lessons" of Jutland influenced an entire generation of naval leaders both in Europe and the United States.[12]

The command and control difficulties faced by British and German naval commanders at Jutland far exceeded those previously experienced by the officers of any other navy. Yet even after the United States entered the European con-

---

[9] Perhaps the most famous e·mple of this was a message sent by the Admiralty stating that the Ge·...an High Seas Fleet was still in port, when in actuality it had put to sea about twelve hours previously. Yates, *Flawed Victory*, 122, 125-127. Assessing the impact of this mistake, Marder writes: "Jellicoe's confidence in all subsequent intelligence of the enemy fleet sent to him by the Admiralty was badly shaken when less than three hours [after the message was received] Beatty sighted the German battle cruisers well out to sea. He consequently tended to give more weight to information obtained from units of the fleet than to that obtained from the Admiralty. This was to have disastrous consequences at the time of the night action." Marder, *From Dreadnought to Scapa Flow*, vol. 3, 47. For a discussion of the British naval intelligence failures at Jutland, along with Marder see Patrick Beesly, *Room 40: British Naval Intelligence, 1914-1918* (1982), 151-168.

[10] For example, both the British and German battle cruiser commanders (David Beatty and Franz Hipper) had great difficulty communicating with their forces after the wireless facilities on their flagships were destroyed. Barrie Kent, *Signal! A History of Signalling in the Royal Navy* (1993), 52, Marder, *From Dreadnought to Scapa Flow*, vol. 3, 116-117, and Hezlet, *Electronics and Sea Power*, 117-118.

[11] See note 3 above.

[12] Analyses of Jutland can be found throughout the professional literature of the period. Writings by American naval officers in the decade after the battle include: Admiral George Dewey, "Lessons of Skagerrack," *Sea Power: The Nation's Defense*, vol. 1, no. 2, (1916), 7-10, 35. Lieutenant Commander Holloway H. Frost, "The Results and Effects of the Battle of Jutland," *United States Naval Institute Proceedings*, vol. 47, no. 9, (1921), 1327-1354, Captain A. W. Hinds, "Practical Lessons for the American Navy from the Battle of Jutland," *United States Naval Institute Proceedings*, vol. 47, no. 12, (1921), 1877-1884, and Captain Thomas C. Hart, "What Might Have Happened at Jutland," *United States Naval Institute Proceedings*, vol. 51, no. 7, (1925), 1143-1151. The influence of Jutland on Japanese naval thought is covered briefly in David C. Evans and Mark R. Peattie, *Kaigun: Strategy, Tactics, and Technology in the Imperial Japanese Navy, 1887-1941* (1997), 167-175.

flict of which Jutland was part, American naval commanders gained little experience coordinating the movements of large groups of geographically-dispersed warships.[13] Not until the early 1920s would the U.S. Navy begin to evaluate systematically its ability to conduct large-scale fleet maneuvers, when the service implemented annual problems designed to provide "practical experience" for "maneuvers on a large scale."[14] During many of these exercises, American commanders found themselves in circumstances that undoubtedly would have been familiar to the senior officers who had been present at Jutland. Confronted with difficult problems related to the command and control of naval forces, these men diligently pursued practical solutions in a restrictive budgetary environment. In so doing, they demonstrated a growing awareness of the importance of information in the practice of warfare at sea.

---

[13] The U.S. Navy's contribution to the allied war effort centered mainly on convoy escort duties. To be sure, these duties entailed significant command and control problems; however, they differed from large-scale fleet actions in at least two important respects. First, a majority of the ships in a convoy were merchant vessels, not warships. Second, the vessels in a convoy sailed in relatively close proximity to one another, so that the area in which they operated was much less geographically dispersed. For more on the U.S. Navy's role in protecting convoys during World War I, see A. B. Feuer, *The U.S. Navy in World War I: Combat at Sea and in the Air* (1999), 17-106, Elting E. Morison, *Admiral Sims and the Modern American Navy* (1942), 337-432, and William S. Sims, *The Victory at Sea* (1984 [1920]). An informative contemporary account is Captain Joseph K. Taussig, "Destroyer Experiences During the Great War: Convoying Merchant Ships," *United States Naval Institute Proceedings*, vol. 49, no. 2, (1923), 221-248.

[14] Commander in Chief, U. S. Fleet, "Report on United States Fleet Problem Number One," 19 June 1923, 3, National Archives Microfilm Collection (NAMC), "Records Relating to United States Navy Fleet Problems I to XXII, 1923-1941" (RRFP), Roll No. 1.

Reminders of War: Aircraft, Ships, and Submarines

On June 28th, 1914, an eighteen-year-old Bosnian nation-
alist assassinated the heir to the Austro-Hungarian throne,
setting in motion a series of events that culminated in the
outbreak of World War I.   Like their civilian masters and
army counterparts, the admirals of Europe's navies antici-
pated a short war, one most believed would be over by Christ-
mas.   When this state of affairs failed to materialize, naval
leaders, both belligerent and neutral, adapted accordingly.
The British Royal Navy, fearful of negating its advantage in
capital ships by operating too close to enemy shores, main-
tained a highly-effective distant blockade of the Central
Powers.   Germany, which at the start of the war had the
world's second most powerful navy,[15] decided in February 1915
to adopt a policy of unrestricted submarine warfare.[16]   Dip-
lomatic and operational considerations led to the abandonment
of this policy in September, at which time the German Navy
renewed efforts to entice the British Grand Fleet into a na-
val action close to the continent, where the numerically in-
ferior High Seas Fleet would possess the advantage of mine-
fields, long-range coastal artillery, submarines, and torpedo
flotillas.   Unsuccessful toward this end, in October 1916 the
German Navy launched a restricted submarine campaign, and on
February 1st, 1917, the Kaiser's government formally resumed

---

[15] A comparative assessment of the world's navies at the start of the
First World War is available in Paul G. Halpern, *A Naval History of
World War I* (1994), 1-20.
[16] German naval strategy at the start of the war was based on the as-
sumption that the Royal Navy would attempt a close-in blockade.   When
this did not happen, naval leaders had to pursue alternative strate-
gies.   Paul M. Kennedy, "The Development of German Operational Plans
against England, 1896-1914," 171-198, in *The War Plans of the Great
Powers, 1880-1914* (1979), ed. Paul M Kennedy, and Ivo Nikolai Lambi,
The Navy and German Power Politics, 1862-1914 (1984), 399-405, 416-424.

its policy of unrestricted submarine warfare. This decision ultimately brought the United States into the war on the side of the allies.

Even before American entry into World War I, the U.S. Navy had undergone some significant organizational changes. Over the objections of the Secretary of the Navy, Congress in 1915 created the Chief of Naval Operations (CNO) to oversee fleet operations and prepare plans for war.[17] Ostensibly, the Chief of Naval Operations held centralized authority, but in practice fleet commanders and bureau chiefs retained a high degree of autonomy. Nevertheless, because the CNO controlled war planning, he had tremendous influence over the future direction of the Navy. Over time, secretaries of the navy relied increasingly on their CNOs for technical guidance, especially with respect to the technologies that most affected fleet operations.[18] Indeed, less than two years after the first CNO assumed office, the Secretary of the Navy promulgated an order transferring administrative responsibility for naval radio communications from the Bureau of Navigation to the Office of the Chief of Naval Operations.[19]

The year 1915 also witnessed the first concerted effort since the Civil War to organize and systematically employ the nation's top scientists and engineers to solve the contemporary problems of naval warfare. Stirred by the sinking of the *Lusitania* and encouraged by some suggestions put forth by

---

[17] According to one highly-respected naval historian, establishment of this billet "was the most important institutional innovation in the Navy Department since the creation of the new bureaus in 1842." William R. Braisted, *The United States Navy in the Pacific, 1909-1922* (1971), 182.

[18] Robert W. Love, "Introduction," xiii-xxii, in *The Chiefs of Naval Operations* (1980), ed. Robert W. Love. See also *American Secretaries of the Navy, 1775-1972*, vol. 2 (1980), ed. Paolo E. Coletta.

[19] Linwood S. Howeth, *History of Communications-Electronics in the United States Navy* (1963), 233-235.

Thomas Edison in an interview with the *New York Times*, on July 7th, 1915, Secretary of the Navy Josephus Daniels wrote the distinguished American inventor to request assistance in organizing a "department of invention and development."[20] Edison responded enthusiastically to Daniels's request, and after consulting with the Secretary he asked eleven professional societies to provide two members each to a new advisory body, designated soon thereafter as the Naval Consulting Board.[21]

The individuals selected to serve on the Naval Consulting Board saw membership as a great honor, and all served without compensation throughout the war. In addition to Edison and his principal assistant, the Board contained some of America's most well-respected and accomplished engineers, including Leo Baekeland, Peter Cooper Hewitt, Elmer Sperry, and Willis R. Whitney.[22] In general, the Board was not particularly effective,[23] although it did make contributions in

---

[20] Daniels wrote that such an organization should be one "to which ideas and suggestions, either from the service or civilian inventors, can be referred for determination as to whether they contain practical suggestions for us to take up and perfect." Josephus Daniels to Thomas Edison, 7 July 1915. This letter is reproduced in its entirety in Lloyd N. Scott, *Naval Consulting Board of the United States* (1920), 286-288.

[21] Initially, the new body was referred to as the Naval Advisory Board; however, after several "top naval officers" objected for semantic reasons (apparently believing that the word "advisory" implied a subordinate role for the Navy itself), the name was changed to the Naval Consulting Board. David Kite Allison, *New Eye for the Navy: The Origin of Radar at the Naval Research Laboratory* (1981), 24.

[22] Scott's work contains a listing of all twenty-four members and the organizations they represented. Scott, *Naval Consulting Board of the United States*, 11-13.

[23] For more on specific Board activities, as well as assessments of its overall effectiveness, in addition to Scott see Thomas P. Hughes, *Elmer Sperry: Inventor and Engineer* (1971), 243-274, Daniel J. Kevles, *The Physicists: The History of a Scientific Community in Modern America* (1979), 105-109, 117-126, Allison, *New Eye for the Navy*, 19-32, 37-38, George Wise, *Willis R. Whitney, General Electric, and the Origins of U.S. Industrial Research* (1985), 182-198, and William M. McBride, "The 'Greatest Patron of Science'? The Navy-Academia Alliance and U.S. Naval Research, 1896-1923," *The Journal of Military History*, vol. 56, no. 1, (1992), 7-33.

several areas, most notably in organizing an industrial pre-
paredness campaign and in developing methods and devices for
combating German submarines, one of the most pressing techni-
cal problems of the war.[24] The Board also created a commit-
tee, chaired by Cooper Hewitt, dedicated specifically to
problems in wireless communications.[25] Although this com-
mittee evidenced little interest in proposed methods for
improving ship-to-ship communications, it did investigate
thoroughly the practicability of radio remote control, espe-
cially for pilotless flying bombs.[26] The Board's focus on
remotely-piloted airborne weapons produced no immediate
results,[27] but Cooper Hewitt's ability to obtain Congres-
sional funding for airborne wireless apparatus benefited the
Navy in its efforts to develop reliable radios for piloted
aircraft.[28]

---

[24] The extent to which the Board contributed to the development of anti-
submarine warfare technologies remains a matter of debate. For a criti-
cal assessment, see McBride, "The 'Greatest Patron of Science'?," 24-27,
32-33. For more positive evaluations, see Allison, New Eye for the
Navy, 24, and Scott, Naval Consulting Board of the United State, 67-108.
Of course, Scott's account reflects his proximity to events and his role
as a liaison officer to the Naval Consulting Board.
[25] Scott, Naval Consulting Board of the United States, 14.
[26] Not coincidentally, Cooper Hewitt was also a member of the Naval Con-
sulting Board's Committee on Aeronautics. Ibid.
[27] The successful deployment of these types of weapons lay several dec-
ades in the future. In general, the early history of remotely-piloted
airborne vehicles has attracted little scholarly interest. Among pub-
lished accounts, the period prior to the Second World War is covered
most thoroughly in Kenneth P. Werrell, The Evolution of the Cruise Mis-
sile (1985), 1-40, 235. See also Charles L. Keller, "The First Guided
Missile Program: The Aerial Torpedo," American Aviation Historical So-
ciety Journal, vol. 20 (1975), 268-273.
[28] Howeth, History of Communications-Electronics, 210, 343-347. Funding
for programs supported by members of the Naval Consulting Board became
more readily available after passage of the Naval Appropriations Act of
1916. For more on this important piece of legislation, see Braisted,
The United States Navy in the Pacific, 186-208, Harold and Margaret
Sprout, The Rise of American Naval Power, 1776-1918 (1990 [1939]), 379-
392, and George W. Baer, One Hundred Years of Sea Power: The U.S. Navy,
1890-1990 (1994), 59-63.

The first successful installation of radio equipment on a U.S. Navy airplane took place in 1912, when Ensign Charles Maddox - one of the officers who had been assigned to evaluate the fleet's tactical employment of wireless during the previous year's battle practice - took a break from his studies at Harvard University to design and build an experimental aircraft radio. Maddox's apparatus consisted of a quenched spark gap transmitter and a crystal receiver, the latter of which had to be suspended from the operator's neck by means of a sling.[29] Not surprisingly, reception was poor, and only very strong radio signals could be heard above the engine noises and plane vibrations. Efforts to transmit while airborne were more successful, and on July 26th a ship received a message sent by Maddox at a range of approximately three nautical miles. With minor modifications to his equipment, Maddox eventually succeeded in transmitting messages at distances of up to fifteen nautical miles (Figure 3-2).[30]

Despite Maddox's exploits, the Navy did not vigorously pursue the development of aircraft radio until 1916, after a study prepared by the Naval Radio Telegraphic Laboratory indicated that tactically useful radio ranges could be obtained with equipment as light as one hundred pounds.[31] Lieutenant

---

[29] In all likelihood, Maddox adopted such an arrangement in order to minimize vibrations on the receiver.

[30] Howeth, *History of Communications-Electronics*, 189-191, 524.

[31] In the mid-to-late 1910s, the Navy envisioned using its air arm primarily for scouting and the spotting of shot, so relatively light radios (i.e., those not significantly reducing aircraft endurance) that provided reliable communications at distances up to the maximum cruising radii of contemporary aircraft were critical. The Navy's attitude toward aviation during this period is covered in Charles M. Melhorn, *Two-Block Fox: The Rise of the Aircraft Carrier, 1911-1929* (1974), 6-20, Thomas C. Hone, Norman Friedman, and Mark D. Mandeles, *American & British Aircraft Carrier Development, 1919-1941* (1999), 11-24, and William M. McBride, *Technological Change and the United States Navy, 1865-1914* (2000), 127-137. The Naval Radio Telegraphic Laboratory's report indicated that ships should be able to receive signals from an airplane with a one hundred pound transmitter and a fifty foot trailing wire an-

Commander Stanford Hooper, who had taken over as head of the Bureau of Steam Engineering's Radio Division in April 1915, discussed this report with the Chief of the Bureau of Steam Engineering, who directed him to procure the desired equipment.[32] Under Hooper's direction, the Radio Division solicited competitive bids and selected four commercial companies from which to purchase experimental sets.[33] To test this equipment, the Bureau established a special laboratory for aircraft radio at the Naval Air Station in Pensacola, Florida.[34]

Preliminary investigations at the Naval Aircraft Radio Laboratory in Pensacola found that none of these experimental sets performed as well as anticipated. As had been the case four years earlier during the tests performed by Maddox, the airborne reception of radio signals remained problematic. In addition to acoustic disturbances, such as wind rush and engine noise, radio receivers also were susceptible to electrical interferences created by vibrating equipment and the in-

---

tenna at distances between fifteen and thirty nautical miles. Howeth, *History of Communications-Electronics*, 267.

[32] Shortly after the outbreak of World War I, the Navy detached Hooper from his post as Atlantic Fleet Radio Officer and sent him to Europe as an observer. He returned to the United States in early 1915, at which time he served briefly on a radio reorganization committee. After an assignment at the Bureau of Steam Engineering, where he served as head of the Radio Division, he assumed command of the destroyer *USS Fairfax* in 1917. In August 1918, the Navy again assigned him to the Bureau of Steam Engineering, where he served for the second time as head of the Radio Division. Howeth, *History of Communications-Electronics*, 113-114, and Susan J. Douglas, "Technological Innovation and Organizational Change: The Navy's Adoption of Radio, 1899-1919," 165, in *Military Enterprise and Technological Change: Perspectives on the American Experience* (1985), ed. Merritt Roe Smith.

[33] Thirteen different companies submitted bids. The four companies that received contracts were Sperry Gyroscope, De Forest Radio Telephone and Telegraph, American Marconi, and E. J. Simon. Howeth, *History of Communications-Electronics*, 267-269. See also T. Johnson, "Naval Aircraft Radio (First Half)," *Proceedings of the Institute of Radio Engineers*, vol. 8, no. 1, (1920), 5-16.

[34] Louis A. Gebhard, *Evolution of Naval Radio-Electronics and Contributions of the Naval Research Laboratory* (1979), 16-17.

duction effects of engine ignition systems. The Naval Aircraft Radio Laboratory solved the first of these dilemmas by crafting a flannel-lined leather helmet with soft rubber ear cups (Figures 3-3).[35] Unfortunately for the Navy, no similarly simple solution existed for the latter difficulty. To minimize the effects of electrical disturbances, the Navy not only had to acquire receivers that were less susceptible to interference, it also had to build shock-absorbing mountings upon which to place these receivers. In addition, the Navy had to incorporate shielding around existing aircraft ignition systems, a step that improved radio reception but reduced engine efficiency.[36]

While the problem of electrical interference would plague radio engineers for decades to come,[37] by the end of World War I U.S. Navy aircraft could send and receive signals with fair reliability. For long-distance communications, the Navy relied primarily on high-power spark transmitters, which could be received at distances of up to 300 nautical miles under normal operating conditions.[38] For shorter distances, the Navy, in conjunction with the General Electric Company, developed a series of multi-purpose continuous wave vacuum tube transmitters. Most of these devices could be operated at multiple discrete frequencies and were capable of transmitting in either a telegraphic (i.e., Morse Code) or a tele-

---

[35] T. Johnson, "Naval Aircraft Radio (Second Half)," *Proceedings of the Institute of Radio Engineers*, vol. 8, no. 2, (1920), 109-110.

[36] Ibid., and Howeth, *History of Communications-Electronics*, 269.

[37] Even after World War II, naval radio pioneer Albert Hoyt Taylor would remark: "The conquest of ignition disturbances in planes is not completed, even at this time." A. Hoyt Taylor, *Radio Reminiscences: A Half Century* (1948), 113.

[38] T. Johnson, "Naval Aircraft Radio (First Half)," 32-40. Often, signals were received at much greater distances, but the Navy considered 300 nautical miles to be ". . . the dependable operating range in daily service." T. Johnson, "Naval Aircraft Radio (Second Half)," 87.

phonic (i.e., voice) mode.[39]   The latter mode was the pre-
ferred method of operation, as it provided the fastest avail-
able means of air-to-ship communication, but radio operators
still frequently communicated via radio telegraphy because
Morse Code signals could more easily be received through con-
ditions of static.[40]

The United States Navy's endeavors to obtain suitable
radio equipment for its aircraft paralleled efforts to im-
prove ship-to-ship wireless communications. As the First
World War dragged on, many within the Navy grew fearful that
American radio apparatus lagged behind state of the art
European equipment. Addressing this concern, in June 1915
the Bureau of Steam Engineering hired six new civilian radio
experts and assigned them to various navy yards throughout
the country. To avoid duplication of effort, the Bureau
designated different yards as the lead facilities for spe-
cific categories of radio apparatus.[41] Between 1915 and the
end of the war, work at these facilities led to some notable
improvements in naval radio equipment. The Radio Test Shop
at the Washington Navy Yard, for example, developed a series
of extremely dependable receivers that served as the serv-
ice's standard for nearly a decade.[42] More durable than com-
parable civilian models – and therefore better able to with-
stand shipboard vibrations and the shock of gunfire – these
receivers were the first to have calibrated dials so that op-

---

[39] The operator selected the mode of transmission; telegraphic and tele-
phonic transmissions could not be performed simultaneously. T. John-
son, "Naval Aircraft Radio (Second Half)," 106-108.
[40] Ibid., 87-108.
[41] For example, the Washington Navy Yard became responsible for receiv-
ers, amplifiers, and wave-meters, while the Mare Island Navy Yard as-
sumed responsibility for transformers, motor-generators, and quenched
spark gap transmitters. A full list of navy yards and the categories
of equipment for which they primarily were responsible is contained in
Howeth, *History of Communications-Electronics*, 213.
[42] Gebhard, *Evolution of Naval Radio-Electronics*, 18-20.

erators could tune quickly to specified frequencies.[43] In later models the Navy substituted vacuum tube detectors for crystal detectors, which, when combined with heterodyned methods of reception, significantly enhanced both the reliability and the sensitivity of these receivers.[44]

As for radio transmitters, the Navy gradually began shifting from spark sets to arc, alternator, and vacuum tube equipment.[45] During World War I, most Navy shore stations employed high-power arc transmitters,[46] but in late 1917 the Navy oversaw installation of two separate 50 kilowatt Alexanderson alternators at the American Marconi station in New Brunswick, New Jersey.[47] The Bureau of Steam Engineering's

---

[43] Howeth, *History of Communications-Electronics*, 216-217.

[44] A heterodyne receiver is one that mixes an incoming frequency with an internally-generated one in order to produce a beat frequency. As one author described the process: "If frequencies are being received . . . [at] 300,000 cycles per second, in order to 'heterodyne' one would generate in the receiving apparatus a frequency say of 301,000 cycles per second. The result of combining the two would be that the 'beat' note would equal the difference between the two or 1000 cycles per second which could easily be transformed into tones suitable for the ear of the listener. Mysterious and magical no doubt, but a scientific fact nevertheless." Gleason L. Archer, *History of Radio to 1926* (1938), 89. See also Samuel S. Robison, *Robison's Manual of Radio Telegraphy and Telephony for Use of Naval Radiomen*, 7th revised edition (1927), 534-535.

[45] In this respect the Navy's radio program paralleled civilian developments. For a detailed analysis of the transition from spark to continuous wave radio, consult Aitken, *The Continuous Wave*.

[46] For example, the Navy installed a 100 kilowatt arc transmitter in the Panama Canal Zone, a 350 kilowatt arc transmitter at Pearl Harbor, Hawaii, and a 500 kilowatt arc transmitter at Annapolis, Maryland. When General John Pershing, Commander of the American Expeditionary Forces, requested the establishment of radio facilities in Europe for trans-Atlantic communications, the Navy began construction of a 1,000 kilowatt arc transmitter station near Bordeaux, France. This station was not completed until 1920, at which time the Navy turned it over to the French government. Howeth, *History of Communications-Electronics*, 239-245, 253-254, and Robert S. Griffin, *History of the Bureau of Engineering Navy Department During the World War* (1922), 91-96.

[47] The Navy assumed control of all shore stations that handled marine radio traffic immediately after American entry into the war. Most of these facilities were owned by the American Marconi Company. Aitken, *The Continuous Wave*, 286-288. For more on development of the Alexanderson alternator, see James E. Brittain, *Alexanderson: Pioneer in American Electrical Engineering* (1992), 64-71, 76-84, 99-132, Archer,

Radio Division had been aware of the possible benefits of an alternator-driven transmitter as early as 1915, but had been unable to reach a suitable agreement with General Electric over terms of sale.[48] Once the New Brunswick station was up and running on the new alternators, however, the Navy quickly concluded that all of its shore-based arc transmitters would soon be outclassed.[49] This conclusion was reinforced the following year when General Electric, with the support and encouragement of naval officials, successfully installed an even more powerful 200 kilowatt alternator at the New Brunswick station. So impressed was the Navy with the performance of this station that after the war it made a concerted effort to prevent General Electric from selling Alexanderson alternators to the British.[50]

In spite of the Navy's enthusiasm for alternator-driven transmitters, the sheer size of these devices precluded their use aboard ship (Figure 3-4).[51] At the outbreak World War I, the fleet relied primarily on spark transmitters for ship-to-ship radio communications, in part because the poor perform-

---

History of Radio to 1926, 115-121, 137-141 and Leonard S. Reich, *The Making of American Industrial Research: Science and Business at GE and Bell, 1876-1926* (1985), 218-224.

[48] Aitken, *The Continuous Wave*, 311-312.

[49] T. Johnson, "Naval Radio Tube Transmitters," *Proceedings of the Institute of Radio Engineers*, vol. 9, no. 5, (1921), 381-433, and Griffin, *History of the Bureau of Engineering*, 94-95, 99-100. Of the Alexanderson alternator, Howeth writes that it became "the most sought after transmitting equipment of the time for long-distance point-to-point circuits." Howeth, *History of Communications-Electronics*, 254.

[50] Specifically, the Navy sought to prevent the sale of two dozen Alexanderson alternators to Marconi's companies. Eventually, discussions between representatives of General Electric and the U.S. Navy led to the establishment of the Radio Corporation of America (RCA). For more on the formation of RCA, see Josephine Young and Everett Needham Case, *Owen D. Young and American Enterprise: A Biography* (1982), 173-191, Brittain, *Alexanderson*, 137-158, Susan J. Douglas, *Inventing American Broadcasting, 1899-1922* (1987), 284-288, Aitken, *The Continuous Wave*, 322-479, 563-571, Howeth, *History of Communications-Electronics*, 353-370, and Archer, *History of Radio to 1926*, 159-189, 375-387.

[51] Howeth, *History of Communications-Electronics*, 254.

ance of the Great White Fleet's radio-telephones had cur-
tailed the Navy's interest in arc sets. Although the Navy
did install arc transmitters on some of its larger warships,
by the time of America's entry into the war the Bureau of
Steam Engineering clearly viewed the vacuum tube as superior
to the arc for ship-to-ship communications.[52] In March 1917,
the Bureau contracted with Western Electric for fifteen of
the company's new vacuum tube radio-telephone transceivers.[53]
Testing confirmed their suitability for naval service, and
the Navy eventually ordered more than one thousand of these
sets over the course of the war. Officially designated the
"CW 936" by the Bureau of Steam Engineering, this radio-tele-
phone apparatus could be set to transmit at any one of five
discrete frequencies as selected by the operator through the
flick of a switch. Significantly, the CW 936 provided the
United States Navy with an effective means of ship-to-ship
voice communications for the first time.[54]

By providing a reliable method of ship-to-ship voice
communications, the CW 936 greatly enhanced the Navy's abil-
ity to support the allied anti-submarine warfare campaign.
During convoy duty, escort commanders generally maintained
strict radio silence, but when chaotic conditions arose dur-
ing an enemy submarine attack the radio-telephone provided an

---

[52] Griffin, *History of the Bureau of Engineering*, 109-110, 115-125.
When located in close proximity to receiving equipment, arc transmit-
ters interfered with incoming radio signals. This problem persisted
even when there existed a large amount of frequency separation between
the transmitted and received signals. Shore installations could avoid
interference by adequately separating reception and transmission fa-
cilities, but this option was not available on board a ship. Gebhard,
Evolution of Naval Radio-Electronics, 6-10.
[53] The Navy had been experimenting with Western Electric radio-tele-
phones for about a year prior to placing this order. Griffin, *History
of the Bureau of Engineering*, 99.
[54] Johnson, "Naval Radio Tube Transmitters," 393-397, Gebhard, *Evolution
of Naval Radio-Electronics*, 12-15, and Howeth, *History of Communica-
tions-Electronics*, 254. The CW 936 served as standard Navy equipment
for more than a decade.

invaluable asset. Admiral William S. Sims, who served as the Commander of the United States Naval Forces Operating in European Waters, wrote in his memoirs that "running conversations were frequently necessary between destroyers and the ships which they had been detailed to escort."[55] Sims went on to portray some typical scenarios:

> 'Being pursued by a submarine Lat. 50N., Long. 15 W.' – cries of distress like this were common. Another message would tell of a vessel that was being shelled; another would tell of a ship that was sinking; while other messages would give the location of lifeboats which were filled with survivors and ask for speedy help . . . . At times the surface of the ocean might be calm . . . yet the air itself would be uninterruptedly filled with these reminders of war.[56]

Sims's description, accurate so far as it goes, fails to address those facets of the United States Navy's system of tactical radio communications that did not function very effectively. For example, after several U.S. battleships joined the British Grand Fleet as the Sixth Battle Squadron in late 1917, dismayed American and British naval personnel discovered that their ships could not communicate with one another via wireless. American and British radio sets operated within different frequency ranges, and the disparity in these ranges was so great that U.S. Navy receivers could not receive signals from Royal Navy transmitters. The opposite also was true.[57] To solve this dilemma, most of the Sixth

---

[55] Sims, *The Victory at Sea*, 120.
[56] Ibid., 120-121.
[57] The Royal Navy operated at frequencies over 2,000 kilocycles per second, while the U.S. Navy generally operated at frequencies between 500 and 1,500 kilocycles per second. Howeth, *History of Communications-Electronics*, 287.

Battle Squadron's radio equipment had to be replaced with British-type apparatus.[58] Furthermore, U.S. Navy communications security was quite poor, as few American naval officers appreciated their adversary's capabilities in communications intelligence. Fortunately for the Americans, Royal Navy officials quickly pointed out this deficiency and helped remedy the situation by creating and providing joint security publications for American ships.[59]

Not all inefficiencies in the U.S. Navy's system of tactical radio communications could be fixed so easily, however, and a number of problems persisted long after the Armistice was signed in November 1918. Despite the development of arc and vacuum tube equipment, a majority of American naval vessels continued to carry only spark transmitters for ship-to-shore communications. Because the operation of spark sets interfered with the reception of other radio signals, ships could not simultaneously use their ship-to-shore and tactical radio circuits. Another dilemma centered on personnel, as the number of adequately trained radio operators declined precipitously after the war. This decline was far more severe than the Navy had anticipated, and created significant manning problems for the fleet.[60] Expressing his concerns to the Secretary of the Navy in 1920, the Atlantic Fleet Commander-in-Chief reported "a serious shortage of men available for radio, either with previous experience or for training," and concluded that, "this condition has been brought about .

---

[58] Ibid., 286-288, 291-292, and Hezlet, *Electronics and Sea Power*, 134-136.

[59] Howeth, *History of Communications-Electronics*, 292-294.

[60] The Atlantic Fleet Commander-in-Chief's annual report for fiscal year 1920 reveals there were nearly as many men under instruction to become radiomen as there were qualified radiomen. Commander in Chief, U.S. Atlantic Fleet to Secretary of the Navy, 1 July 1920, 24-25, NAMC, "Annual Reports of Fleets and Task Forces of the U.S. Navy, 1920-1941" (ARFTF), Roll No. 1.

. . by discharge of practically all the prewar and war personnel [and by] the high wages paid radio operators on merchant ships."[61]

In all likelihood, however, the most significant problem faced by the Navy with respect to tactical communications was the lack of a standard system for managing the information obtained through radio. Passage of the Naval Appropriations Act of 1916 provided the Bureau of Steam Engineering with sufficient funds to create standard shipboard allowances for radio equipment,[62] but the Bureau had no real authority to develop uniform methods and procedures for processing the information made available by radio. Such authority rested primarily with the fleet commanders, but prior to 1923 they had limited opportunities to address this issue.[63] Almost by default, subordinate commanders and individual commanding officers were left on their own to determine how best to integrate radio reports with the other information available to them, an approach that created numerous inefficiencies.

---

[61] Ibid., 23. The quality of radio training also may have declined after war as the Navy had to close down its advanced radio school at Harvard University, a facility through which nearly half of all U.S. Navy radiomen had passed. Captain E. L. Bennett, "History of Training Division, Bureau of Navigation, Navy Department, During World War," 11 November 1920, located in NADC, Record Group 45 - Records of the Office of Naval Records and Library, Subject File 1920, Filing Designator ZGU, Box No. 911.

[62] Howeth, *History of Communications-Electronics*, 219.

[63] From the end of World War I until 1922, the U.S. Navy was divided into three fleets: Atlantic, Pacific, and Asiatic (the last of these functioned more as a squadron than as a fleet). A major reorganization took place in December 1922, when the Atlantic and Pacific Fleets were combined into a single U.S. Fleet, itself consisting of a Battle Fleet, commanded by an admiral, and a Scouting Fleet, commanded by a vice admiral. Confusion over nomenclature and a desire to reorganize eventually led the Navy to rename the Battle and Scouting Fleets as the Battle Force and the Scouting Force, respectively. Marie B. Allen, *Annual Reports of Fleets and Task Forces of the U.S. Navy, 1920-1941* (1974), 2-3, Commander in Chief, U.S. Fleet to Secretary of the Navy, 1 July 1923, NAMC, ARFTF, Roll No. 4, and Annual Report of Commander in Chief, U.S. Fleet for FY 1931, circa July 1931, 1-2, NAMC, ARFTF, Roll No. 8.

To begin, because each officer developed his own methods and procedures, personnel had to learn a new system each time they transferred to a new ship. In addition, some commanders were simply better than others at developing ways to manage and process tactical information. This posed a particular problem for the fleet commanders, whose ability to coordinate large fleet movements depended in part on the interchange-ability of individual units. Finally, by the early 1920s radio was but one of several new technologies that provided naval commanders with access to tactically relevant informa-tion. The marriage of aircraft and radio, along with the development of radio direction finding and underwater sound equipment, changed both the distances and dimensions at which opposing forces could be detected and tracked. The net effect of these developments was to create an increasingly complex environment, one in which naval commanders came to depend heavily on the efficacy of their shipboard command and control systems.

Command at Sea: The U.S. Navy in the 1920s

In February 1923, the United States Navy conducted its
first large-scale fleet exercise, a simulated attack on the
Panama Canal involving a majority of American naval forces.
In this inaugural fleet exercise, appropriately designated
Fleet Problem Number One, vessels of the United States
Scouting Fleet operated as a friendly "BLUE" fleet tasked to
protect the Canal against attack by an enemy "BLACK" fleet
consisting of warships from the United States Battle Fleet.[64]
Broadly speaking, the Navy's goals in Fleet Problem Number
One were: (1) to train the fleet in as realistic a manner as
possible, (2) to provide technical evaluation of ships and
various kinds of naval equipment, and (3) to test war plans
and fleet doctrine.[65] Unfortunately for the Navy, problems
of command and control were a recurrent theme in all three of
these areas.

The chief umpire for Fleet Problem Number One was Admi-
ral Hilary P. Jones, the Commander-in-Chief of the United
States Fleet, whose responsibilities included the monitoring
and evaluation of both BLACK and BLUE forces. In his final
report on the Navy's inaugural fleet exercise, Jones noted
numerous deficiencies related specifically to issues of com-
mand and control,[66] going so far as to write that fleet com-

---

[64] The Scouting Fleet was augmented by the Control Force, the Battle
Fleet by the Base Force. Commander in Chief, U.S. Fleet to Secretary
of the Navy, 1 July 1923, NAMC, ARFTF, Roll No. 4.
[65] Mark A. Campbell, "The Influence of Air Power Upon the Evolution of
Battle Doctrine in the U.S. Navy, 1922-1941," M.A. Thesis, University
of Massachusetts at Boston (1992), 120-121.
[66] Jones's comments referred principally to BLUE Fleet communications,
as the BLACK Fleet maintained radio silence during most of the exer-
cise. Nevertheless, his commentary clearly pertained to all U.S. naval
forces, not just those of the Scouting (BLUE) Fleet. For evidence of
this see Commander in Chief, U. S. Fleet, "Report on United States
Fleet Problem Number One," 19 June 1923, 4-5, 136-139, NAMC, RRFP, Roll

munications ". . . as carried through in this problem show a similarity, on a small scale, with the British Fleet before and during the Battle of Jutland."[67] The admiral began by pointing out that the fleet possessed an inadequate number of radio channels, which had resulted in congested circuits and ineffective tactical communications throughout the exercise.[68] According to Jones, the fleet also lacked sufficient procedures for prioritizing messages, or as he stated succinctly: "Important information was delayed by the transmission of relatively unimportant information."[69] This point had been emphasized by the BLUE Fleet Commander-in-Chief, who in his own report included a copy of all messages sent from or intercepted by his flagship along with a wry comment that the amount of tactically relevant information could have "been reduced to about six messages."[70] Finally, Jones reported that because commanding officers generated so many duplicated reports, fleet commanders had considerable difficulty maintaining a coherent tactical picture during the exercise.[71] In a nutshell, Fleet Problem Number One demonstrated to the U.S. Navy's senior leadership that fleet commanders did not yet possess the necessary means to manage and process all available tactical information.

Jones's observations were supported by and based largely upon reports submitted by his subordinate commanders and individual commanding officers. For example, the commanding officer of USS Delaware remarked that his main problem "was

No. 1, and Commander in Chief, U.S. Fleet to Secretary of the Navy, 1 July 1923, NAMC, ARFTF, Roll No. 4.

[67] Ibid., 138.

[68] Commander in Chief, U.S. Fleet, "Report on United States Fleet Problem Number One" 19 June 1923, 137-138, NAMC, RRFP, Roll No. 1.

[69] Ibid., 138.

[70] Ibid., 115. The final report for Fleet Problem One contained extracts from the reports of the BLACK and BLUE Fleet Commanders.

[71] Ibid., 138.

one of communications," and lamented the fact that "the average length of time to get through a contact report was about two hours."[72] The Commander of a BLUE Fleet destroyer squadron reported the same type of lengthy delays, noting that these delays had resulted in "great confusion."[73] Other officers were even more blunt. The Commander of the Scouting Fleet's Air Patrol commented that radio communications between his aircraft and vessels of the BLUE Fleet "were very unsatisfactory," while several destroyer commanding officers stated simply that ship-to-ship communications "were inadequate" and had "failed completely."[74]

Nor were the communications difficulties experienced in Fleet Problem Number One limited to radio communications. The BLACK Fleet, which maintained radio silence during most of the exercise, encountered numerous problems attempting to execute existing visual signalling procedures. Screening vessels in particular had considerable trouble maintaining contact with the main body, leading one squadron commander to state that "[p]resent means of destroyer communications by visual for great distance are very unsatisfactory,"[75] and one division commander to suggest that the Navy had greatly underestimated "the importance of visual communication at long

---

[72] Commanding Officer, USS Delaware to Commander in Chief, Scouting Fleet, undated but known written the last week in February 1923. Located in Commander-in-Chief, U.S. Fleet, "Report on United States Fleet Problem Number One," 19 June 1923, 116, NAMC, RRFP, Roll No. 1.
[73] Commander, Destroyer Squadron Nine to Commander in Chief, Scouting Fleet, undated but known written in late February 1923. Located in Ibid., 120.
[74] Commander, Air Patrol to Commander in Chief, Scouting Fleet, Commanding Officer, USS Corry to Commander in Chief, Battle Fleet, Commanding Officer, USS Sumner to Commander in Chief, Battle Fleet, and Commanding Officer, USS Selfridge to Commander in Chief, Battle Fleet, all undated but known written in late February 1923. Located in Ibid., 117, 104, 101.
[75] Commander, Destroyer Squadron Twelve to Commander in Chief, Battle Fleet, 27 February 1923, NAMC, RRFP, Roll No. 1.

range."[76] Message delays frequently exceeded two or three hours, with the result that warships in the screen had great difficulty maintaining proper position.[77] As one destroyer commanding officer aptly summarized the situation: "[T]he system of visual communication employed was, at best, unsatisfactory. . . . accurate and efficient communication is imperative in order that the scouts may be kept informed as to the movement of the fleet. The whole basis of the communication system is embodied in one principle – the dissemination of information. If the information received is faulty and incorrect it does more harm than good."[78]

Most of the Navy's senior leadership recognized that these problems would have to be addressed and corrected before the next fleet exercise. In July 1923, Chief of Naval Operations (CNO) Edward W. Eberle appointed a special committee to make recommendations for improvement.[79] Minutes and hand-written notes from this committee reveal great concern over the demonstrated unreliability of communications between a fleet's main body and its screening vessels. Committee members felt that solutions ultimately had to come from the material bureaus and the fleet,[80] but uniformly agreed that

---

[76] Commander, Destroyer Division Thirty-One to Commander in Chief, Battle Fleet, undated but known written in late February 1923. Located in Commander in Chief, U.S. Fleet, "Report on United States Fleet Problem Number One," 19 June 1923, 96, NAMC, RRFP, Roll No. 1.

[77] Commanding Officer, USS Wood to Commander in Chief, Battle Fleet, Commanding Officer, USS Corry to Commander in Chief, Battle Fleet, Commanding Officer, USS Sumner to Commander in Chief, Battle Fleet, and Commanding Officer, USS Robert Smith to Commander in Chief, Battle Fleet, all undated but known written in late February 1923. Located in Ibid., 100, 104, 106.

[78] Commanding Officer, USS Melvin to Commander in Chief, Battle Fleet, undated but known written in late February 1923. Located in Ibid., 105.

[79] Chief of Naval Operations to Captain William H. Standley, 25 July 1923, NAMC, RRFP, Roll No. 1. Significantly, Eberle initiated this action only four days after assuming his duties as CNO.

[80] In general, officers within the Office of the Chief of Naval Operations took care to avoid infringing upon the authority of the fleet commanders. As such, the CNO generally phrased correspondence con-

future exercises should continue to test rigorously the fleet's system of tactical communications. Several officers suggested that scenarios for future fleet problems should require commanders to employ voice radio-telephone and/or tactical radio direction finding, and at least one officer argued that the next fleet problem should include "simulation of a complicated action, in which, during the smoke and confusion of battle, the O.T.C. is faced with the necessity of communicating by radio with some of his own units . . . whose identity is uncertain and whose flagship and unit organization is destroyed or crippled."[81]

That Eberle would take steps to address the command and control problems which arose during Fleet Problem Number One is hardly surprising. Characterized by more than one biographer as a technophile,[82] early in his career Eberle served as the flag lieutenant for the North Atlantic Fleet, during which time he compiled instructions and codes for some of the Navy's earliest shipboard radio communications equipment.[83] In 1922, while serving as the Pacific Fleet Commander-in-Chief, Eberle convened a special board to investigate the modernization of capital ships' radio installations,[84] and in early 1923 he served as the BLACK Fleet Commander (Commander-in-Chief, Battle Fleet) during Fleet Problem Number One. Perhaps as much as any senior naval officer of the day,

cerning fleet problems as requests or suggestions, rather than as directives. Campbell, "The Influence of Air Power Upon the Evolution of Battle Doctrine," 121.

[81] Hand-written note by an unknown officer, attached to "Minutes of Meeting of Special Board to Consider Problems for the Winter Maneuvers of the U.S. Fleet," 31 July 1923, NAMC, RRFP, Roll No. 1.

[82] Richard W. Turk, "Edward Walter Eberle," 36-46, in The Chiefs of Naval Operations (1980), ed. Robert W. Love, and Clark G. Reynolds, Famous American Admirals (2002 [1978]), 105-106.

[83] Turk, "Edward Walter Eberle," 38, and Reynolds, Famous American Admirals, 105-106.

[84] Commander in Chief, Battle Fleet to Secretary of the Navy, 12 January 1923, NAMC, ARFTF, Roll No. 3.

Eberle could appreciate the difficulties inherent to the command and control of large, steam-powered, balanced fleets.[85]

Yet even in his role as the Chief of Naval Operations, Eberle could only do so much. In the early 1920s a confluence of events, including more expensive naval technologies, the perceived need for a greater U.S. Navy presence in the Pacific, and the famous arms limitations treaties of the Washington Naval Conference, created a need for greater fiscal austerity within the Navy Department.[86] Furthermore, even though Navy regulations gave Eberle the authority to "coordinate all repairs and alterations to vessels and the supply of personnel and material thereto,"[87] in practice he generally acceded to the decisions of his fleet commanders and bureau chiefs. Like Eberle, these senior officers frequently felt constrained by the Navy Department's tight budget, and fleet commanders in particular often identified obsolete radio equipment as a primary reason for ship-to-ship communications problems.[88]

---

[85] A "balanced fleet" is one of multiple warship types, each intended to fulfill a specific mission or missions. For more on this concept, see Thomas C. Hone, "Spending Patterns of the United States Navy, 1921-1941," *Armed Forces and Society*, vol. 8, no. 3, (1982), and Waldo Heinrichs, "The Role of the United States Navy," 205-211, in *Pearl Harbor as History* (1973), ed. Dorothy Berg and Shumpei Okamoto.

[86] Spending on all U.S. Navy ships in commission was just over $192 million in fiscal year 1922. Not until fiscal year 1939 would this amount be exceeded. Hone, "Spending Patterns of the United States Navy," 447.

[87] From Article 233 of the 1924 Navy regulations. Quoted in Robert W. Love, "Introduction," xviii, in Love, ed., *The Chiefs of Naval Operations*.

[88] Commander, Battleship Divisions, Battle Fleet to Commander in Chief, Battle Fleet, 17 June 1924, NAMC, ARFTF, Roll No. 4, Commander, Battleship Divisions, Battle Fleet to Commander in Chief, Battle Fleet, 30 May 1925, Commander in Chief, U.S. Fleet to Secretary of the Navy, 9 July 1925, Commander in Chief, Scouting Fleet to Commander in Chief, U.S. Fleet, 16 June 1925, Commander in Chief, Scouting Fleet to Commander in Chief, U.S. Fleet, 25 June 1926, Commander in Chief, U.S. Fleet to Secretary of the Navy, 25 August 1926, all on NAMC, ARFTF, Roll No. 5, Commander in Chief, Battle Fleet to Commander in Chief,

In spite of these budgetary constraints, many of the Navy's senior officers aggressively sought ways to improve the fleet's system of tactical command and control. During the 1920s, the most successful of these officers was Admiral Samuel S. Robison, Eberle's successor as Commander-in-Chief of the United States Battle Fleet and an individual highly regarded for his tactical expertise.[89] Like Eberle, Robison's experience with radio dated to the first decade of the twentieth century, when in late 1904 the Navy selected Robison (then a Lieutenant Commander) to head the Bureau of Equipment's Radio Division.[90] In this capacity, the future admiral wrote an instruction manual on wireless telegraphy for use by naval electricians.[91] The enduring quality of this work is attested to by the fact that Robison's manual (with revisions) served as the Navy's standard textbook on radio for more than two decades.[92]

Without a doubt, Robison's expertise in radio communications surpassed that of any previous fleet commander in the U.S. Navy, and he used this expertise as a basis for numerous reforms. Robison banned the use of all remaining spark sets and pushed vigorously for modern equipment from the Bureau of Engineering. He oversaw the establishment of communications departments on board combatant ships and encouraged the Navy Department to establish a radio material school on the West

---

U.S. Fleet, 15 December 1925, Commander in Chief, U.S. Fleet to Chief of Naval Operations, 14 March 1926, both on NAMC, RRFP, Roll No. 7, and Annual Report of Commander in Chief, U.S. Fleet for the period 8 November 1927 to 30 June 1928, 26 September 1928, 62, NAMC, ARFTF, Roll No. 7.

[89] After he retired, Robison and his wife wrote what now is considered a classic work on the history of naval tactics. See Samuel S. and Mary L. Robison, *A History of Naval Tactics from 1530 to 1930* (1942).

[90] Howeth, *History of Communications-Electronics*, 92.

[91] This manual initially was published in January 1907. Ibid., 110.

[92] Samuel S. Robison, *Robison's Manual of Radio Telegraphy and Telephony for Use of Naval Radiomen*, 8th revised edition (1928).

Coast. Robison also eliminated radio "strikers," a personnel practice that allowed individuals with no formal schooling in wireless to qualify as radiomen through on board training. To Robison, the complexity of contemporary radio equipment made the training of operators solely on board ship an inefficient and uneconomical practice.[93]

During his tenure as Commander-in-Chief, United States Battle Fleet, Robison enthusiastically supported other initiatives to improve fleet communications. He backed the Navy Department's decision to reinstate annual competitions for visual and radio communications, and regularly encouraged his subordinate commanders to improve their communications efficiency.[94] Toward this end, the admiral achieved noticeable success. In May 1923, a month before Robison assumed command of the Battle Fleet, the average time required to deliver a radio dispatch within the fleet was greater than half an hour. By June 1924, the average time had decreased to just over five minutes.[95] The following month, Robison instituted a record-keeping system for radio traffic and began publishing a monthly report showing the average transmission times of all of his subordinate commands. By April 1925, the average time to transmit a message was down to approximately four minutes, with Robison's flagship USS California leading all commands at an average transmission time of under three min-

[93] Commander in Chief, Battle Fleet to Commander in Chief, U.S. Fleet, 22 July 1924, and Commander in Chief, U.S. Fleet to Secretary of the Navy, 28 August 1924, both on NAMC, ARFTF, Roll No. 4. See also Commander in Chief, U.S. Fleet to Secretary of the Navy, 25 August 1925, NAMC, ARFTF, Roll No. 5.

[94] Commander in Chief, Battle Fleet to Commander in Chief, U.S. Fleet, 22 July 1924, Annual Report of Commanding Officer, USS Pennsylvania for FY 1924, circa July 1924, 4, and Annual Report of Commander, Destroyer Squadrons for FY 1924, 30 June 1924, 15, all on NAMC, ARFTF, Roll No. 4.

[95] Commander in Chief, Battle Fleet to Commander in Chief, U.S. Fleet, 22 July 1924, NAMC, ARFTF, Roll No. 4.

utes.[96] These improvements prompted the satisfied admiral to write: "From an organization which was used without confidence . . . the radio organization has become the most important carrier as regards both quality and quantity of communications in the Battle Fleet."[97]

Robison's efforts to improve the fleet's system of tactical command and control extended beyond visual and radio communications. In the latter half of 1923 one of Robison's aides, a young commander named Chester W. Nimitz, suggested a new type of cruising formation in which cruisers and destroyers positioned themselves in concentric circles around the fleet's battleships.[98] This "circular formation" differed considerably from the traditional scouting line, a rectilinear formation in which echelons of scouting/screening vessels sailed ahead of the fleet's capital ships (Figure 3-5). Vessels in the outer circles of the new formation were divided into three separate sectors (right flank, left flank, and center), greatly minimizing the likelihood of attack from an unexpected direction. The formation's circularity also made it easier to orient the fleet along a new threat axis and allowed for a more rapid transformation from a cruising to an approach formation.[99]

Despite these theoretical advantages, a number of officers believed that the circular cruising formation would make station-keeping prohibitively difficult, especially at

---

[96] Annual Report of Commander in Chief, Battle Fleet for FY 1925, circa July 1925, 51-52, NAMC, ARFTF, Roll No. 5.
[97] Ibid., 53.
[98] Nimitz learned of this type of formation while a student at the Naval War College during the 1922-1923 school year. According to Nimitz's official biographer, the aptly-named "circular formation" was invented by Commander Roscoe MacFall, who conceived of the idea during a war-gaming exercise. E. B. Potter, *Nimitz* (1976), 138.
[99] Campbell, "The Influence of Air Power Upon the Evolution of Battle Doctrine," 83-86.

night.[100] Robison decided that the only way to confirm the efficacy of the new formation was to implement it at sea, and this he did in January 1924 during the Navy's annual fleet maneuvers.[101] During Fleet Problem Number Two, a simulated advance across the Pacific Ocean through a barrier of enemy submarines, Robison thoroughly tested Nimitz's circular formation for the first time.[102] A few weeks later in Problem Number Four, a simulated fleet movement from a main U.S. base in the Western Pacific to an advanced base within five-hundred miles of the Tsushima Straits, Robison further experimented with different kinds of cruising formations. Because some of the communications difficulties experienced during Fleet Problem Number One had not yet been remedied, however, these exercises failed to provide an unambiguous verdict on the circular formation. One of the senior officers who operated with the Battle Fleet during the 1924 maneuvers reported station-keeping to be "most difficult," and complained that with existing means "it seems practically impossible to devise any effective methods of communication with vessels of

---

[100] Commander, Battleship Divisions, Battle Fleet to Commander in Chief, Battle Fleet, 15 January 1924, NAMC, RRFP, Roll No. 1, and Potter, *Nimitz*, 139-140.

[101] In 1924 the Navy divided its annual maneuvers into three parts, naming them Fleet Problem Number Two, Number Three, and Number Four, respectively. Fleet Problem Number Three consisted of a simulated attack on the Panama Canal while the Battle Fleet was transiting through it, and as such did not involve any cruising dispositions. In only one other year, 1930, did the U.S. Navy officially conduct more than one fleet problem. (Even though problems became longer and more complex over time, after 1930 the Navy grouped all portions of its annual maneuvers under a single numeric heading). Chief of Naval Operations to Commander in Chief, U.S. Fleet, 20 September 1923, NAMC, RRFP, Roll No. 1, and Timothy K. Nenninger, *Records Relating to United States Navy Fleet Problems I to XXII, 1923-1941* (1975), 1, 7-12.

[102] Robison had experimented with Nimitz's circular formation as early as December 1923, but did not test it thoroughly until the Navy's annual maneuvers the following month. Commander, Fleet Base Force to Commander in Chief, Battle Fleet, 16 January 1924, NAMC, RRFP, Roll No. 1.

the distant screen."[103] Conversely, another senior officer declared the circular cruising formation "the best thing of the kind thus far devised," and looked forward to the day when "a broadcast message would be hardly less certain of immediate accurate receipt by every vessel of the Formation, than would be the case if the same message were delivered by spoken word to the Commanding Officers of those vessels assembled in the O.T.C.'s Cabin."[104] Robison himself concluded that while substantial communications difficulties remained to be solved, the circular formation "has successfully met such tests as it has been possible to apply."[105]

Robison was not alone among the Navy's senior operational commanders in believing that ship-to-ship communications were the cornerstone of tactical coordination for naval forces. Prior to Fleet Problem Number Five,[106] for example, the Commander-in-Chief of the Scouting Fleet (Robison's "adversary"), claimed that the exercise "is as much a problem in communications as it is a scouting problem and the success or failure of the whole maneuver will depend largely upon the radio personnel of the fleet,"[107] while after Fleet Problem Number Eight the Commander-in-Chief of the United States Fleet expressed his conviction that tactical communications were "indispensable to the fullest efficiency in the exercise

[103] Commander in Chief, Scouting Fleet to Commander in Chief, U.S. Fleet, 12 February 1924, NAMC, RRFP, Roll No. 3.
[104] Commander, Battleship Divisions, Battle Fleet to Commander in Chief, Battle Fleet, 15 January 1924, NAMC, RRFP, Roll No. 1.
[105] Commander in Chief, Battle Fleet to Commander in Chief, U.S. Fleet, 1 February 1924, NAMC, RRFP, Roll No. 1.
[106] Fleet Problem Number Five, designed to be a simulated coordinated attack against a slightly smaller battle fleet, was held in March 1925. Commander in Chief, Scouting Fleet to Commander in Chief, U.S. Fleet, 24 March 1925, NAMC, RRFP, Roll No. 3, and Nenninger, *Records Relating to United States Navy Fleet Problems*, 7.
[107] Josiah S. McKean [Commander in Chief, Scouting Fleet], "Communications Instructions, Problem No. 5 (BLUE SCOUTING FLEET) Modifications," 20 February 1925, NAMC, RRFP, Roll No. 3.

of command."[108] Reflecting back years later, Robison's pro-
tégé Nimitz stated simply that "effective coordination and
ultimate operational success depends upon efficient commu-
nications."[109]

Unfortunately for the Navy, two fundamental issues
constrained the fleet's system of tactical communications.
First, budgetary constraints limited the service's ability to
acquire modern radio equipment, and even when such apparatus
became available it often necessitated extensive (and expen-
sive) shipboard alterations to be employed in a more effec-
tive manner.[110] Second, the best naval radio communications
system in the world was useless when a commander determined
that the tactical situation dictated radio silence, for as
Bradley Fiske had pointed out two decades earlier, no admiral
desired to "make a present to the enemy" of the fact that he
was near.[111]

These two issues were at the heart of the United States
Navy's problems with tactical command and control during the

---

[108] Annual Report of Commander in Chief, U.S. Fleet for the period 8 No-
vember 1927 to 30 June 1928, 26 September 1928, 11, NAMC, ARFTF, Roll
No. 7. The U.S. Fleet Commander in Chief again emphasized this senti-
ment after Fleet Problem Number Nine. Commander in Chief, U.S. Fleet
to Chief of Naval Operations, 21 May 1929, NAMC, ARFTF, Roll No. 7.
[109] Chester W. Nimitz, "Introduction," xi, in Howeth, *History of Commu-
nications-Electronics*.
[110] Budgetary limitations also restricted the Navy's ability to improve
visual signalling systems. In the fall of 1927, for example, Admiral
Charles F. Hughes complained to Eberle: "During Fleet Problem No. One,
held in February 1923, the unsatisfactory signal searchlight equipment
on destroyers was indicated unequivocally. . . . four years later,
only 11 destroyers in the United States Fleet are equipped with these
new signal searchlights. It is noted that the Bureau of Construction
and Repair's proposed program of alterations for the fiscal year, 1928,
calls for installing the necessary platform for these new signal
searchlights on only 7 destroyers, leaving at the end of the fiscal
year 1928, sixty U.S. Fleet destroyers unequipped with the new signal
searchlights. At the rate of 7 a year it will be eight more years
before this project is completed." Commander in Chief, U.S. Fleet to
Chief of Naval Operations, 27 September 1927, NAMC, ARFTF, Roll No. 6.
[111] Commander Bradley A. Fiske, "War Signals," *United States Naval Insti-
tute Proceedings*, vol. 29, no. 4, (1903), 932. Chapter Four further
explores the Navy's efforts to solve this dilemma.

interwar period, and naval personnel – both within the fleet
and at the material bureaus – devoted considerable time and
energy attempting to solve them. At the suggestion of Com-
mander Stanford C. Hooper, who was then finishing his second
tour as head of the Bureau of Engineering's Radio Division,
the Navy in mid-1923 consolidated all radio and sound re-
search at the newly-established Naval Research Laboratory.
This consolidation brought together in one location personnel
from the Navy's Radio Test Shop, the Naval Radio Research
Laboratory, and the Naval Aircraft Radio Laboratory.[112] Evi-
dently, Hooper's goal in seeking this arrangement was to
economize and improve his service's communications systems
(both tactical and strategic) by reducing overhead costs and
creating an exclusive facility to house the Navy's radio en-
gineers, but even the most stringent economizing could not
alleviate the budgetary challenges faced by American naval
leaders.[113] During the 1920s and early 1930s the Naval Re-
search Laboratory's Radio Division conducted pioneering
research on high frequency (HF) radio communications, devel-
oping new equipment and contributing to contemporary under-
standings of propagation theory, quartz-crystal frequency
control, power generation, antenna design, and reception

---

[112] Taylor, *Radio Reminiscences*, 173-178, Gebhard, *Evolution of Naval
Radio-Electronics*, 31-34, Allison, *New Eye for the Navy*, 36-37, and
Ivan Amato, *Pushing the Horizon: Seventy-Five Years of High Stakes
Science and Technology at the Naval Research Laboratory* (1998), 26.
[113] Allison, *New Eye for the Navy*, 37. Bringing together the Navy's ra-
dio engineers likely did create a more productive environment for re-
search and experimentation, as the efforts of Naval Research Laboratory
personnel led to numerous improvements in communications equipment. For
more on these improvements, see especially A. Hoyt Taylor, *The First
Twenty-Five Years of the Naval Research Laboratory* (1948), 16-24, and
Idem, *Radio Reminiscences*, 173-318, Gebhard, *Evolution of Naval Radio-
Electronics*, 43-70, 86, 96-99, 169-172, and Amato, *Pushing the Horizon*,
31-44.

techniques.[114] Yet the Bureau of Engineering, which provided funds for nearly all radio research conducted at the Naval Research Laboratory,[115] simply did not have the resources to contract for (and supply the fleet with) sufficient quantities of modern radio equipment.[116]

Probably even more detrimental to the Navy's evolving system of tactical command and control, however, was the fact that the proliferation of new communications equipment outpaced the amount of shipboard space originally allocated to house such equipment. The Bureau of Construction and Repair, which faced its own budgetary constraints, often balked at requests from fleet commanders and/or the Bureau of Engineering to perform expensive – and what they often viewed as unnecessary – shipboard modifications. Of course, this bureaucratic friction was a problem which had existed for decades, and was one that would not be resolved until the Bureau of Engineering and the Bureau of Construction and Repair combined to form Bureau of Ships in June 1940.[117] In the 1920s, however, this institutional solution still lay in the future, and naval commanders struggled to command their forces from facilities only slightly better than those used by their brethren at Jutland.

To be sure, some improvements were made, particularly with respect to the physical location of shipboard communications systems. Jutland had demonstrated the vulnerability

---

[114] Gebhard, *Evolution of Naval Radio-Electronics*, 43, and Allison, *New Eye for the Navy*, 56.

[115] Allison, *New Eye for the Navy*, 52.

[116] See note 89 above. At one point in the mid-1920s an exasperated Robison wrote: "WITH PRESENT RADIO EQUIPMENT THE BATTLE FLEET IS NOT READY FOR BATTLE." Annual Report of Commander in Chief, Battle Fleet for FY 1925, circa July 1925, 86, NAMC, ARFTF, Roll No. 5.

[117] Paul J. Strayer and Edward J. Pope, *An Administrative History of the Bureau of Ships During World War II* , vol. 1 (1947), 1-48, and Julius A. Furer, *Administration of the Navy Department in World War II* (1959), 217-222.

of exposed radio equipment,[118] and the Navy in late 1923 commissioned two new battleships with armor-protected radio facilities and centrally-located "communications control centers." These two vessels, *USS Colorado* and *USS West Virginia,* each had eight receivers and four transmitters, half of which were devoted to tactical circuits. A new vacuum tube coupling system developed by engineers at the Naval Research Laboratory enabled all eight receivers to use the same antenna simultaneously, and both ships were capable of duplex operations.[119] Nevertheless, *Colorado* and *West Virginia* were just two vessels in a fairly sizeable Navy, and officers on other combatants were quick to point out the tactical constraints created by a lack of duplexing capability.[120]

Limited available funds also affected the Navy's ability to improve the shipboard facilities from which command was exercised. Robison in particular understood how successful coordination of naval forces depended increasingly on adequate facilities to process the information made available by new sensor and communications technologies.[121] As Commander-

---

[118] See note 10 above.

[119] Howeth, *History of Communications-Electronics*, 326-330, 383-384, and Taylor, *Radio Reminiscences*, 150-151, 165. Duplex operations permitted simultaneous transmission and reception of radio messages. To minimize interference, transmitters and receivers were installed at opposite ends of the ship. Gebhard, *Evolution of Naval Radio-Electronics*, 24.

[120] Commander, Battleship Divisions, Battle Fleet to Commander in Chief, Battle Fleet, 17 June 1924, and Annual Report of Commander, Destroyer Squadrons for FY 1924, 30 June 1924, 16, both on NAMC, ARFTF, Roll No. 4.

[121] These new technologies included not only improved visual signalling and radio communications systems, but also radio direction finding equipment and underwater sound apparatus. For a further discussion of the latter two technologies, see especially Griffin, *History of the Bureau of Engineering*, 47-73, 96-98, Howeth, *History of Communications-Electronics*, 261-265, 297-312, Marvin Lasky, "A Historical Review of Underwater Acoustic Technology, 1916-1939, With Emphasis on Undersea Warfare," *Journal of Underwater Acoustics*, vol. 24, no. 4, (1974), 603-604, 611-613, 616-619, and Willem Dirk Hackmann, *Seek & Strike: Sonar,*

in-Chief of the Battle Fleet he carefully studied "the best way to coordinate visual, radio and sound," concluding that improved tactical coordination could be obtained only with better command and control facilities.[122] Writing to his immediate superior in mid-1924, Robison remarked: "In order for the Commander in Chief, Battle Fleet, to dispose his forces to the best advantage, he must have information of enemy and own forces plotted on a chart where he can clearly visualize their relative positions and determine his own disposition and courses of action . . . [currently] it is inconceivable that the Commander in Chief, Battle Fleet, can obtain any valuable information regarding the enemy forces from the instruments provided him."[123] The admiral went on to recommend the rearrangement of shipboard communications facilities, chart houses, and plotting rooms, but acknowledged that many desired shipboard alterations were "impracticable without very extensive changes in the bridge and conning tower structures."[124]

Many senior officers shared Robison's concerns. In a lengthy report written immediately after Fleet Problem Number Two, one of Robison's battleship division commanders, Rear Admiral Louis M. Nulton, commented extensively on the need for new and better command facilities. Because his remarks so eloquently and accurately reflected the sentiments of contemporary American naval commanders, they are worth quoting at length. Of his flagship, Nulton wrote:

Anti-Submarine Warfare, and the Royal Navy, 1914-1954 (1984), 56-60, 89-95, 135-138.
[122] Commander in Chief, Battle Fleet to Commander in Chief, U.S. Fleet, 22 July 1924, NAMC, ARFTF, Roll No. 4.
[123] Ibid.
[124] Ibid.

The NEW YORK is not designed, nor at present
arranged, to meet the requirements of a Com-
mander of mixed forces. Conditions for which
she was planned and arranged have gone into
the past and are now obsolete. A man on a
bicycle is as well fixed to compete with a
man on motorcycle as the material flag ar-
rangements are filled to meet present screen
(and fleet) Sector Commander's work. . . .
There are few facilities for handling the
work leaving the Division Commander and his
staff practically wandering around with their
equipment under their arms . . . I consider
the present lack of [command] facilities on
board the NEW YORK the best asset the enemy
has.[125]

To make sure his comments were not misconstrued as superfi-
cial complaints, the future fleet commander then made the
following statement:

If the paragraphs relating to the lack of fa-
cilities and personal inconvenience of the
Sector Commander are read as merely being an
expression of individual lack of ease, the en-
tire fundamental principle involved will have
been lost by the reader. The point involved
is that if 80% or 90% of one's physical and
mental energy is spent in overcoming overhead
or an obstacle supplied by lack of facilities
there remains but a small fraction of the to-
tal available to be applied to the legitimate
work of the problem in hand.[126]

---

[125] Commander, Battleship Division Three to Commander in Chief, Battle
Fleet, 14 January 1924, NAMC, RRFP, Roll No. 1. For similar reports,
see also: Annual Report of Commander in Chief, Battle Fleet for FY
1925, circa July 1925, 5, Commander in Chief, U.S. Fleet to Secretary
of the Navy, 25 August 1926, both on NAMC, ARFTF, Roll No. 5, Annual
Report of Commander, Destroyer Squadrons, Battle Fleet for FY 1926-
1927, circa July 1927, 4-5, NAMC, ARFTF, Roll No. 6, Annual Report of
Commander in Chief, U.S. Fleet for the period 8 November 1927 to 30
June 1928, 26 September 1928, 13, 72, and Commander in Chief, Scouting
Fleet to Commander in Chief, U.S. Fleet, 1 July 1928, both on NAMC,
ARFTF, Roll No. 7.
[126] Commander, Battleship Division Three to Commander in Chief, Battle
Fleet, 14 January 1924, NAMC, RRFP, Roll No. 1. Nulton served as
Commander in Chief, Battle Fleet, from 21 May 1929 to 24 May 1930.

Nulton, Robison, and many of their contemporaries clearly understood that naval officers could no longer take the facilities from which they commanded for granted. New sensor and communications technologies provided commanders with access to a greater amount of tactical information, and their capacity to process this information increasingly depended on the development and successful employment of systems that could make the decision-making process more manageable. Yet improved command facilities required expensive shipboard alterations, and the interwar Navy's senior leaders often could not or would not allocate funds for this purpose. For these men other priorities took precedence, not least of which was acquiring and improving the very sensor and communications technologies that made better command facilities necessary in the first place.

Even as these budgetary constraints slowed the pace at which improvements to shipboard facilities could be accomplished, American naval commanders still sought to do their best with the "instruments" they did possess. Appreciating the benefits of highly-trained radio personnel, the Navy Department detailed a greater number of officers to the Post Graduate Radio School and established formal schools in maintenance and repair.[127] Frustration over mutual interference led to the introduction of a new and extremely success-

---

[127] Commander in Chief, U.S. Fleet to Secretary of the Navy, 9 July 1925, Annual Report of Commander in Chief, Battle Fleet for FY 1925, circa July 1925, 115, both on NAMC, ARFTF, Roll No. 5. The Navy also established a sound school in San Diego and two new radio operators' schools (one on each coast) to supplement the existing operators' school at Great Lakes. Commander in Chief, Battle Fleet to Commander in Chief, U.S. Fleet, 22 July 1924, NAMC, ARFTF, Roll No. 4, and Commander in Chief, U.S. Fleet to Secretary of the Navy, 25 August 1926, NAMC, ARFTF, Roll No. 5.

ful fleet frequency plan in April 1927,[128] and by decade's end nearly all Navy vessels had been modified to permit duplex operations.[129] Because the mid-to-late 1920s also witnessed the development of HF radio – which enabled long-distance communications with less powerful and therefore much smaller transmitters[130] – space constraints for transmitting equipment became less problematic. This development was particularly significant for American submarines, whose cramped interiors precluded the installation of large transmitters,[131] and carrier-based aircraft, which could not carry such heavy equipment without sacrificing operational performance.[132]

Although the fleetwide adoption of HF radio apparatus helped alleviate shipboard space constraints, this development countered an overall trend toward more crowded facilities.[133] Beginning in the mid-1920s, fleet commanders increasingly employed radio direction finding systems to locate enemy forces, demanding new and better equipment for this

---

[128] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 27 September 1927, Commander in Chief, Battle Fleet to Commander in Chief, U.S. Fleet, 1 July 1927, and Annual Report of Commander in Chief, Scouting Fleet for FY 1927, 30 June 1927, 28, all on NAMC, ARFTF, Roll No. 6.

[129] Annual Report of Commander in Chief, Battle Fleet for FY 1925, circa July 1925, 85, Commander in Chief, Battle Fleet to Secretary of the Navy, 25 August 1926, Annual Report of Commander in Chief, Battle Fleet for the period 4 October 1925 to 30 June 1926, 1 July 1926, 101, all on NAMC, ARFTF, Roll No. 5, and Annual Report of Commander in Chief, Scouting Fleet for FY 1927, 30 June 1927, 29-30, NAMC, ARFTF, Roll No. 6. See also Howeth, *History of Communications-Electronics*, 388.

[130] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 21 May 1929, NAMC, ARFTF, Roll No. 7.

[131] Taylor, *Radio Reminiscences*, 236-242, and University of Pittsburgh Historical Staff at ONR, *The History of United States Naval Research and Development in World War II*, n.d. but known written in the late 1940s or early 1950s, 1006m. This document is available at the Navy Department Library in Washington, DC.

[132] Commander in Chief, U.S. Fleet to Secretary of the Navy, 9 July 1925, NAMC, ARFTF, Roll No. 5. See also Melhorn, *Two Block Fox*, 100, and Campbell, "The Influence of Air Power Upon the Evolution of Battle Doctrine," 64-80.

[133] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 21 May 1929, NAMC, ARFTF, Roll No. 7.

purpose.[134] A debate over the adequacy of existing visual
signalling stations led to proposals for (and in some cases,
construction of) more ergonomic facilities,[135] and consider-
able effort went into developing devices and procedures for
distinguishing between friendly and enemy units.[136] On many
classes of ship the Bureau of Engineering installed systems
for underwater communications and/or the detection of subma-
rines,[137] and after the Navy adopted radar in the late 1930s
and early 1940s, space constraints became especially problem-
atic. Before investigating these issues further, however,
the service's efforts to develop command and control systems

[134] Commander in Chief, Battle Fleet to Secretary of the Navy, 12 January
1923, NAMC, ARFTF, Roll No. 3, Commander in Chief, U.S. Fleet to Secre-
tary of the Navy, 1 July 1923, NAMC, ARFTF, Roll No. 4, Josiah S.
McKean [Commander in Chief, Scouting Fleet] , "Communications Instruc-
tions, Problem No. 5 (BLUE SCOUTING FLEET) Modifications," 20 February
1925, NAMC, RRFP, Roll No. 3, Commander in Chief, U.S. Fleet to Chief
of Naval Operations, 4 May 1927, NAMC, RRFP, Roll No. 8, Commander,
Battleship Divisions, Battle Fleet to Commander in Chief, Battle Fleet,
17 June 1924, NAMC, ARFTF, Roll No. 4, and Commander, Battleship Divi-
sions, Battle Fleet to Commander in Chief, Battle Fleet, 30 May 1925,
NAMC, ARFTF, Roll No. 5.
[135] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 27 Sep-
tember 1927, Annual Report of Commander in Chief, Scouting Fleet for FY
1927, 30 June 1927, 27, both on NAMC, ARFTF, Roll No. 6, Annual Report
of Commander in Chief, U.S. Fleet for the period 8 November 1927 to 30
June 1928, 26 September 1928, 56-57, 71, and Commander in Chief, Scout-
ing Fleet to Commander in Chief, U.S. Fleet, 1 July 1928, both on NAMC,
ARFTF, Roll No. 7.
[136] Taylor, Radio Reminiscences, 307-310, Commander in Chief, U.S. Fleet
to Chief of Naval Operations, 27 September 1927, Annual Report of Com-
mander in Chief, Scouting Fleet for FY 1927, 30 June 1927, 25, both on
NAMC, ARFTF, Roll No. 6, and Commander in Chief, Scouting Fleet to Com-
mander in Chief, U.S. Fleet, 1 July 1928, NAMC, ARFTF, Roll No. 7.
[137] Commanders frequently reported these systems to be ineffective. Com-
mander in Chief, U.S. Pacific Fleet to Secretary of the Navy, 22 July
1922, NAMC, ARFTF, Roll No. 2, Commander in Chief, Battle Fleet to
Commander in Chief, U.S. Fleet, 22 July 1924, NAMC, ARFTF, Roll No. 4,
Commander in Chief, U.S. Fleet to Secretary of the Navy, 25 August 1926,
Annual Report of Commander in Chief, Battle Fleet for the period 4 Oc-
tober 1925 to 30 June 1926, 1 July 1926, 63, Commander in Chief, Scout-
ing Fleet to Commander in Chief, U.S. Fleet, 25 June 1926, all on NAMC,
ARFTF, Roll No. 5, Commander in Chief, U.S. Fleet to Chief of Naval Op-
erations, 27 September 1927, NAMC, ARFTF, Roll No. 6, and Annual Report
of Commander in Chief, U.S. Fleet for the period 8 November 1927 to 30
June 1928, 26 September 1928, 58-59, NAMC, ARFTF, Roll No. 7.

that could provide seaborne commanders with access to accurate, timely, and secure information must first be explored.

PLAN OF H.M.S. IRON DUKE'S MANOEUVRING PLATFORM
AND FORE BRIDGE

SHOWING POSITIONS OF JELLICOE AND OTHER OFFICERS WHEN HE FORMED LINE
OF BATTLE IN BATTLE OF JUTLAND

SCALE 0 1 2 3 4 5 FEET

FORWARD
TO STEM

PORT   STARBOARD

MANOEUVRING PLATFORM

GYRO COMPASS

The Central Compass Platform was raised only about ONE FOOT.

MAGNETIC COMPASS

BEARING PLATE

BEARING PLATE

T.   W.   FH.   B.

LADDER

CHART TABLE

LADDER

SLIDING DOOR

SHIP'S CHART HOUSE

SLIDING DOOR

Z is a sliding shutter through which signals were passed between C.inC. and Signal House. A pneumatic tube carried signals in a cylinder between Signal House and Distributing Centre below.

SIGNAL TABLE IN SIGNAL HOUSE

TACTICAL PLOT OR A CHART IN C.in C.'s CHART HOUSE

SETTEE

SECTION OF C.in C.'s CHART HOUSE & SIGNAL HOUSE AND SHIP'S CHART HOUSE

DOOR   DOOR

FORE BRIDGE
Three feet below level of manoeuvring platform

FIGURE 3-1

This diagram shows the command and control facilities available to Admiral John Jellicoe at the Battle of Jutland. From these cramped facilities Jellicoe had to command forces that were dispersed over hundreds of square miles.

134
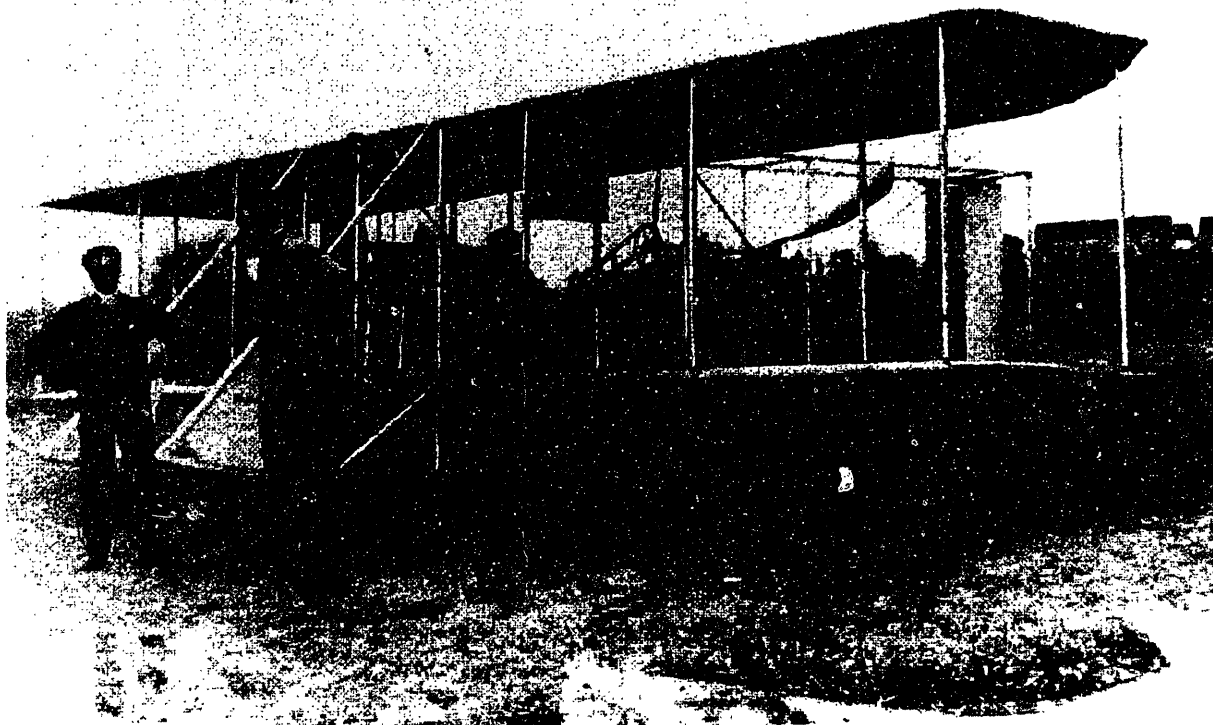
FIGURE 3-2

Due to open-air cockpits and a lack of elec-
tronic shielding, aviators had tremendous dif-
ficulty picking up radio signals in aircraft
like the Wright B-1 shown here in this 1911
photograph.
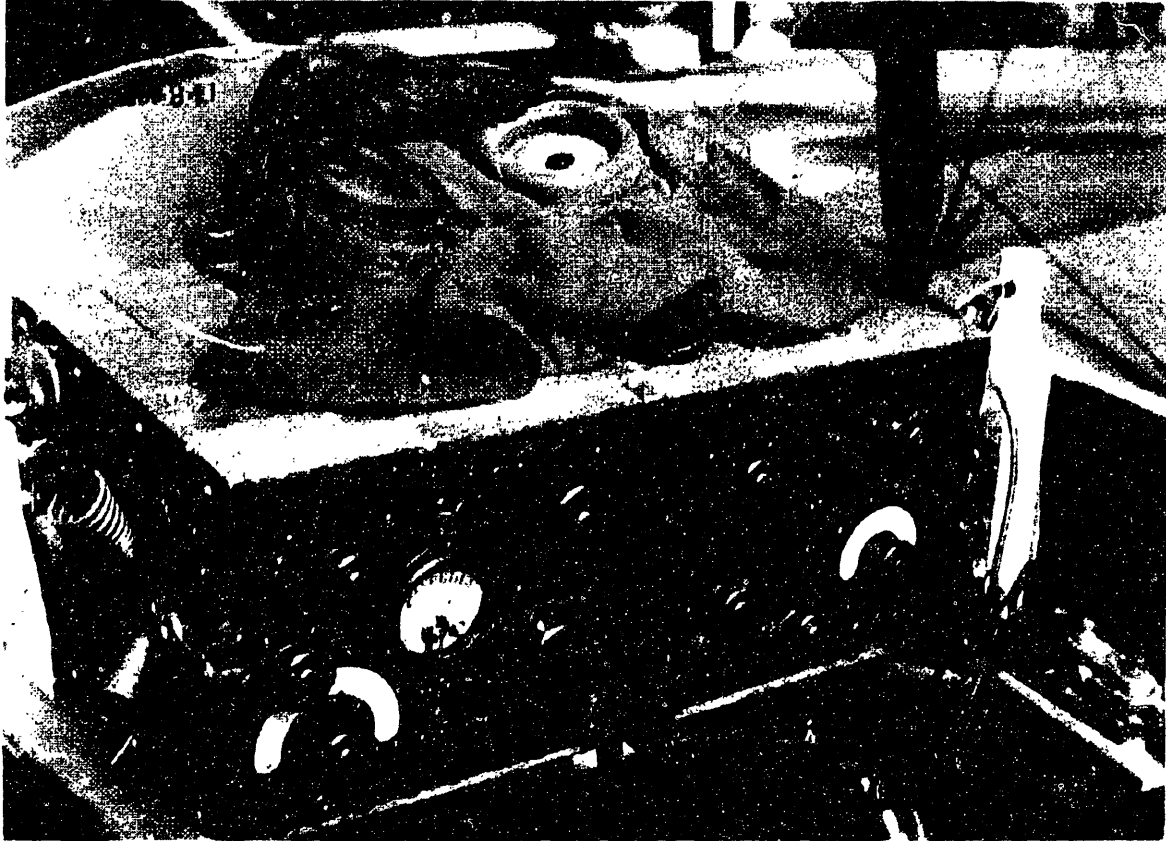
FIGURE 3-3

Developed by the Naval Aircraft Radio Labo-
ratory in Pensacola, Florida, flannel-lined
leather helmets like the one pictured above im-
proved pilots' ability to receive radio signals
while airborne.
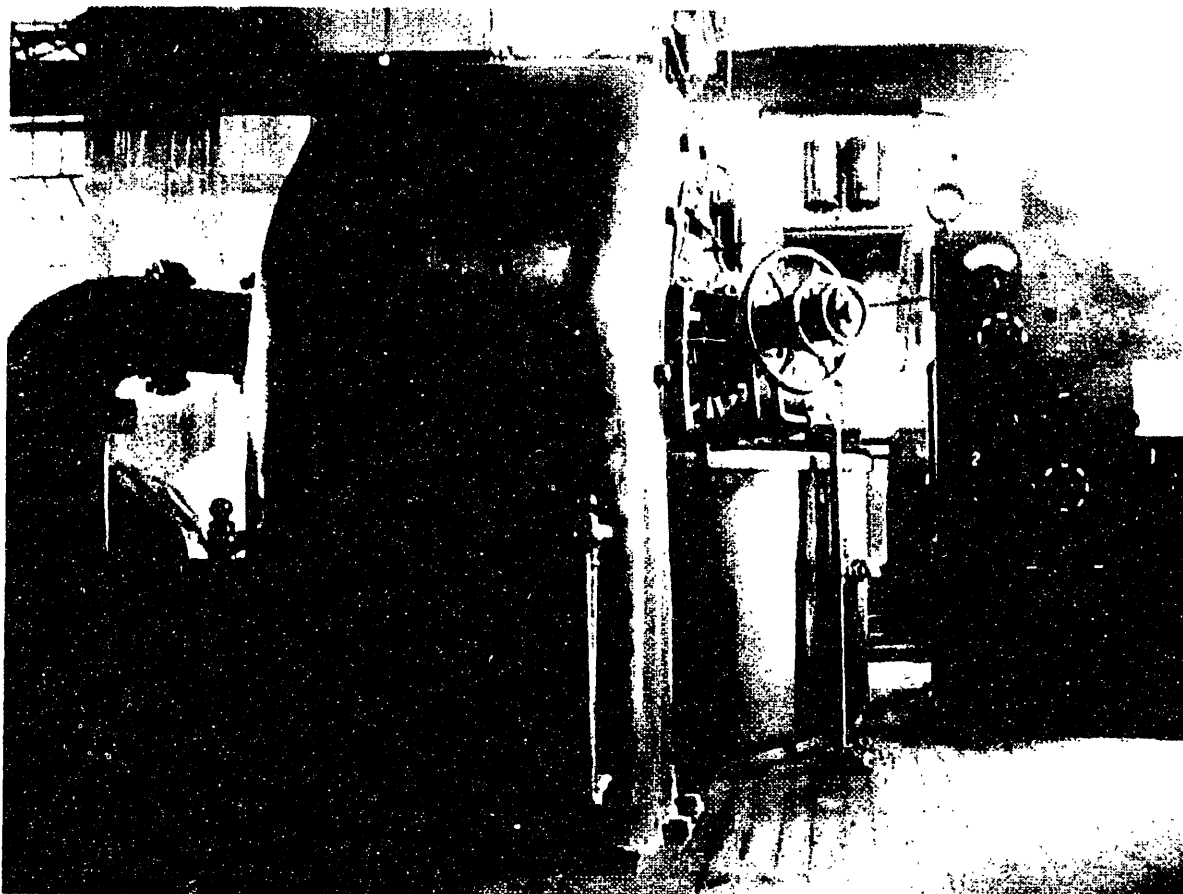
FIGURE 3-4

This photograph, taken in the late 1910s or
early 1920s, shows a 500 kilowatt arc trans-
mitter at the U.S. Navy's radio station in the
Philippines. Despite its advantages, this type
of transmitter was considered too big for
installation on board naval vessels.

Rectilinear Formation

c. 10 nm.

Fleet | Course

▲ Cruiser ▲   ▲ Scouting ▲   ▲ Line ▲

Main Body
(battleships)

Circular Formation

Destroyers
on this circle

Center Force

Fleet Course

Cruisers on
this circle

Sector Boundary

Sector Boundary

BatDiv

Fleet
Guide
Point

Left Flank Force

Right Flank Forces

Carriers
(if present)

Sector Boundary
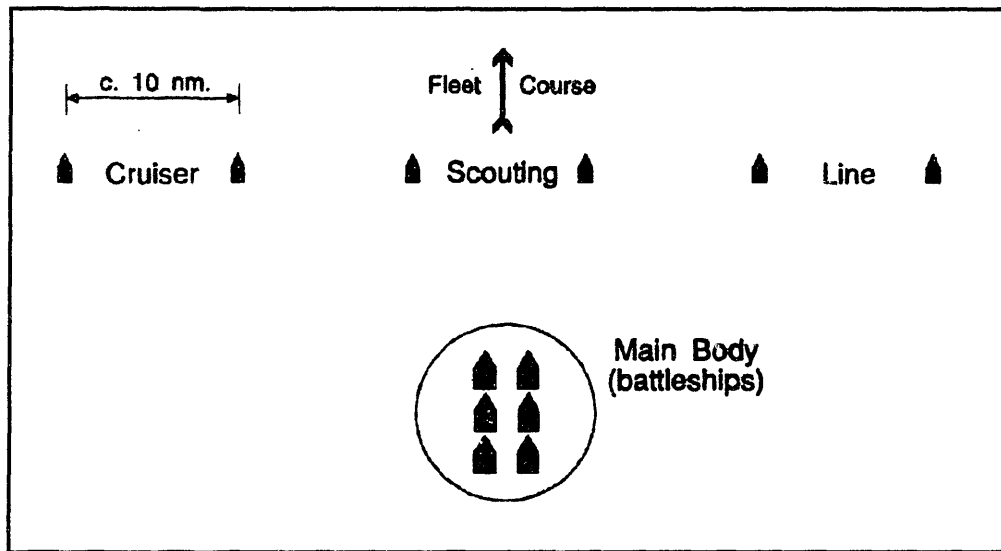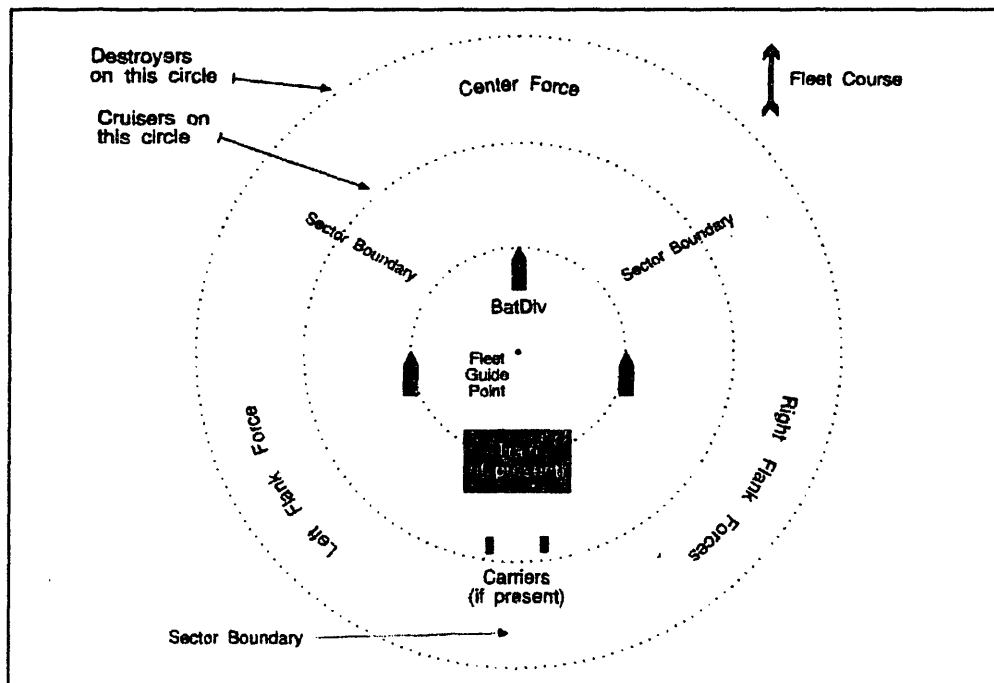
FIGURE 3-5

The circular formation, introduced into the fleet by Samuel S. Robison in 1924, was more difficult to maintain than the rectilinear formation, but it minimized the likelihood of attack from unexpected directions and allowed for a better transition to new threat axes.

Citations for Figures

Figure 3-1: Frederic C. Dreyer, *The Sea Heritage: A Study of Maritime Warfare*, interleaf between 144-145.

Figure 3-2: Courtesy of the Naval Historical Center.

Figure 3-3: Courtesy of the Naval Historical Center.

Figure 3-4: Courtesy of the Naval Historical Center.

Figure 3-5: Mark A Campbell, "The Influence of Air Power Upon the Evolution of Battle Doctrine in the U.S. Navy, 1922-1941," 84-85.

THIS PAGE INTENTIONALLY LEFT BLANK

CHAPTER FOUR
ACCURATE, TIMELY, AND SECURE:
THE DEMAND FOR INFORMATION

The Importance of Information

Before dawn on the morning of January 26th, 1929, the new
fleet carrier *USS Saratoga* launched seventy planes for a simu-
lated attack on the Panama Canal as part of Fleet Problem IX.[1]
Bound for the Canal's southernmost locks, *Saratoga*'s aircraft
arrived undetected over their target just after daybreak, at
which time they (hypothetically) destroyed the unprotected
locks. Back on the *Saratoga*, however, developing events tem-
pered enthusiasm for this bold raid, as three battleships from
the opposing BLUE fleet successfully intercepted and "sank" the
defenseless carrier. This unfortunate occurrence resulted pri-
marily from a faulty tactical picture on the part of the BLACK
Fleet Commander, who had tried but failed to position four of
his battleships between *Saratoga* and the BLUE vessels that
caught her.[2] If *Saratoga* really had been sunk, in one fatal
blow the United States Navy would have lost not only an air-

---

[1] *Saratoga* was part of the BLACK Fleet, which consisted primarily of
ships from the United States Battle Fleet. Commander in Chief, U.S.
Fleet to Chief of Naval Operations, 18 March 1929, National Archives
Microfilm Collection (NAMC), "Records Relating to United States Navy
Fleet Problems I to XXII, 1923-1941" (RRFP), Roll No. 12. The reader
may notice that I have changed convention from written numbers to Roman
numerals. This is in keeping with practices of the day as reflected in
records pertaining to fleet problems. The initial four problems always
were designated by written numbers or Arabic numerals (e.g., "Fleet
Problem Number Two" or "Fleet Problem No. 2"). Fleet Problem Number
Five was the first for which contemporaries used Roman numerals, a
practice increasingly employed over the next three fleet problems. By
the time of Fleet Problem IX, the original convention had disappeared
almost entirely.

craft carrier, but also up to three-fifths of all officer pilots trained for carrier operations (Figure 4-1).[3]

A number of authors have pointed to *Saratoga*'s strike on the Panama Canal in Fleet Problem IX as a revolutionary development in naval warfare, and to a certain ext nt this is an accurate assertion.[4] Several senior American naval officers previously had considered the idea of a carrier-led task force, but not until Fleet Problem IX was this concept actually implemented.[5] *Saratoga*'s exploits made national news and prompted an enthusiastic reaction from the Battle Fleet Commander-in-Chief, who certainly benefited from the positive press.[6] Yet there was another important first in Fleet Problem IX, and it is one that has been little noticed by historians. For the first time, the Navy's official report for a fleet problem contained an entry under the heading "INFORMATION."[7]

---

[2] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 18 March 1929, NAMC, RRFP, Roll No. 12.
[3] Ibid. The three-fifths figure comes from page 29 of Part III of this document. The reason *Saratoga* had so many aviators on board was because the Navy Department had transferred *USS Langley*'s aircraft squadrons to the *Saratoga* prior to the start of the problem. Rear Admiral Joseph M. Reeves, "Statement on Fleet Problem Nine," 2 February 1929, 38, NAMC, RRFP, Roll No. 12.
[4] See Archibald D. Turnbull and Clifford L. Lord, *History of United States Naval Aviation* (1949), 270-272, Eugene E. Wilson, *Slipstream: The Autobiography of an Air Craftsman* (1950), 148-149, Melhorn, *Two-Block Fox*, 113-115, Thomas Wildenberg, *Destined for Glory: Dive Bombing, Midway, and the Evolution of Carrier Airpower* (1998), 62-63, and Idem, *All the Factors of Victory: Admiral Joseph Mason Reeves and the Origins of Carrier Airpower* (2003), 1-10.
[5] Melhorn, *Two-Block Fox*, 114, and Reeves, "Statement on Fleet Problem Nine," 2 February 1929, 42, NAMC, RRFP, Roll No. 12.
[6] Admiral William V. Pratt, who later served as Commander in Chief of the United States Fleet and Chief of Naval Operations, was the Battle Fleet Commander during Fleet Problem IX. Pratt's biographer states that Fleet Problem IX provided a boon to Pratt's career. Gerald E. Wheeler, *Admiral William Veazie Pratt, U.S. Navy: A Sailor's Life* (1974), 274-275. For a contemporary press account, see Lewis R. Freeman, "Canal 'Destroyed' by 'Foe' in Pacific," *New York Times*, 28 January 1929, 1-2.
[7] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 18 March 1929, NAMC, RRFP, Roll No. 12. See page 5 of Part II of this document.

In his report on Fleet Problem IX, Admiral Henry A. Wiley, Commander-in-Chief of the United States Fleet, expressed considerable dismay over the periodic mishandling of important tactical information. With respect to BLACK's failure to interdict the BLUE battleships that sank *Saratoga*, the Commander-in-Chief believed that such a failure should not have occurred, declaring: "It should have been possible to establish the positions of the forces concerned with sufficient exactness to make such a failure impossible."[8] Wiley also was unhappy about the high number of incorrect and/or inconsistent contact reports,[9] but he leveled his harshest criticism at BLUE Fleet personnel for their inability to communicate securely via radio.[10] During the exercise, a special group of intelligence officers stationed on board the BLACK Fleet flagship intercepted and decrypted a large percentage of BLUE's messages,[11] prompting one observer to comment that there had been a "complete breakdown of Blue radio communications so far as secrecy is concerned."[12] Wiley was so upset about this breakdown that he recommended making the misuse of codes and ciphers a punish-

---

[8] Ibid. The Battle Fleet's Chief of Staff had even harsher words, calling this failure ". . . the most serious and mortifying blot on a record of very fair achievement." Captain Arthur J. Hepburn, "Remarks by Chief of Staff, Battle Fleet, at Critique on Fleet Problem IX," 5 February 1929, 13, NAMC, RRFP, Roll No. 12.

[9] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 18 March 1929, NAMC, RRFP, Roll No. 12.

[10] Ibid. See especially Part IV of this document.

[11] Lieutenant (junior grade) Thomas H. Dyer, "Outline of Remarks on Black Communications," undated but believed written in late January or early February 1929, NAMC, RRFP, Roll No. 12.

[12] Fleet Observer Black [William Glassford] to Commander in Chief, U.S. Fleet, 29 January 1929, NAMC, RRFP, Roll No. 12. Glassford went on to write: "For all practical purposes it can be said that all Blue despatches [sic] by radio were translated into original English text and made available to the Commander in Chief, Black Naval Forces in time, in most cases, for appropriate action to be taken. With all due regard to the cleverness and efficiency of the Decrypting Unit in the Black Force Flagship, it is desired to stress as emphatically as is possible that this complete lack of secrecy was not due so much to the Decrypting Unit

able offense equal in severity to that of providing codes and ciphers directly to the enemy.[13]

Wiley's immediate subordinates shared their boss's concerns about the management of tactical information. Based in part on their experiences in Fleet Problem IX, both William V. Pratt and Montgomery M. Taylor, the respective commanders of the BLACK and BLUE forces, argued after the exercise that a cruiser - not a battleship - should serve as the flagship for a fleet commander.[14] According to Taylor, effective command and control required a large staff, adequate space for offices and plotting rooms, and ample means of communication. Because the installation of such facilities on a capital ship would "seriously affect her efficiency as a battle unit," Taylor recommended transferring his flag as Commander-in Chief, Scouting Fleet to a cruiser.[15] A year later Pratt went one step further, arguing that the three highest-ranking officers at sea all should command from newly-constructed cruisers.[16] Other senior officers expressed similar sentiments.[17]

---

as to the simplicity of the task presented to the Unit, due to our own general and serious lack of knowledge of communications."

[13] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 18 March 1929, NAMC, RRFP, Roll No. 12. I have found no evidence indicating that the Navy Department ever implemented this recommendation.

[14] From 1923 to 1927 the United States Fleet Commander-in-Chief used an armored cruiser (USS Seattle) as his flagship; however, this was a temporary expedient and not a permanent state of affairs. Commander in Chief, U.S. Fleet to Secretary of the Navy, 1 July 1923, NAMC, "Annual Reports of Fleets and Task Forces of the U.S. Navy, 1920-1941" (ARFTF), Roll No. 4, and Commander in Chief, U.S. Fleet to Chief of Naval Operations, 27 September 1927, NAMC, ARFTF, Roll No. 6.

[15] Annual Report of Commander in Chief, Scouting Fleet for the period 1 July 1928 to 31 March 1929, circa April 1929, 2-5, NAMC, ARFTF, Roll No. 7. The phrase quoted is from page 2 of this document.

[16] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 1 August 1930, NAMC, ARFTF, Roll No. 8.

[17] Senior Member, General Board [Andrew T. Long] to Secretary of the Navy, 27 February 1929, National Archives, Washington, DC (NADC), Record Group 80 - General Records of the Department of the Navy, (RG 80), Records of the General Board (GB), Subject File 420-8, Box No. 84, President, Naval War College [Harris Laning] to Chief of Naval Operations, 2 April 1931, NADC, RG 80, GB, Subject File 420-8, Box No. 85,

That many of the Navy's most experienced officers wanted to change the type of vessel from which they exercised command is revealing, as it sheds light on shifting perceptions about the nature of command at sea. Historically, cruisers were intermediate-sized warships associated with commerce raiding and the defense of merchant vessels. Starting in the early twentieth century, however, the United States Navy increasingly designed and built cruisers to serve as scouts for the fleet.[18] Because these vessels had less armor and lighter armament than capital ships, cruiser commanding officers relied on advantages in speed and maneuverability to avoid lethal encounters with their larger and more powerful brethren. Taylor, Pratt, and others believed that these advantages in speed and maneuver-ability, when combined with the increased space available for command facilities in the new classes of cruisers then entering the fleet, made such vessels excellent platforms from which to exercise command.[19] Of course, cruisers had been used as flag-ships before (e.g., Beatty and Hipper at Jutland), but rarely had a navy considered placing its highest-ranking combat com-mander on something other than a capital ship. By recommending just such a step, these men evidenced a growing realization that the escalating complexity of warfare at sea necessitated better facilities and a new role for naval commanders, one in

---

Commander in Chief, U.S. Fleet to Chief of Naval Operations, 28 July 1931, NAMC, ARFTF, Roll No. 8, and Annual Report of Commander, Battle Force for FY 1932, circa July 1932, 8-9, NAMC, ARFTF, Roll No. 9.

[18] President, General Board [George Dewey] to Secretary of the Navy, 19 October 1904, NADC, RG 80, GB, Subject File 420-8, Box No. 83. See also Norman Friedman, U.S. Cruisers: An Illustrated Design History (1984), 1-11.

[19] Here I am referring specifically to the Pensacola-class (also some-times referred to as the Salt Lake City-class) and Northhampton-class cruisers. Friedman provides a useful technical description of these vessels in his illustrated design history. Friedman, U.S. Cruisers, 67-158. For launch and commissioning dates of the ships in these two classes, consult page 451.

which the efficacy of an individual commander increasingly depended on his ship's ability to receive, process, and disseminate relevant tactical information.

To be sure, not all senior American naval officers agreed with the idea that fleet command should be exercised from a cruiser modified for that purpose. In 1932, United States Fleet Commander-in-Chief Frank H. Schofield stated unequivocally that fleet command should be exercised from a battleship,[20] although he apparently did not oppose changing the flagship of the Scouting Fleet from a battleship to a cruiser.[21] Indeed, a year earlier the Navy had done just that, replacing the aging *USS Arkansas* with the recently-commissioned *USS Augusta* as flagship of the newly-organized Scouting Force.[22] Debate over the optimal type of flagship for a fleet commander continued for several years, and in 1934 the Chief of Naval Operations asked the General Board to study and make a recommendation on the matter.[23] The Board found it "unnecessary for

---

[20] To the Chief of Naval Operations Schofield wrote: "I have carefully studied the question of the proper type of vessel to be the flagship of the Commander-in-Chief, and recommend that the present assignment of a battleship be continued . . . In time of battle when the Commander-in-Chief is present, I believe that if he is in a battleship in the battle line he will be in the best possible position to observe and to influence the battle as a whole. I further believe that the Commander Battle Force as second in command [of the] United States Fleet, should have a battleship as his flagship." Commander in Chief, U.S. Fleet to Chief of Naval Operations, 21 July 1932, NAMC, ARFTF, Roll No. 9.
[21] When the Navy made this change, Schofield was serving as Commander-in-Chief of the Battle Fleet.
[22] The United States Fleet reorganized in April 1931 in accordance with a General Order from the Secretary of the Navy. The Battle and Scouting Fleets were renamed the Battle and Scouting Forces, respectively. C. F. Adams, "Organization of Naval Forces" (General Order No. 211), 10 December 1930, NAMC, "Navy Department General Orders, 1863-1948," Roll No. 3. Although signed by Secretary of the Navy Charles Francis Adams, the impetus for this reorganization lay squarely with Chief of Naval Operations William V. Pratt. Wheeler, *A Sailor's Life*, 269-270, 286-289, 325-326.
[23] Chief of Naval Operations to Secretary of the Navy, 17 April 1934, and Secretary of the Navy to General Board, 17 April 1934, both in NADC, RG 80, GB, Subject File 420-8, Box No. 86. The CNO wrote: "It is evi-

any force flagship to be assigned specifically to the Commander-in-Chief, U.S. Fleet," but advised that two specially-configured cruisers should be made available to the Commander-in-Chief.[24] In a nutshell, the General Board was advocating that the Navy's senior fleet commanders should have a choice over the types of vessels from which they exercised command.[25]

Yet even as the Navy reached a compromise on this issue, advances in aviation technology compounded the information-management difficulties faced by operational commanders. During the mid-to-late 1930s especially, improvements in aircraft performance were considerable. Faster airplanes gave commanders less time to make critical decisions, and heavier ordnance loads made the price of miscalculation even more costly. New avionics, especially radios, and longer cruising radii for naval aircraft increased the distances at which a commander could control his forces.[26] Furthermore, as the Navy added new carriers to the fleet, so too did it logically increase the number

dent that the whole matter of flagships in our present and prospective cruiser strength should be settled at this time."
[24] Chairman, General Board [Richard H. Leigh] to Secretary of the Navy, 20 April 1934, NADC, RG 80, GB, Subject File 420-8, Box. No. 86.
[25] The General Board was following the lead of Admiral Robert H. Leigh, who, upon being relieved as United States Fleet Commander in Chief, had argued: "The Commander in Chief should have available both a battleship and a cruiser as fleet flagship; one as the relief of the other. There will be times when it will be advantageous to be on a battleship, and other times on a cruiser. . . . It is believed that the selection of the flagship should depend greatly upon the immediate task of the fleet and the activities of the Commander-in Chief therein, hence a vessel of each type should be available, an 8-inch cruiser the primary flagship and a battleship the secondary or relief flagship." Commander in Chief, U.S. Fleet to Chief of Naval Operations, 10 June 1933, NAMC, ARFTF, Roll No. 9.
[26] Campbell, "The Influence of Air Power Upon the Evolution of Battle Doctrine," 80 (see also Appendix B, 202-203). For a detailed analysis of changes in naval aircraft performance in the latter half of the 1930s, see Curtis Alan Utz, "Carrier Aviation Policy and Procurement in the U.S. Navy, 1936-1940," M.A. Thesis, University of Maryland (1989). Specific performance characteristics are found in Tables 1, 3, and 5.

of aircraft squadrons.[27] Consequently, the 1930s witnessed a
growing number of discrete units over which command had to be
exercised. Put another way, as the Navy integrated aviation
into the fleet, commanders increasingly found themselves in
situations of alarming and often disquieting complexity. Sim-
plifying this complexity required the Navy to develop shipboard
systems for the management of information. Not until then
could the full potential of carrier aviation be realized.

Carrier Vulnerability

One of the distinguishing characteristics of the litera-
ture that depicts the interwar U.S. naval officer corps of the
1930s as inherently conservative is that it relies heavily on
public statements and personal reminiscences.[28] Conspicuously
absent from such accounts is an examination of the Navy's op-
erational experiences during the critical decade leading up to
World War II. These experiences reveal that operational com-
manders embraced carrier aviation as a means of scouting and
power projection, but that they remained skeptical of the car-
rier's capacity to survive a naval engagement. The small num-
ber of operational carriers available to American naval com-
manders in the 1930s exacerbated concerns over the issue of
carrier vulnerability, but the primary basis for officers'
skepticism was knowledge gained through the service's annual
fleet maneuvers. In these exercises the Navy's senior leader-
ship discovered that aircraft carriers frequently were sunk

---

[27] From 1934 to 1941 the U.S. Navy commissioned five aircraft carriers:
Ranger, Yorktown, Enterprise, Wasp, and *Hornet.* Norman Friedman, *U.S.
Aircraft Carriers: An Illustrated Design History* (1983), 412.
[28] See note 22 in Chapter One.

(hypothetically of course), and that these sinkings generally resulted from incorrect, or more often, incomplete, tactical information. These experiences, some of which will be examined here briefly, help explain why the development of effective shipboard command and control systems was an indispensable element in making carrier warfare the dominant naval paradigm of the Pacific War.

*   *   *

The architect of *USS Saratoga*'s historic raid on the Panama Canal was Rear Admiral Joseph M. Reeves, commander of the Battle Fleet's aircraft squadrons. As the story has been told elsewhere, Reeves, a brilliant but often obstinate officer famous for turning the experimental carrier *USS Langley* into an efficient fighting platform, convinced his superior (William V. Pratt) that a coordinated air attack on the Canal's locks held a high probability of success.[29] Events proved Reeves correct, but the future fleet commander was not nearly as prescient in foreseeing the danger to his carrier. Believing that *Saratoga* would be able to remain safely out of range of opposing surface vessels, at one point Reeves remarked that he truly feared only the BLUE Fleet's carrier.[30] As outlined above, however, *Saratoga*'s ultimate demise resulted from an unanticipated encounter with three enemy battleships after a failed rendezvous. This was not the last time command and control difficulties would contribute to the loss of an aircraft carrier.

---

[29] Wilson, *Slipstream*, 135-139, Wheeler, *A Sailor's Life*, 274-275, and Wildenberg, *All the Factors of Victory*, 187-191.
[30] Reeves, "Statement on Fleet Problem Nine," 2 February 1929, 42, NAMC, RRFP, Roll No. 12.

Between 1930 and 1940 the Navy conducted twelve separate fleet problems,[31] and in every year except one all of the service's operational carriers participated.[32] Remarkably, in a majority of these exercises some or all of the participating carriers were engaged and hypothetically sunk by surface warships of the opposing fleet. In Fleet Problem X (1930), for example, enemy cruisers found both flattops assigned to the defending forces, "badly damaging" one of them.[33] In a similar exercise conducted later that same year (Fleet Problem XI), surface warships engaged and impaired *Lexington* and *Saratoga*, the latter of which was sunk accidentally by her own forces.[34] During Fleet Problem XII (1931), another simulated attack on the Panama Canal, *Lexington* had the misfortune of being caught by enemy cruisers twice in one day.[35] Two years later in Fleet Problem XIV, *Lexington* suffered hypothetical destruction yet again, this time after opposing battleships surprised the flattop at a range of less than 5,000 yards as she came out of the fog. The Navy's other fleet carrier fared little better, as enemy vessels – in this instance, a battleship and a cruiser – also inflicted heavy damage on *Saratoga* during the exercise.[36]

Drawing on lessons learned from these exercises, naval commanders attempted to devise tactics and methods that would

---

[31] The U.S. Navy conducted two fleet problems in 1930. See note 102 in Chapter Three for additional information on this point.

[32] Campbell, "The Influence of Air Power Upon the Evolution of Battle Doctrine," 140.

[33] Commander in Chief, U.S. Fleet, "Report of United States Fleet Problem X," 7 May 1930, 1-3, 44-45, NAMC, RRFP, Roll No. 13. Fleet Problem X was a simulated European naval offensive in the Caribbean.

[34] Commander in Chief, U.S. Fleet, "Report on United States Fleet Problem XI," 14 July 1930, 1-3, 30, 48-49, 73, NAMC, RRFP, Roll No. 13.

[35] Commander in Chief, U.S. Fleet, "Report on United States Fleet Problem XII," 1 April 1931, 1-4, 10-13, 32-33, NAMC, RRFP, Roll No. 13.

[36] Commander in Chief, U.S. Fleet, "Report on United States Fleet Problem XIV," 20 April 1933, Section Two, 9-11, 14, Section Three, 19, 21-22, and Section Four, 8, NAMC, RRFP, Roll No. 15.

reduce carrier vulnerability; however, these efforts bore lim-
ited fruit as the decade progressed. During Fleet Problem XV,
an extensive exercise carried out in three phases during the
spring of 1934, aircraft carriers again were engaged and sunk
by surface warships. In the second part of this problem, ves-
sels of the United States Scouting Force operated as part of a
"GRAY" naval coalition tasked to attrit the slightly superior
forces of the United States Battle Force (BLUE) as they moved
eastward from the Panama Canal.[37] On the morning of May 6th,
more than one hundred carrier-launched GRAY aircraft conducted
a successful attack on two BLUE carriers, sinking one and in-
flicting heavy damage on the other.[38] Just as in Fleet Problem
IX, however, the exhilaration of success turned rapidly to con-
sternation when the launching carriers themselves came under
fire. The United States Fleet Commander-in-Chief described
this unfortunate situation in somewhat melodramatic prose,
writing: "Just as the GRAY squadrons were returning to [their
carriers] , flushed with this decisive victory over BLUE, an
embarrassing situation arose in turn for GRAY. While these
planes were about to land, there appeared over the horizon

---

[37] Frank H. Brumby [Commander, Scouting Force] , "Summary of Gray Estimate
of the Situation and Doctrine, Fleet Problem XV, Second Phase - Exercise
M," 23 April 1934, and Idem, "GRAY Estimate of the Situation, U.S. Fleet
Problem XV 2nd Phase, Exercise 'M' ," 24 April 1934, 1-2, 15, both on
NAMC, RRFP, Roll No. 16. Although each side had the same number of car-
riers, BLUE had a decided advantage in battleship strength (14:4). This
was partially offset by GRAY's advantage in cruisers (33:18). Ibid., 3.
See also Commander in Chief, U.S. Fleet to Chief of Naval Operations, 11
November 1933, NAMC, RRFP, Roll No. 16.
[38] Commander in Chief, U.S. Fleet, "Report on United States Fleet Prob-
lem XV," 1 June 1934, 19, NAMC, RRFP, Roll No. 16. One of these two
carriers was constructive (i.e., an imaginary platform represented by
another ship). In Fleet Problem XV, the BLUE carrier *Saratoga* repre-
sented three carriers (herself and two others). The GRAY carrier *Lex-
ington* also represented three carriers during this problem. The Navy
sometimes used constructive units in order to achieve a greater amount
of operational experience. For a further discussion of the use of con-
structive forces in the interwar fleet problems, see Campbell, "The In-
fluence of Air Power Upon the Evolution of Battle Doctrine," 127-129.

[three BLUE cruiser divisions], consisting of eight heavy cruisers."[39] These eight cruisers, in combination with six dozen BLUE planes launched just prior to the destruction of their own carriers, made quick work of the GRAY flattops.[40] The following day GRAY cruisers returned the favor, catching the lone remaining BLUE carrier and sinking her at close range with a barrage of simulated torpedoes.[41]

Surface warships did not locate any opposing carriers during the 1935 annual maneuvers (Fleet Problem XVI), in part because all exercise-related air operations were suspended at one point so carrier aircraft could be used to search for a missing patrol plane.[42] Both force commanders also took care to operate assigned carriers at a distance from their main bodies, a task made somewhat easier by the geography of the problem.[43] Whether the carriers in Fleet Problem XVI survived primarily due to good tactics or serendipity cannot be known, but several officers seem to have been pleasantly surprised by this development. As one senior officer later commented, "It is interesting to note that although more carriers were present during this problem than ever before, it was the first time

---

[39] Commander in Chief, U.S. Fleet, "Report on United States Fleet Problem XV," 1 June 1934, 19, NAMC, RRFP, Roll No. 16.

[40] Ibid., 20. The Chief Umpire allowed one GRAY carrier to escape in order to extend the training value of the exercise.

[41] Ibid., 22.

[42] Commander in Chief, U.S. Fleet, "Report on United States Fleet Problem XVI," 15 September 1935, 32, and Lieutenant Commander F. C. Denebrink, "Remarks of Flag Secretary, Staff of Commander-in-Chief, United States Fleet, at Critique of Fleet Problem Sixteen," 15 June 1935, 17, both on NAMC, RRFP, Roll No. 18.

[43] Fleet Problem XVI simulated a strategic offensive by the United States against a hostile power which had seized and was attempting to hold Midway Island. As such, it was the first annual maneuver to combine a major landing operation with a fleet engagement. Commander in Chief, U.S. Fleet, "Operation Plan No. 1-35," 1 March 1935, and Admiral Harris Laning, "Remarks at Critique of Fleet Problem XVI," 15 June 1935, 1, both on NAMC, RRFP, Roll No. 18.

during any problem that no carrier was accurately located [by the opposing forces] ."[44]

Existing documentation does not reveal whether carriers were engaged by surface vessels in the 1936 annual maneuvers (Fleet Problem XVII), but this circumstance clearly arose during Fleet Problem XVIII (1937).[45] In that exercise, surface warships engaged and heavily damaged all three flattops operating with the Battle Force.[46] This development exacerbated a brewing debate over the proper location for aircraft carriers with respect to a fleet's main body. One school of thought held that carriers generally should operate in close proximity to the battle line, so that they could be afforded greater protection and also so the battle line would have use of the carrier's aircraft for tactical scouting.[47] Proponents of the

---

[44] Vice Admiral Henry V. Butler, "Remarks at Critique of Fleet Problem XVI," 15 June 1935, 2, NAMC, RRFP, Roll No. 18. See also Commander-in-Chief, U.S. Fleet, "Report on Fleet Problem XVI," 15 September 1935, 32, NAMC, RRFP, Roll No. 18. Fleet Problem XVI was the first in which four carriers participated: *Langley*, *Lexington*, *Saratoga*, and *Ranger*.
[45] The remaining records for Fleet Problem XVII consist mainly of correspondence pertaining to plans and preparations for the exercise. The official report of the problem appears not to have survived. Regrettably, the same is also true for Fleet Problem XIX. Timothy K. Nenninger, *Records Relating to United States Navy Fleet Problems I to XXII, 1923-1941* (1975), 3, 21-22. See also NAMC, RRFP, Rolls No. 21, 23, and 24.
[46] Commander, Battle Force to Commander in Chief, U.S. Fleet, 11 May 1937, Commander Aircraft, Battle Force, to Commander in Chief, U.S. Fleet, 11 May 1937, both on NAMC, RRFP, Roll No. 22, Commander, Scouting Force to Commander in Chief, U.S. Fleet, 10 May 1937, Commander, Battleships, WHITE Fleet [Joseph K. Taussig] to Commander in Chief, U.S. Fleet, 10 May 1937, and Commander, Destroyers, Scouting Force to Commander in Chief, U.S. Fleet, 8 May 1937, all on NAMC, RRFP, Roll No. 23. Just prior to Fleet Problem XVIII the Navy re-designated *Langley* as a seaplane tender, but the BLACK Fleet employed her much like a carrier during the exercise. Friedman, *U.S. Aircraft Carriers*, 412, and Claude C. Bloch [Commander, Battle Force] , "Estimate of the Situation (Briefed) of the Black Fleet, Fleet Problem XVIII," 15 March 1937, NAMC, RRFP, Roll No. 22.
[47] Addressing the loss of his carriers during the 1937 annual maneuvers, BLACK Fleet Commander Claude C. Bloch wrote: "In Problem XVIII the BLACK carriers, being with the Main Body, were able to contribute their full and proportionate share . . . [this] is only the normal expectation in warfare, and as all types shared in the damage sustained, the carriers may be said to have borne no more than their part of the brunt of

other school believed that flattops were better utilized as independent strike platforms, since this enabled full-speed evasive maneuvers during an air attack.[48] The truth probably lay somewhere in the middle, or as one senior officer who had participated in Problem XVIII put it: "There is no infallible rule for the stationing of carriers. Each problem is distinct and individual in itself, and must be solved upon its merits. . . . the variables are many and a change in the value of any, or several, results in a different tactical treatment to obtain a proper solution."[49]

As was the case in Fleet Problem XVIII, carriers operated in close proximity to the main body for much of Fleet Problem XX (1939).[50] Although most of the damage to participating carriers came from hostile air attacks, at one point during the exercise a cruiser fired upon the *Lexington* at a range of only 14,000 yards.[51] Fleet Problem XXI, conducted during the spring

---

the battle." Commander, Battle Force to Commander in Chief, U.S. Fleet, 23 June 1937, NAMC, RRFP, Roll No. 23.

[48] Arguing this point, the commander of the BLACK Fleet Air Forces [Frederick J. Horne] stated: "Fleet Problem XVIII again proved that evasive movements at high speed are a carrier's best protection against air attack and the old, oft repeated lesson - a carrier tied down to a slow formation is quite certain to be put out of action." Commander, Aircraft, Battle Force to Commander in Chief, U.S. Fleet, 4 June 1937, NAMC, RRFP, Roll No. 23.

[49] Commander, Battleship Divisions, Battle Force to Commander, Battle Force, undated but likely written in mid-June 1937. Quoted in Commander, Battle Force to Commander in Chief, U.S. Fleet, 23 June 1937, NAMC, RRFP, Roll No. 23. Writing three years later, another senior officer expressed the same sentiments: "It is clear that it would be a mistake to formulate a hard and fast rule covering the question as to whether the carrier should be separated or kept with the disposition. The situations that may confront a commander are too varied. The best location must be determined by the attendant circumstances." Commander, Battle Force to Commander in Chief, U.S. Fleet, 15 May 1940, NAMC, RRFP, Roll No. 32.

[50] Commanding Officer, USS Ranger to Commander in Chief, U.S. Fleet, 31 March 1939, NAMC, RRFP, Roll No. 26, Commander, Battle Force to Commander in Chief, U.S. Fleet, 19 March 1939, and Enclosure (A) to Commander, Aircraft, Battle Force to Commander, Battle Force, 15 March 1939, both on NAMC, RRFP, Roll No. 28.

[51] Commanding Officer, USS Brooklyn to Commander in Chief, U.S. Fleet, 2 March 1939, NAMC, RRFP, Roll No. 27, Ship Umpire, USS Ranger [C. B.

of 1940, played out much the same way. Enemy air strikes once again caused a majority of the damage suffered by flattops during the exercise, but one cruiser did find and engage the carrier *Yorktown*.[52] The U.S. Navy's operational experiences thus revealed that even as late as 1940, surface warships presented a continuing threat to aircraft carriers. Furthermore, those same exercises indicated that improvements in aircraft payload and performance made flattops increasingly susceptible to damage or destruction by enemy air forces. Either way, naval commanders faced the same problem; namely, how to protect vital yet vulnerable assets without excessively diminishing their combat effectiveness.[53]

In his excellent thesis on the evolution of United States Navy battle doctrine during the interwar period, Mark Campbell argues that there were three major reasons why surface warships so often discovered, engaged, and sank opposing aircraft carriers during the annual fleet problems. The first of these was

---

Hardison] to Commander in Chief, U.S. Fleet, 27 February 1939, Enclosure (A) of Commanding Officer, USS Enterprise to Commander in Chief, U.S. Fleet, 3 March 1939, both on NAMC, RRFP, Roll No. 28, Ship Umpire, USS Lexington [Elliott Buckmaster] to Commander in Chief, U.S. Fleet, 28 February 1939, and Ship Umpire, USS Enterprise [James C. Monfort] to Commander in Chief, U.S. Fleet, 28 February 1939, both on NAMC, RRFP, Roll No. 30. *Yorktown* was the only carrier out of four participating not to be damaged significantly during the exercise. Ship Umpire, USS Yorktown [C. P. Mason] to Commander in Chief, U.S. Fleet, 27 February 1939, NAMC, RRFP, Roll No. 30.

[52] Commander, Battle Force to Commander in Chief, U.S. Fleet, 15 May 1940, and Enclosures (B) and (C) of Commander, Battleships, Battle Force to Commander in Chief, U.S. Fleet, 29 April 1940, all on NAMC, RRFP, Roll No. 32.

[53] My analysis highlights encounters between surface warships and carriers because these encounters are critical for understanding contemporary perceptions of carrier vulnerability. Aircraft engaged and (hypothetically) damaged opposing carriers numerous times, but these occurrences are covered extensively elsewhere. See Campbell, "The Influence of Air Power Upon the Evolution of Battle Doctrine," 146-182 passim, and James M. Grimes, *U.S. Naval Administration in World War II: Deputy Chief of Naval Operations (Air) – Aviation in the Fleet Exercises, 1911-1939*, vol. 16, circa 1945, 23-207. The latter of these is available at the Navy Department Library in Washington, DC.

the relatively short cruising radii of carrier-launched air-
craft. Throughout the 1930s, U.S. Navy scout planes had a
maximum cruising radius of about 200 nautical miles,[54] a dis-
tance that did not increase significantly until the Douglas
SBD-2 "Dauntless" entered operational service in 1941.[55] Sec-
ond was the inability of carrier aircraft to function effec-
tively at night or in bad weather. Because the Navy considered
night operations especially dangerous, carrier aircraft did not
routinely fly after dusk.[56] In theory, this meant that a car-
rier steaming at twenty knots might encounter enemy vessels
which had been 320 nautical miles distant just eight hours
earlier (Figure 4-2).[57] A surprise encounter between a flattop
and a battleship or cruiser greatly favored the latter, for a
surface warship could begin firing at a carrier far sooner than
the carrier could respond by launching an air strike.[58] Camp-

---

[54] Curtiss Aeroplane & Motor Company, "Characteristics Sheet, Vought
Corsair, Model O3U-1," 3 February 1930, National Air and Space Museum
(NASM), Aviation Technical Files (ATF), Vought O3U-1 Corsair Folder,
Commanding Officer, U.S. Naval Air Station Norfolk to Chief, Bureau of
Aeronautics, 18 May 1937, NASM, ATF, Curtiss XSBC-3 Folder, Navy De-
partment Board of Inspection and Survey, "Final Report on Production
Inspection Trials of Model SB2U-2 Airplane No. 1326," 10 January 1939,
NASM, ATF, Vought SB2U-2 Vindicator, Wright Field Documents Folder, and
Campbell, "The Influence of Air Power Upon the Evolution of Battle Doc-
trine," 201. Table VII of the Inspection and Survey Report compares
the characteristics of all U.S. Navy scouting aircraft then in service.
[55] Gordon Swanborough and Peter M. Bowers, *United States Navy Aircraft
Since 1911* (1968), 183-185, and James C. Fahey, *The Ships and Aircraft
of the United States Fleet: Two-Ocean Fleet Edition* (1994 [1941]), 25.
The Dauntless was a scout-bomber, later to achieve fame at the Battle of
Midway.
[56] For a brief overview of carrier night operations prior to the Second
World War, see Charles H. Brown, *Dark Sky, Black Sea: Aircraft Carrier
Night and All-Weather Operations* (1999), 5-11, and Gerald G. O'Rourke,
Night Fighters over Korea (1998), 1-5. According to O'Rourke, carrier
aviation was "very much a dawn-to-dusk operation . . . pilots making
only four night landings with a full moon once or twice a year." This
excerpt is from page 2 of O'Rourke's book.
[57] This assumes opposing forces traveling at the same speed on recipro-
cal courses. Even if one force approached the other on a perpendicular
course, over the same eight hour period a distance of over 225 nautical
miles could be closed.
[58] As the reader may recall, this is exactly what happened during Fleet
Problem XIV.

bell's third reason why surface combatants so often encountered and hypothetically sank aircraft carriers was that fleet commanders frequently failed to provide adequate escorting vessels to the flattops. Here he is less convincing, for as discussed above there was much debate within the Navy over the optimal positioning of carriers with respect to the rest of the fleet. Although additional escorts may have prevented carriers from being sunk, enemy warships usually targeted these vessels first anyway, and as Campbell himself acknowledges, from an immediate tactical standpoint destroying a carrier's flight deck was very nearly equivalent to sinking her outright.[59]

Campbell's analysis highlights the central dilemma faced by senior naval officers in their efforts to integrate aviation into fleet operations: commanders frequently lacked the information they needed to keep carriers out of harm's way, and even when such information was available, they had a limited ability to defend against attacks. Carriers were vulnerable not only to gunfire and torpedoes from opposing surface vessels, but also to attacks by submarines and aircraft. In fleet problem after fleet problem, flattops were (hypothetically) torpedoed, bombed, and shelled.[60] From the naval commander's perspective,

---

[59] Campbell, "The Influence of Air Power Upon the Evolution of Battle Doctrine," 161-165.

[60] Submarines, which had to close to within several thousand yards of a target to achieve a constructive kill, were not as successful in attacking carriers during fleet problems, although they did accomplish this feat on several occasions. See Commander, Submarine Division Eight to Commander in Chief, U.S. Fleet, 9 May 1937, Commander, Aircraft, Battle Force to Commander in Chief, U.S. Fleet, 4 June 1937, BLACK Fleet Umpire [R. M. Brainard] to Commander in Chief, U.S. Fleet, 9 May 1937, and Commander, Battle Force to Commander in Chief, U.S. Fleet, 23 June 1937, all on NAMC, RRFP, Roll No. 23 [Fleet Problem XVIII], Commanding Officer, USS Ranger to Commander in Chief, U.S. Fleet, 31 March 1939, Commander, Submarine Squadron Six to Commander in Chief, U.S. Fleet, 14 March 1939, and Commander, Submarine Division Fifteen to Commander in Chief, U.S. Fleet, 12 March 1929, all on NAMC, RRFP, Roll No. 27, Ship Umpire, USS Ranger [C. B. Hardison] to Commander in Chief, U.S. Fleet, 27 February 1939, NAMC, RRFP, Roll No. 28 [Fleet Problem XX], Ship Um-

then, these platforms introduced an unprecedented level of uncertainty into warfare at sea. As the incoming Battle Force Commander opined after the 1932 maneuvers: "Fleet Problem XIII should call to the attention of all officers associated with it, the idea of the swiftness of events in a modern sea battle. Enemy battleships almost over the horizon . . . bombers, torpedo planes, cruisers . . . destroyers assembling behind a smoke screen for attack, submarines unseen – these indicate the necessity for quick perception, quick response to a situation which may be partially hidden, and a thorough knowledge of the tactics of all arms."[61] Another senior officer described the situation in even more colorful terms, arguing that opposing carrier forces were like ". . . blindfolded men armed with daggers in a ring. There is apt to be sudden destruction of one or both. If the bandage over the eyes of one is removed the other is doomed."[62] Improved systems for the command and control of naval forces came directly out of the United States Navy's efforts to remove these bandages.

---

pire, USS Saratoga [J. M. Shoemaker] to Commander in Chief, U.S. Fleet, 10 April 1940, and Commander, Submarine Squadron Four to Commander, Patrol Wing Two, 12 April 1940, both on NAMC, RRFP, Roll No. 32 [Fleet Problem XXI].

[61] Vice Admiral Luke McNamee to Commander in Chief, U.S. Fleet, undated but probably written in April 1932. Quoted in Commander in Chief, U.S. Fleet, "Report on United States Fleet Problem XIII," 23 May 1932, 24, NAMC, RRFP, Roll No. 14.

[62] Commander, Aircraft Squadrons, Scouting Fleet to Commander in Chief, U.S. Fleet, undated but probably written in April 1930. Quoted in Commander in Chief, U.S. Fleet, "Report of United States Fleet Problem X," 7 May 1930, 66, NAMC, RRFP, Roll No. 13.

Timely Information: Risks and Rewards

Early twentieth century navies were extremely capital-
intensive organizations. The United States Navy was no excep-
tion to this, and American naval officers devoted much of their
time and effort toward developing new and better technologies
for warfare at sea. Unquestionably, many of these technologies
were truly sublime.[63] Yet for all their grandeur, airplanes,
battleships, cruisers, destroyers, submarines, and aircraft
carriers were individual platforms that could achieve maximum
effectiveness only through coordinated operations. While this
task was more difficult than some historians have recognized,
it was one understood clearly by senior American naval officers
in the early-to-middle part of the twentieth century. As one
interwar United States Fleet Commander-in-Chief aptly summa-
rized the situation: "The coordination of activities of each
type with every other type is a serious problem requiring con-
centrated study and long experience before high efficiency can
be attained. The coordination of the air force effort as a
whole, with that of the surface [and submarine] forces, then
remains as the most complex problem of all."[64]

Essential to the coordination of naval forces was infor-
mation about enemy and own forces. By the 1930s this type of
information increasingly came from electrical and electronics
technologies, which not only meant there was more information
available, but also that it had to be filtered through an in-

---

[63] The enduring popularity of these technologies is attested to by the
large number of historic naval ships in the United States, a state-by-
state listing of which can be found at http://www.maritime.org/hnsa-
guide.htm. Viewed May 1, 2003.
[64] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 18 March
1929, RRFP, Roll No. 12. This quotation is taken from page 31 of Part
III of this document.

termediary. To manage this situation, naval commanders requested and developed systems that could provide them with relevant information in the quickest and most reliable manner.

Indeed, one of the most prominent themes found in the reports and memoranda of senior American naval officers during the interwar period is the demand for timely information. In his report on Fleet Problem VI (1926), for example, Battle Fleet Commander and future Chief of Naval Operations Charles F. Hughes wrote that ship-to-ship communications had become too complicated, a situation, he argued, which led to unacceptable delays in the receipt of important information.[65] In later problems other officers expressed similar sentiments, making comments like: "Timely information prevents a tactical surprise,"[66] and "To execute with decision, intelligent action demands good and timely information."[67] Before Fleet Problem XI (1930), one fleet commander informed his subordinates that success would depend on the "quick dissemination of information and orders to own Force with a timely knowledge of the enemy resulting from accurate information and contact reports,"[68] and just a few years later *USS Langley*'s commanding officer bemoaned the information delays that had prevented his air wing

---

[65] At one point in his report a frustrated Hughes wrote: "Delayed communications are of little or no value. In this Problem there were serious delays in getting information to the O.T.C." Commander in Chief, Battle Fleet to Commander in Chief, U.S. Fleet, 15 December 1925, NAMC, RRFP, Roll No. 7.

[66] Chief Observer, Fleet Problem X [Thomas P. Magruder] to Commander in Chief, U.S. Fleet, undated but probably written in April 1930. Quoted in Commander in Chief, U.S. Fleet, "Report of United States Fleet Problem X," 7 May 1930, 71, NAMC, RRFP, Roll No. 13.

[67] Commanding Officer, Submarine V-3 to Commander in Chief, U.S. Fleet, undated but probably written in April 1930. Quoted in Ibid., 70.

[68] Commander, BLACK Fleet [Lucius A. Bostwick] to BLACK Fleet, 29 March 1930, NAMC, RRFP, Roll No. 13.

from crippling the *Saratoga* and her aircraft in Fleet Problem XIV (1933).[69]

One of the biggest obstacles to the rapid transmission and receipt of tactical information was communications security.[70] During the First World War British naval officers had impressed upon their American counterparts the risks associated with the transmission of unencoded messages, but this danger always had to be balanced against the need for timely information. Naval exercises in the 1920s further highlighted the need for a system of rapid and secure radio communications, as American naval commanders took steps both to protect their own and to exploit the enemy's radio traffic during these exercises. Fleet Problem VIII (1928) was the first in which dedicated attempts were made to intercept and decrypt the opposing fleet's wireless messages. In that problem, the Navy Department assigned a special decrypting unit of three officers and an enlisted assistant to the ORANGE Fleet. Although this group intercepted only one tactical message during the exercise, American naval officers clearly grasped the potential benefits of such a

---

[69] The commanding officer noted that even "a minute's delay in launching an attack has a serious effect on the results. Timely information is vitally important." Captain Patrick Bellinger, "Remarks at Critique of Fleet Problem XIV," likely held on 3 March 1933. Located in Commander-in-Chief, U.S. Fleet, "Report on Fleet Problem XIV," 20 April 1933, Section Three, 13, NAMC, RRFP, Roll No. 15. The date of the critique is specified in Commander in Chief, U.S. Fleet to The Fleet, 31 January 1933, NAMC, RRFP, Roll No. 15.

[70] For readers unfamiliar with the science of cryptography, a brief note on nomenclature may be useful. A code is a system for encrypting messages that replaces each word or phrase of the original text with a different character or characters. The list of replacements is contained in a single source, the codebook. A cipher is a system for encrypting messages that replaces each letter of the original text with a different letter. A "key" is used to determine which letters replace the original letters. Ciphers are potentially more secure than codes, one reason being that a key can be changed more easily than a codebook. To encrypt is either to encipher or encode. Likewise, to decrypt is either to decipher or decode. In drawing these distinctions I have relied heavily on Simon Singh, *The Code Book: The Science of Secrecy from Ancient Egypt to Quantum Cryptography* (1999).

unit.[71] Accordingly, the Navy assigned a decrypting team to the BLACK Fleet for the following year's maneuvers, this time stationing it on the flagship of the Commander-in-Chief.[72]

Unfortunately for BLUE, the accomplishments of the BLACK decrypting unit in Fleet Problem IX were nothing short of outstanding. Over the course of the exercise this group logged over five-hundred intercepted messages, many of which provided vital tactical information to the BLACK Fleet Commander-in-Chief. According to one member of the decrypting team, intercepted messages provided significant details about the enemy's plans and dispositions, and in most instances important information was available to the BLACK Fleet Commander less than three hours after transmission by BLUE.[73] The Navy's highest ranking operational commander called this "complete breakdown of secrecy" a "serious matter,"[74] and BLACK Fleet Commander William V. Pratt noted simply that "the value resulting to our own forces when enemy information was obtainable was prominent."[75]

Five factors contributed to the success of the BLACK decrypting group during Fleet Problem IX. First was the excel-

[71] Commander in Chief, U.S. Fleet to Chief of Naval Operations, undated but known written in May 1928, and F. H. Bond [Officer in Charge, Orange Decrypting Unit] to Commander in Chief, U.S. Fleet, 15 May 1928, both on NAMC, RRFP, Roll No. 11.

[72] A special decrypting unit also was assigned to the BLUE Fleet, but because radio silence was maintained by BLACK throughout much of the exercise this unit had few opportunities available to it. Commander in Chief, U.S. Fleet to Chief of Naval Operations, 18 March 1929, NAMC, RRFP, Roll No. 12. See especially page 1 of Part IV of this document.

[73] Lieutenant (junior grade) Thomas H. Dyer, "Outline of Remarks on Black Communications," undated but believed written in late January or early February 1929, NAMC, RRFP, Roll No. 12.

[74] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 18 March 1929, NAMC, RRFP, Roll No. 12. See page 6 of Part II of this document.

[75] Admiral William V. Pratt, "Remarks by Commander in Chief, Battle Fleet, at Critique on Fleet Problem IX," 5 February 1929, 58, NAMC, RRFP, Roll No. 12.

lent work of the decrypting team itself.[76] Second was the relatively high volume of radio traffic between BLUE Fleet platforms, which not only made BLACK's task of breaking BLUE's codes and ciphers easier, it also meant that more information was available for the taking.[77] Third was simple carelessness by radio personnel, who in many instances violated established procedures by relaying previously encrypted messages in plain language.[78] Fourth was the relative ease with which the codes and ciphers employed by the Navy could be broken.[79] Fifth and most significantly, however, was the slowness of the encryption and decryption processes themselves, which routinely introduced time delays of up to several hours.[80] These delays were especially pernicious for air operations. As one knowledgeable

---

[76] Members of the group included Laurence F. Safford, Joseph J. Rochefort and Thomas H. Dyer, all of whom were instrumental in U.S. Navy code-breaking successes against the Japanese during World War II. For a list of decrypting unit members, see Lieutenant (junior grade) Thomas H. Dyer, "Outline of Remarks on Black Communications," undated but believed written in late January or early February 1929, NAMC, RRFP, Roll No. 12. For more on the careers of Safford, Rochefort, and Dyer, see John Prados, *Combined Fleet Decoded: The Secret History of American Intelligence and the Japanese Navy in World War II* (1995), and Stephen Budiansky, *Battle of Wits: The Complete Story of Codebreaking in World War II* (2000).

[77] Fleet Observer Black [William Glassford] to Commander in Chief, U.S. Fleet, 29 January 1929, and Thomas H. Dyer, "Outline of Remarks on Black Communications," undated but believed written in late January or early February 1929, both on NAMC, RRFP, Roll No. 12.

[78] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 3 February 1929, Commander in Chief, Scouting Fleet to Commander in Chief, U.S. Fleet, 9 February 1929, and Commander in Chief, U.S. Fleet to Chief of Naval Operations, 18 March 1929, all on NAMC, RRFP, Roll No. 12. See especially Part IV of the latter document.

[79] Commander in Chief, Scouting Fleet to Commander in Chief, U.S. Fleet, 9 February 1929, and Thomas H. Dyer, "Outline of Remarks on Black Communications," undated but believed written in late January or early February 1929. Not all officers believed the Navy's codes and ciphers were easy to break, as revealed by comments in Fleet Observer Black [William Glassford] to Commander in Chief, U.S. Fleet, 29 January 1929, and Commander in Chief, U.S. Fleet to Chief of Naval Operations, 3 February 1929, both on NAMC, RRFP, Roll No. 12. In the latter of these two documents, Admiral Henry A. Wiley suggested that the success of the BLACK decrypting unit was due largely to its familiarity with U.S. Navy enciphering equipment.

officer commented after the exercise: "Communications with aircraft as described above brings up the subject of, when to use code or plain English. In this operation if code had been used the delay in transmission might have caused the aircraft squadrons to entirely miss their objectives. . . . [I am] of the opinion that the importance of the time element in any aircraft operation is greater than that of secrecy."[81]

Recognizing that the Navy's existing system of tactical radio communications could not provide information that was both timely and secure, naval commanders called upon the shore establishment to provide a "rapid service system of cryptography."[82] Simultaneously, they continued to use communications intelligence as a means of acquiring information about enemy forces. In Fleet Problem XI (1930), for example, the BLACK Fleet Commander organized three separate decrypting units, instructing them to make every possible effort to break the enemy cipher.[63] Ironically, however, it was the BLUE Fleet decrypting team that broke BLACK's cipher during the exercise.[84] As such, throughout much of the problem the BLUE Fleet Commander-in-Chief had valuable information regarding his opponent's in-

[80] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 3 February 1929, NAMC, RRFP, Roll No. 12.
[81] District Communications Officer, Fifteenth Naval District to Commandant, Fifteenth Naval District, 30 January 1929, NAMC, RRFP, Roll No. 12. The Fifteenth Naval District encompassed the Panama Canal.
[82] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 3 February 1929, and Idem, 18 March 1929, both on NAMC, RRFP, Roll No. 12. See also Annual Report of Commander in Chief, Battle Fleet for the period 1 July 1929 to 30 April 1930, circa May 1930, 107, NAMC, ARFTF, Roll No. 8.
[83] Commander, BLACK Fleet [Lucius A. Bostwick] to BLACK Fleet, 29 March 1930, NAMC, RRFP, Roll No. 13.
[84] After the exercise, the BLACK Fleet Commander complained to the Chief of Naval Operations that the BLUE Fleet had been allowed to use a more complex cipher than his own forces, thus putting his decrypting units at distinct disadvantage. Commander Battleship Divisions, Battle Fleet to Chief of Naval Operations, 26 April 1930, NAMC, RRFP, Roll No. 13.

tentions. As one staff officer described the resultant situation:

> The BLUE Commander, by breaking the BLACK
> codes, was in the earlier stages of the prob-
> lem advised of the movements and plans of the
> enemy's single vessels and small forces in
> time to act against them. In the final stages
> of the problem positive information relegated
> BLACK's plans from the realm of surprise to
> that of precisely known facts. The informa-
> tion thus obtained was of far more value to
> BLUE than all the combined information he did
> obtain or could have obtained from his entire
> scouting forces and it was obtained without
> the expenditure of a gallon of fuel or risk of
> a single vessel.[85]

The success of early shipboard decrypting teams prompted operational commanders to expand the presence of such units in the fleet. In Fleet Problem XIV (1933), for example, the BLACK Fleet Commander-in-Chief ordered the establishment of *at least* one decrypting unit in every task group under his command.[86] One difficulty with this approach, however, was that the information obtained by decryption units on board vessels other than the force flagship had to be sent back to the Commander-in-Chief, either through visual signals or radio transmissions.[87]

---

[85] Communications Officer, Staff, Chief Observer to Commander in Chief, U.S. Fleet, undated but likely written in late April or early May 1930. Quoted in Commander in Chief, U.S. Fleet, "Report of United States Fleet Problem XI," 14 July 1930, 72-73, NAMC, RRFP, Roll No. 13.

[86] Frank H. Clark [Commander, Scouting Force], "U.S. Fleet Problem XIV (BLACK), Brief Estimate of the Situation," 6 February 1933, NAMC, RRFP, Roll No. 15. See "Communication Plan No. 1" in Annex C2 of this docu-ment. In Fleet Problem XIV special "Combat Intelligence Units" also were organized on board each battleship, cruiser, and aircraft carrier. Director of Naval Communications to Director of Naval Intelligence, 29 June 1933, NAMC, ARFTF, Roll No. 9.

[87] Commander, BLACK Fleet [Lucius A. Bostwick] to BLACK Fleet, 29 March 1930, NAMC, RRFP, Roll No. 13, Commander in Chief, U.S. Fleet to Chief of Naval Operations, 1 August 1930, Commander in Chief, U.S. Fleet to Chief of Naval Operations, 28 July 1931, both on NAMC, ARFTF, Roll No.

This increased the volume of communications within the fleet, which led not only to congested tactical circuits, but also to enhanced opportunities for the communications intelligence specialists of the opposing force. Thus, the burgeoning cryptographic skills of American naval personnel added a new urgency to the push for a rapid and secure system of radio communications.

Operational commanders pursued two tacks in their efforts to develop a system with these capabilities. First, they sought to improve the fleet's existing methods and procedures for radio security. One way to accomplish this goal was to decrease the amount of radio traffic between naval forces. Chief of Naval Operations William H. Standley recognized this fact when he informed his senior operational commander that the "degree of security desired must govern the volume of communications,"[88] but such a task was easier said than done. In 1930 the United States Fleet radio operating plan contained eighty-three different frequencies,[89] and commanders-in-chief typically gave their subordinates considerable discretion in deciding how to use these circuits.[90] Such latitude was essential for a service that emphasized tactical flexibility and indi-

---

8, Commander, BLACK Force [Frank H. Clark], "United States Fleet Problem XIII, Brief Estimate of the Situation, Operation Plan 1-32," 3 March 1932, NAMC, RRFP, Roll No. 15 (see Annex II of this document), and Commander, Battle Force to Commander in Chief, U.S. Fleet, 12 July 1935, NAMC, ARFTF, Roll No. 10.
[88] Chief of Naval Operations to Commander in Chief, U.S. Fleet, undated but known written in mid-1934 (most probably in mid-to-late June), NAMC, RRFP, Roll No. 16.
[89] Commander in Chief, Battle Fleet to Commander in Chief, U.S. Fleet, 27 September 1930, NADC, RG 80, GB, Subject File 419, Box No. 84.
[90] Commander, Battleship Divisions, Battle Fleet to Chief of Naval Operations, 26 April 1930, Commander in Chief, U.S. Fleet, "Report of United States Fleet Problem X," 7 May 1930, 63-65, 72-73, Commander in Chief, U.S. Fleet, "Report of United States Fleet Problem XI," 14 July 1930, 72-73, all on NAMC, RRFP, Roll No. 13, and Commander in Chief, U.S. Fleet, "Report on United States Fleet Problem XIV," 20 April 1933, Section Four, 20, NAMC, RRFP, Roll No. 15.

vidual initiative,[91] yet commanders still found ways to improve radio security within the fleet.

A key procedural change that reduced the amount of traffic between operating naval forces was the broadcast method of radio communications. First implemented for tactical purposes in April 1930, this method relieved subordinate commands of the requirement to acknowledge receipt of messages from the Commander-in-Chief. In addition to reducing the amount of traffic between vessels, the broadcast method also prevented an enemy from determining the composition of its opponent's forces by recording the number of responses to transmitted messages. An obvious disadvantage of such a system was that the Commander-in-Chief had no positive assurance that any given unit had received a message. Conversely, individual commanding officers never knew if they were in receipt of all the information their superiors had sent. Senior commanders quickly found a solution to this dilemma by providing each message with a serial number so that subordinate commands could ascertain when messages had been missed.[92]

[91] I draw this characterization from multiple sources, but particularly from records pertaining to the fleet's annual maneuvers. The Navy's development of a tactical doctrine that incorporated these principles is discussed in Trent Hone, "Building a Doctrine: U.S. Naval Tactics and Battle Plans in the Interwar Period," *The International Journal of Naval History*, vol. 1, no. 2, (2002), 39 pages. This article is accessible at http://ijnhonline.org/index_oct_02.html. Viewed May 1, 2003.

[92] Commander Battleship Divisions, Battle Fleet to Chief of Naval Operations, 26 April 1930, and Commander in Chief, U.S. Fleet, "Report of United States Fleet Problem XI," 14 July 1930, 70-71, both on NAMC, RRFP, Roll No. 13. The Navy later designated the broadcast method of radio communication as the "F" or "FOX" method, also referred to by naval personnel as the "no answer" or "no receipt" method. Commander in Chief, U.S. Fleet to Chief of Naval Operations, 11 October 1935, Commander, Battle Force to Commander in Chief, U.S. Fleet, 21 May 1936, Annual Report of Commander, Battle Force for FY 1937, circa July 1937, 14, all on NAMC, ARFTF, Roll No. 10, and Commander, BLACK Fleet [Adolphus Andrews], "Appendix '3' to Annex Cast, BLACK Fleet Operation Plan 1S-39," 18 February 1939, 2, NAMC, RRFP, Roll No. 25.

The Navy also reduced the volume of tactical radio traffic by developing a common operational doctrine. According to the service's *War Instructions*, doctrine entailed a mutual understanding of the intentions and plans of the commander in chief.[93] Ideally, this situation enabled the coordination of naval forces even when subordinate commanders failed to possess detailed tactical orders, but during the 1920s the fleet rarely if ever achieved this optimal state of affairs.[94] Significant progress toward a common operational doctrine began in 1930, when United States Fleet Commander-in-Chief William V. Pratt introduced a new and extremely effective set of battle instructions.[95] These instructions gave officers in tactical command (OTCs) increased flexibility by providing a general outline for the tactical employment of the fleet.[96] Unless the OTC provided orders to the contrary, subordinate commanders were expected to take initiative in accordance with the overall plan. As such, OTCs only had to communicate broad changes to the original plan, since subordinates could be expected to do their utmost to fulfill the previously declared intentions of the Commander-in-Chief.

Praise for the new instructions was widespread. The commander of the fleet's battleship divisions found them "simple

---

[93] Chief of Naval Operations, "War Instructions, United States Navy, 1923" (W.P.L. 7), 29 August 1923, National Archives, College Park, Maryland (NACP), Record Group 38 – General Records of the Chief of Naval Operations, (RG 38), Records of the Strategic Plans/War Plans Division (W.P.L. Series), Box No. 5. See pages 13-15 and 89-91 of this publication.

[94] Hone, "Building a Doctrine," 1-13.

[95] This new publication was entitled "Tentative Fleet Dispositions and Battle Plans." Commander in Chief, Scouting Fleet to Commander in Chief, U.S. Fleet, 5 June 1930, and Commander in Chief, U.S. Fleet to Chief of Naval Operations, 1 August 1930, both on NAMC, ARFTF, Roll No. 8.

[96] "Tentative Fleet Dispositions and Battle Plans" contained many different plans. Prior to an engagement, the OTC would select a specific

to understand and to use in operations,"[97] and the Scouting Fleet Commander-in-Chief called them "the greatest single advance in fleet tactics I have known in my years of service in the fleet."[98] Over the next several years the service refined these tentative instructions, finally codifying them as a fleet tactical publication in 1934.[99] By then most senior officers considered the fleet's tactical doctrine to be fundamentally sound. The United States Fleet Commander-in-Chief noted after the 1934 annual maneuvers that he had given no important orders to his detached forces, remarking that these forces "conducted their operations entirely by means of the current Battle Instructions, thus proving the great progress made in the indoctrination of the fleet."[100] Nevertheless, the Chief of Naval Operations endeavored to remind him that ". . . even the best of doctrines will not cover all situations and the provisions for a senior to communicate with his subordinate must remain.

---

plan and broadcast it (via visual or radio) to the forces under his command. Hone, "Building a Doctrine," 15.

[97] Commander, BLACK Fleet [Lucius A. Bostwick] to Commander in Chief, U.S. Fleet, undated but likely written in late April or early May 1930. Quoted in Commander in Chief, U.S. Fleet, "Report of United States Fleet Problem XI," 14 July 1930, 65, NAMC, RRFP, Roll No. 13.

[98] The Scouting Fleet Commander went on to write: "It affords to the O. T. C. an extraordinary increase in the flexibility of control from the beginning of tactical scouting through the general engagement, and until the final dispersion of the enemy." Commander, BLUE Fleet [William C. Cole] to Commander in Chief, U.S. Fleet, undated but likely written in late April or early May 1930. Quoted in Commander in Chief, U.S. Fleet, "Report of United States Fleet Problem XI," 14 July 1930, 65, NAMC, RRFP, Roll No. 13. See also Commander in Chief, U.S. Fleet to Chief of Naval Operations, 1 August 1930, NAMC, ARFTF, Roll No. 8.

[99] Chief of Naval Operations, "General Tactical Instructions, United States Navy, 1934" (F.T.P. 142), 30 January 1934, U.S. Navy Operational Archives, Washington, DC (NOA), World War II Command File, Box 108, and Hone, "Building a Doctrine," 17.

[100] Commander in Chief, U.S. Fleet, "Report on United States Fleet Problem XV," 1 June 1934, 57, NAMC, RRFP, Roll No. 16.

Communications are the servant of command, and, therefore, must provide the tools with which command is exercised."[101]

The Navy took another step to improve existing methods and procedures for communications security in 1934 when the Commander-in-Chief of the United States Fleet organized a group of specially-trained officers and tasked them to examine the fleet's message traffic for cryptographic violations.[102] Designated the Fleet Security Unit,[103] this group of officers scrutinized all encrypted messages originated in or addressed to units of the fleet, and advised the Commander-in-Chief on how to improve communications security. The Chief of Naval Operations attached high importance to the work of this group, commenting that it was of "inestimable value in training and indoctrinating our officer personnel with regard to the military weaknesses and dangers which result from radio messages which have been poorly or carelessly prepared and encrypted."[104] In the years after the establishment of the Fleet Security Unit senior operational commanders repeatedly praised its work, noting distinct progress in the drafting of messages and the employment of cryptographic aids.[105] Indeed, this unit was so successful that in mid-1939 the Commander-in-Chief dis-

[101] Chief of Naval Operations to Commander in Chief, U.S. Fleet, undated but known written in mid-1934 (most probably in mid-to-late June), NAMC, RRFP, Roll No. 16.
[102] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 15 June 1934, and Commander, Battle Force to Commander in Chief, U.S. Fleet, 5 May 1934, both on NAMC, ARFTF, Roll No. 9.
[103] The Fleet Security Unit also was known as the CINCUS unit. Ibid.
[104] Chief of Naval Operations to Commander in Chief, U.S. Fleet, 7 December 1934, NAMC, ARFTF, Roll No. 9.
[105] Commander, Battle Force to Commander in Chief, U.S. Fleet, 12 July 1935, Commander in Chief, U.S. Fleet to Chief of Naval Operations, 24 June 1936, Annual Report of Commander, Battle Fleet for FY 1937, circa July 1937, 21, and Commander in Chief, U.S. Fleet to Secretary of the Navy, 3 August 1938, all on NAMC, ARFTF, Roll No. 10.

banded it after concluding that a single staff officer could adequately monitor communications security for the fleet.[106]

The focal point of naval commanders in their second tack toward a more rapid and secure communications system was encryption technology. In the mid-1920s the Navy introduced some new encryption devices into the fleet, but these machines remained slow and cumbersome to use.[107] Improved versions of this equipment did not markedly shorten delays between the generation and receipt of messages,[108] and operational commanders repeatedly called for cryptographic systems that could reduce or eliminate this so-called coding lag.[109] The first major step toward this end came in 1932, when the Navy tested a small, hand-held encryption machine known as the strip cipher.[110] Initial tests were promising, so the Navy purchased more than 200 of these devices for use in the following year's

---

[106] Commander in Chief, U.S. Fleet to Secretary of the Navy, 27 July 1940, NAMC, ARFTF, Roll No. 10.
[107] Fleet Radio Officer, BLACK [Commander H. W. Boynton], "Fleet Problem VI, Report of Operations, Communications," circa February 1926, NAMC, RRFP, Roll No. 7, Annual Report of Commander in Chief, Scouting Fleet for FY 1927, 30 June 1927, 33, and Commander in Chief, U.S. Fleet to Chief of Naval Operations, 27 September 1927, both on NAMC, ARFTF, Roll No. 6.
[108] Commander in Chief, U.S. Fleet, "Report on Fleet Problem XII," 1 April 1931, NAMC, RRFP, Roll No. 13, and Commander in Chief, U.S. Fleet to Chief of Naval Operations, 21 July 1932, NAMC, ARFTF, Roll No. 9.
[109] One disgruntled commanding officer went so far as to proclaim sarcastically that "radio may be put out of action or the ship sunk during the time required to code messages." Comments of Commanding Officer, USS Barney, likely written in late February 1933. Located in Commander in Chief, U.S. Fleet, "Report on United States Fleet Problem XIV," 20 April 1933, Section Four, 21, NAMC, RRFP, Roll No. 15. Remarks about "coding lag" are found in Commander, Battle Force to Commander in Chief, U.S. Fleet, 5 May 1934, NAMC, ARFTF, Roll No. 9, and Commander, Battle Force to Commander in Chief, U.S. Fleet, 12 July 1935, Roll No. 10.
[110] During World War I both the Navy and the Army used cryptographic devices referred to as "strip" ciphers, but these were much larger machines than those adopted by the Navy in 1932. Louis Kruh, "An Armchair View of the Smithsonian Institution Cipher Machine Exhibit," *Cryptologia: A Quarterly Journal Devoted to Cryptology*, vol. 9, no. 1 (1985), 40-41.

fleet problem.[111] Experience gained during that exercise re-
vealed the strip cipher to be "somewhat faster" than its prede-
cessors, but still too slow for tactical purposes.[112] Opera-
tional commanders therefore continued to persist in their de-
mands for better encryption technology.[113]

A partial response to these demands came in 1936, when
the Navy adopted a new electro-mechanical encryption device,
the ECM.[114] First tested on larger warships during Fleet Prob-
lem XVII, American naval commanders hailed the new machine as
a considerable improvement over previous cryptographic de-
vices.[115] Initial models evidenced some unwelcome mechanical
defects, but the Navy was able to correct most of these dif-

---

[111] Chief of Naval Operations to Commander in Chief, U.S. Fleet, 1 Sep-
tember 1932, NAMC, RRFP, Roll No. 15.
[112] Commandant, Eleventh Naval District to Chief of Naval Operations, 3
March 1933, and Rear Admiral John Halligan, "Remarks at Critique of
Fleet Problem XIV," likely held on 3 March 1933, located in Commander-
in-Chief, U.S. Fleet, "Report on Fleet Problem XIV," 20 April 1933,
Section Three, 12, both in NAMC, RRFP, Roll No. 15. The date of the
critique is specified in Commander in Chief, U.S. Fleet to The Fleet,
31 January 1933, NAMC, RRFP, Roll No. 15.
[113] For example, in 1934 the United States Fleet Commander-in-Chief
(David F. Sellers) wrote to Chief of Naval Operations William Standley
that "adequate security with adequate speed will not be obtained until
the Fleet is provided with apparatus by which a message can be simul-
taneously encoded and transmitted, and received and decoded. [The Com-
mander-in-Chief] has consistently urged development of such apparatus .
. . [and] realizes that cryptographically secure apparatus cannot be de-
veloped overnight, but it must be developed before Fleet communications
can be said to be adequately prepared for war." Commander in Chief,
U.S. Fleet to Chief of Naval Operations, 15 June 1934, NAMC, ARFTF, Roll
No. 9. For similar demands, see Commander in Chief, U.S. Fleet to Chief
of Naval Operations, 10 June 1933, NAMC, ARFTF, Roll No. 9, and Annual
Report of Commander, Scouting Force for the period 1 July 1934 to 31
March 1935, circa April 1935, 35, NAMC, ARFTF, Roll No. 10.
[114] ECM stood for "Electric Cipher Machine." The Navy's other electro-
mechanical encryption device was the Hebern Cipher Machine, introduced
into fleet service in the early 1930s. It was the service's highest-
level cryptographic system until adoption of the ECM (Mark I). Edward
Hebern, principal designer of the machine that bore his name, assisted
the Navy in developing the ECM. Commander in Chief, U.S. Fleet to Chief
of Naval Operations, 21 July 1932, NAMC, ARFTF, Roll No. 9, and Glenn
Zorpette, "The Edison of Secret Codes," *American Heritage of Invention &
Technology,* vol. 10, no. 1 (1994), 34-43.

ficulties by the late 1930s.[116] Nevertheless, the ECM was far from a panacea. It was complicated to operate, could not be used for voice circuits, and was considered by some to be inadequately secure.[117] In addition, for reasons that remain unclear, the Navy failed to procure a sufficient number of ECMs for fleet use.[118] Ships that did not receive an ECM (primarily smaller vessels) continued to encrypt and decrypt messages with older equipment, which meant that traffic sent by ECM-equipped ships might have to be encrypted and transmitted twice.[119] Eventually the Navy developed an improved ECM (Mark II), entering it into operational service shortly before the Japanese attack on Pearl Harbor. This device served as the principal type of enciphering equipment for both the Army and the Navy during World War II.[120]

Of course, even the best of cryptographic equipment could not reduce the possibility that an opposing force might detect and obtain a line of bearing to a transmitting ship or airplane. With two or more lines of bearing a cross-fix could be plotted, thereby disclosing the geographic position of the transmitting platform. This theoretically simple concept was not, however, easy to implement. Early radio direction finding (RDF) equipment was difficult to operate, and the quality of

---

[115] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 24 June 1936, and Commander, Battle Force to Commander in Chief, U.S. Fleet, 21 May 1936, both on NAMC, ARFTF, Roll No. 10.
[116] Annual Report of Commander, Battle Force for FY 1937, circa July 1937, 21, and Commander in Chief, U.S. Fleet to Secretary of the Navy, 27 July 1940, both on NAMC, ARFTF, Roll No. 10.
[117] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 11 September 1937, NAMC, ARFTF, Roll No. 10. I am indebted to Richard Pekelney for bringing the last of these points to my attention.
[118] Commander in Chief, U.S. Pacific Fleet to Secretary of the Navy, 15 August 1941, NAMC ARFTF, Roll No. 3.
[119] Alternatively, an ECM-equipped ship could encrypt a message only once using the older equipment. Of course, this would negate the increased rapidity that the new system provided.

any given cross-fix was highly dependent upon range and rela-
tive position, two factors often beyond the control of the in-
tercepting forces. Most critically, small errors in bearing
(as indicated by the direction finder) could result in very
large range errors. Despite these obstacles, the potential ad-
vantages of an accurate RDF system were such that operational
commanders repeatedly called for better equipment from the
Navy's shore establishment. When this equipment became avail-
able, the fleet rapidly developed ways to employ the new tech-
nology for both strategic and tactical purposes.

*   *   *

The United States Navy had recognized the potential value
of radio direction finding only a few years after acquiring its
first wireless sets. In 1906 the Bureau of Equipment tested an
American-manufactured RDF system, but quickly concluded it was
not yet suitable for naval service.[121] The Navy made no fur-
ther attempts at shipboard RDF until 1913, when Atlantic Fleet
Radio Officer Stanford C. Hooper modified some standard receiv-
ing equipment and successfully determined the movements of sev-
eral vessels on the basis of their radio transmissions. On
Hooper's recommendation, the head of the Bureau of Engineer-
ing's Radio Division (future United States Fleet Commander-in-
Chief Arthur J. Hepburn) arranged for shipboard tests of sev-

[120] Richard Pekelney, "Electronic Ci, ,r Machine (ECM) Mark II." Avail-
able at http://www.maritime.org/ecm2.htm#refs. Viewed May 1, 2003.
[121] Alex P. Browne [of Stone Telegraph and Telephone Company] to Chief,
Bureau of Equipment, 13 December 1906, NADC, Record Group 19 - Bureau
of Ships, (RG 19), Bureau of Equipment General Correspondence, 1899-
1910 (BuEq), Box No. 59. Among other problems the equipment had a
fixed antenna, which required maneuvering the ship in order to obtain
bearings to a transmitting platform. Linwood S. Howeth, History of
Communications-Electronics in the United States Navy (1963), 261.

eral commercial direction finding systems, but as before the performance of this apparatus was disappointing. The Bureau of Engineering nevertheless continued its efforts to acquire an adequate RDF system for shipboard use, finally manufacturing and installing radio direction finders on twenty of the Navy's battleships and cruisers in late 1916. The following year the Bureau developed a smaller version of this direction finder, eventually installing it on American destroyers for use against German submarines.[122]

For their part, operational commanders aggressively sought to develop methods and procedures for the employment of RDF technology. During the 1920s these men led efforts to incorporate tactical direction finding into fleet operations,[123] achieving some notable successes along the way. As late as the mid-1920s shipboard radio direction finders remained relatively inaccurate and generally unreliable,[124] but by the end of the decade considerable improvements had been made. During Fleet Problem VII (1927), for example, a division of battleships used bearings obtained from its RDF equipment to intercept an enemy force,[125] prompting the Battle Fleet Commander to report that

[122] Ibid., 261-264, and Louis A. Gebhard, *Evolution of Naval Radio-Electronics and Contributions of the Naval Research Laboratory* (1979), 263-264.

[123] Commander in Chief, U.S. Pacific Fleet to Secretary of the Navy, 22 July 1922, NAMC, ARFTF, Roll No. 2, Commander in Chief, Battle Fleet to Secretary of the Navy, 12 January 1923, NAMC, ARFTF, Roll No. 3, Commander in Chief. U.S. Fleet to Secretary of the Navy, 1 July 1923, NAMC, ARFTF, Roll No. 4, Commander, Battleship Divisions, Battle Fleet to Commander in Chief, Battle Fleet, 30 May 1925, Annual Report of Commander in Chief, Battle Fleet for the period 4 October 1925 to 30 June 1926, 1 July 1926, 101, both on NAMC, ARFTF, Roll No. 5, and Commander in Chief, Battle Fleet to Commander in Chief, U.S. Fleet, 1 July 1927, NAMC, ARFTF, Roll No. 6.

[124] Commander in Chief, Battle Fleet to Commander in Chief, U.S. Fleet, 22 July 1924, NAMC, ARFTF, Roll No. 4, and Annual Report of Commander in Chief, Battle Fleet for FY 1925, circa July 1925, 10, NAMC, ARFTF, Roll No. 5.

[125] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 4 May 1927, NAMC, RRFP, Roll No. 8.

radio direction finders on battleships were "giving excellent results."[126] After Fleet Problem VIII (1928) the United States Fleet Commander-in-Chief remarked that the exercise had "well demonstrated" the value of radio direction finding,[127] and in Fleet Problem IX (1929) intercepted transmissions likely provided BLACK Fleet Commander William Pratt with important information on the location of enemy battleships.[128]

Despite these enthusiastic endorsements, most senior American naval officers recognized that more had to be done if the full potential of shipboard RDF was to be realized. Adoption of high frequency (HF) radio by the world's navies rendered obsolete the direction finders successfully employed by the United States Navy in the late 1920s, as this equipment was not capable of detecting emissions in the HF band.[129] In 1930 Pratt requested that the development of HF direction finding equipment be given highest priority,[130] and after he became Chief of Naval Operations later in the year the service tested a number of experimental high frequency direction finders.[131] Unfortunately, none of these devices performed as well as anticipated, leading one fleet commander to comment that ". . .

---

[126] Supplement to the Annual Report of Commander in Chief, Battle Fleet for the period 1 July 1927 to 10 September 1927, 10 September 1927, 20, both on NAMC, ARFTF, Roll No. 7.

[127] Annual Report of Commander in Chief, U.S. Fleet for the period 8 November 1927 to 30 June 1928, 26 September 1928, 69, NAMC ARFTF, Roll No. 7.

[128] Admiral William V. Pratt, "Remarks by Commander, BLACK Fleet, at Critique on Fleet Problem IX," 5 February 1929, 48, NAMC, RRFP, Roll No. 12. Pratt's remarks suggest that this position information derived from RDF intercepts; however, it is possible he learned the location of the enemy battleships from decrypted messages.

[129] Chief, Bureau of Engineering to Chief of Naval Operations, 25 March 1931, NAMC, ARFTF, Roll No. 8.

[130] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 1 August 1930, NAMC, ARFTF, Roll No. 8.

[131] Commander, Scouting Force to Commander in Chief, U.S. Fleet, 10 June 1932, NAMC, ARFTF, Roll No. 9, and Annual Report of Commander, Scouting Force for the period 1 July 1932 to 15 May 1933, circa late May 1933, 52, NAMC, ARFTF, Roll No. 9.

lack of high frequency direction finder equipment remains the most serious deficiency in Fleet radio material."[132]

In accord with the wishes of the Navy's senior operational commanders, the Bureau of Engineering continued to pursue aggressively an accurate and reliable HF direction finding system for the fleet. By 1935 new and improved shipboard equipment had become available, so the Navy installed a limited number of these devices on larger warships for Fleet Problem XVI.[133] One platform to receive the new equipment was the carrier *USS Saratoga*, whose radiomen employed her direction finders with substantial success during the exercise. In many instances senior officers on board *Saratoga* determined unit movements on the basis of RDF information, and in several cases hypothetical attacks against enemy submarines were made possible by intercepted HF transmissions. This latter development prompted one American naval commander to observe that "submarines operating against our Fleet during an overseas passage will be unable to use radio or expose themselves to great danger as a consequence."[134]

The events of World War II would reveal that enemy submariners did in fact have much to fear from high frequency direction finders, but in the mid-to-late 1930s the U.S. Navy still had numerous difficulties to overcome with respect to the

[132] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 10 June 1933, NAMC, ARFTF, Roll No. 9.
[133] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 11 October 1935, NAMC, ARFTF, Roll No. 10.
[134] Vice Admiral Henry V. Butler, "Remarks at Critique of Fleet Problem XVI," 15 June 1935, 1, NAMC, RRFP, Roll No. 18. See also Lieutenant Commander F. C. Denebrink, "Remarks of Flag Secretary, Staff of Commander-in-Chief, United States Fleet, at Critique of Fleet Problem Sixteen," 15 June 1935, 7, NAMC, RRFP, Roll No. 18.

employment of RDF technology.[135] The best HF direction finders were very large, a characteristic that essentially precluded installation on smaller vessels, and there still existed no adequate equipment for the upper end of the HF band.[136] For the most part, operational commanders called on the Bureau of Engineering to provide solutions to these problems,[137] but another difficulty inherent to the fleetwide operation of shipboard RDF systems could only be solved by the commanders themselves; specifically, the development of methods and procedures to correlate the bearings obtained by operators on different vessels.

At first, seaborne commanders tried a de-centralized approach. Operators on each RDF-equipped warship plotted bearings to intercepted radio transmissions, informing their respective superiors via interior communications circuits whenever relevant information was obtained. As evidenced by *Saratoga*'s experience in Fleet Problem XVI, this approach provided commanders with bearings to transmitting platforms; however, it did little to establish range.[138] To determine range accurately a cross-fix was necessary, and this required correlating one ship's RDF intercept with that of another. Other factors being equal, the best cross-fixes resulted when two intercepting units had nearly perpendicular lines of bearing to a target (Figure 4-3). Such a geometry usually occurred

[135] For an excellent discussion of United States Navy direction finding during the war, see Kathleen Broome Williams, *Secret Weapon: U.S. High-Frequency Direction Finding in the Battle of the Atlantic* (1996).
[136] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 24 June 1936, NAMC, ARFTF, Roll No. 10.
[137] Commander, Battle Force to Commander in Chief, U.S. Fleet, 12 July 1935, and Annual Report of Commander, Battle Force for FY 1937, circa July 1937, 19, both on NAMC, ARFTF, Roll No. 10.
[138] Depending on the characteristics of the intercepted signal (e.g., frequency, signal strength), operators also often could identify the transmitter from which it originated.

only when significant distances were involved, which meant that a fleet maintaining radio silence generally was unable to correlate intercepted bearings. This is exactly what happened to the senior officer present on *Saratoga*, who commented after the exercise that he had been unable to provide important information to the OTC.[139]

Fleet Problem XVI thus highlighted for naval commanders the desirability of a more centralized approach to radio direction finding. Yet without a system of ship-to-ship communications that was itself immune to the RDF facilities of an opposing force, the limitations of such an approach were conspicuous. Eventually the Bureau of Engineering would develop shipboard radio equipment that was much less susceptible to enemy direction finding, but the Navy's leaders could not know for sure when this system would become available. As such, they first tried to achieve centralization through the creation of shore-based control and tracking centers. The purpose of these centers was to correlate RDF intercepts and provide operational commanders with an overall picture of the tactical environment through a "no receipt"[140] broadcast. Although these systems were not particularly successful, they reveal much about the ways in which senior American naval officers pursued innovative methods and procedures to manage the growing amount of information available to commanders at sea.

---

[139] Vice Admiral Henry V. Butler, "Remarks at Critique of Fleet Problem XVI," 15 June 1935, 1, NAMC, RRFP, Roll No. 18. Another senior officer commented: "It has been found impracticable satisfactorily to decentralize intercept watches to a number of vessels. Centralization of intercept watches . . . is necessary." Commander, Battle Force to Commander in Chief, U.S. Fleet, 12 July 1935, NAMC, ARFTF, Roll No. 10.
[140] See note 92 above.

*   *   *

Throughout the 1930s arguably the biggest proponent of
centralized HF RDF facilities was Admiral Arthur J. Hepburn,
the same officer who as a Lieutenant Commander two decades
earlier had supervised the acquisition of some of the Navy's
earliest radio direction finding equipment (Figure 4-4). Dur-
ing Fleet Problem XVI (1935) forces under Hepburn's command hy-
pothetically had been sunk as a result of the opposing fleet's
RDF capabilities, and for the remainder of his tour as Scouting
Force Commander Hepburn ensured that his own high frequency
direction finding equipment was tested rigorously.[141] When
Hepburn became United States Fleet Commander-in-Chief in June
1936, he continued to seek methods for integrating high fre-
quency direction finding into fleet operations. The admiral
believed that the best way to accomplish this end was to create
"an efficient shore net-work with a control and tracking cen-
ter."[142] According to Hepburn, lessons learned from this expe-
rience could then be applied to the creation of such facilities
aboard ship.[143]

During Hepburn's nineteen-month tenure as Commander-in-
Chief, the Navy aggressively pursued the establishment of
shore-based RDF facilities. Selected naval districts experi-
mented with different physical layouts, while the fleet worked
with the Bureau of Engineering to test several classes of high
frequency direction finding equipment. By early 1938 the Chief
of Naval Operations believed the Navy was ready to conduct a

---

[141] Annual Report of Commander, Scouting Force for the period 1 July 1935
to 24 June 1936, circa June 1936, 22-23, NAMC, ARFTF, Roll No. 10.
[142] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 11 Sep-
tember 1937, NAMC, ARFTF, Roll No. 10.
[143] Ibid.

general test of its high frequency direction finding equipment. Accordingly, he and Hepburn directed their staffs to draft preliminary plans for that purpose.[144]

In Fleet Problem XIX, a multi-part exercise conducted in March and April of 1938, the Navy fashioned the perfect environment in which to execute these plans.[145] During the problem, the Navy Department placed a shore-based control and tracking station at the disposal of each force commander. These "Central Control Stations," located in San Francisco (for BLACK) and Pearl Harbor (for WHITE), were linked to a series of shore-based high frequency direction finders.[146] The purpose of these stations was to coordinate intercepted transmissions and to provide operational commanders with position information on enemy units.[147] In addition, the Navy provided the BLACK Commander with a separate direction finding system exclusively for locating patrol aircraft. Designated "Air Net," this system consisted of three HF direction finders linked to a central control station in San Diego. Operators at this station plotted lines of bearing to all transmissions from BLACK patrol planes, deriving cross-fixes whenever multiple simultaneous intercepts were received.[148] Air Net thus served a dual purpose by: (1) providing corroborating information on enemy contact

---

[144] Chief of Naval Operations to Commander in Chief, U.S. Fleet, 12 January 1938, NAMC, RRFP, Roll No. 24. Additional addressees included the Commandants of the Eleventh, Twelfth, Thirteenth, and Fourteenth Naval Districts.
[145] For more on the dates and phases of Fleet Problem XIX, see Nenninger, *Records Relating to United States Navy Fleet Problems*, 11-12.
[146] Except for island stations, the HF direction finders were linked by "landwire or cable." Due to budgetary limitations the Navy simulated these connections during Problem XIX, relying instead on HF radio to link the direction finders with their corresponding control stations. Chief of Naval Operations to Commander in Chief, U.S. Fleet, 12 January 1938, NAMC, RRFP, Roll No. 24.
[147] Ibid.

reports, and (2) providing a datum for search operations in the event of a downed aircraft.[149] Because flying for extended periods over open ocean created considerable navigational difficulties for naval aviators, operational commanders saw great promise in Air Net.[150]

Unfortunately, neither Air Net nor the other two HF direction finding networks established for Fleet Problem XIX performed as well as expected. The commander responsible for the WHITE Fleet HF direction finding network reported negligible results,[151] and the Air Net Control Officer observed that only about fifty percent of cross-fixes were "reasonably accurate."[152] Admiral Hepburn, whom the Navy had placed in charge of the BLACK Fleet HF direction finding network,[153] remarked that the performance of his RDF stations had been "wholly inadequate."[154] Nevertheless, the former Commander-in-Chief discerned a number of positive trends in the U.S. Navy's inaugural test of centralized HF RDF facilities. He noted how operators had improved their skills over the course of the exercise, and pointed out that excellent cross-fixes generally were achieved whenever transmitting frequencies could be estimated accurately

[148] Lieutenant L. J. Dow [Air Net Control Officer], "Fleet Problem XIX, Report of Performance of West Coast Air Net, High Frequency Direction Finders," circa April 1938, NAMC, RRFP, Roll No. 24.
[149] Chief of Naval Operations to Commander, Scouting Force, 16 January 1939, NAMC, RRFP, Roll No. 25. Additional addressees included the District Communications Officer, San Juan, Puerto Rico, and the Commandants of the First, Third, Fourth, Fifth, Eighth, and Fifteenth Naval Districts.
[150] Chief of Naval Operations to Commander in Chief, U.S. Fleet, 12 January 1938, NAMC, RRFP, Roll No. 24.
[151] Commandant, Fourteenth Naval District to Chief of Naval Operations, 13 May 1938, NAMC, RRFP, Roll No. 24.
[152] Lieutenant L. J. Dow [Air Net Control Officer], "Fleet Problem XIX, Report of Performance of West Coast Air Net, High Frequency Direction Finders," circa April 1938, 7, NAMC, RRFP, Roll No. 24.
[153] Claude C. Bloch relieved Hepburn as Commander-in-Chief on 29 January 1938. Hepburn participated in Fleet Problem XIX as Commandant of the Twelfth Naval District.

ahead of time. Especially encouraging, according to Hepburn, was the fact that multiple simultaneous bearings could sometimes be obtained even on relatively short radio transmissions.[155]

Heartened by these tangible if somewhat limited achievements, the Chief of Naval Operations once again ordered the establishment of shore-based high frequency radio direction finding networks for Fleet Problem XX (1939). As before, the Navy Department provided the BLACK Fleet Commander with two separate direction finding networks: one to plot, analyze, and report WHITE transmissions, another to track BLACK patrol aircraft (i.e., Air Net).[156] In addition, the BLACK Fleet Commander in Problem XX, Vice Admiral Adolphus Andrews, established an RDF control and tracking center on his flagship.[157] Like Hepburn before him, Andrews believed centralized RDF facilities could provide naval commanders with strategic and/or tactical advantages over their adversaries. He argued that such facilities, if operated properly, would provide operational commanders with better access to timely information. Expressing these sentiments to his superiors shortly after the 1939 maneuvers, Andrews remarked:

> The OTC or the Fleet Commander with all his
> immediate sources of information . . . may
> find that quick but sound estimates made from
> a radio analysis right at hand, will be of

---

[154] Commandant, Twelfth Naval District to Chief of Naval Operations, 1 June 1938, NAMC, RRFP, Roll No. 24.

[155] Ibid.

[156] Chief of Naval Operations to Commander, Scouting Force, 16 January 1939, NAMC, RRFP, Roll No. 25.

[157] Vice Admiral Adolphus Andrews [Commander, Scouting Force], "Report on Radio Intelligence Work, BLACK Unit During Fleet Problem XX," circa March 1938, 4-6. Attached as Enclosure (A) to Commander in Chief, U.S. Fleet to Chief of Naval Operations, 8 May 1939, NAMC, RRFP, Roll No. 25. Andrews also authorized three of his subordinate commanders to create similar facilities.

definite assistance. The ability of the ship
to hear transmissions not heard on shore at
some distant point, the question of the value
of minutes and seconds when determining
courses of action, the responsibility of the
Fleet Commander in evaluating all sources of
information at first hand, these considera-
tions must be weighed. It appears that the
establishing and training of a number of
officers and 20 or 30 such men in this work
is demanded. . . . Remember that we want
every bit of information concerning the enemy
which we are able to obtain. Some little
detail which might appear insignificant at
first, might very well prove to be an impor-
tant clue in determining just what the enemy
is doing.[158]

Despite this high-level support, the United States Navy's
HF direction finding networks performed only slightly better in
Fleet Problem XX than they had the previous year. The lead
radioman at one direction finding station reported that his
operators had trouble intercepting enemy transmissions during
daylight hours,[159] while the commander in charge of Air Net
lamented his inability to obtain multiple simultaneous bearings
on a regular basis.[160] The control and tracking center on
Andrews's flagship was a bit more successful, but like their
shore-based counterparts the operators within it often had
difficulty deriving accurate cross-fixes. Because of this,
plots of intercepted WHITE transmissions generally provided

---

[158] Ibid., 2, 7.
[159] Radioman in Charge, U.S. Naval Radio Station, Winter Harbor, Maine
to Chief of Naval Operations, 4 March 1939, NAMC, RRFP, Roll No. 25.
[160] Commandant, Fifth Naval District to Chief of Naval Operations, 4 May
1939, NAMC, RRFP, Roll No. 25.

BLACK commanders with little more than "area limits" for opposing naval forces.[161]

The one aspect of Andrews's centralized approach that worked fairly well was the exchange of HF direction finding information over BLACK's strategic and tactical radio circuits. In this respect the admiral was aided considerably by the scenario for Fleet Problem XX,[162] which did not necessitate strict radio silence on the part of BLACK naval forces.[163] Nevertheless, Andrews and his contemporaries clearly understood that in many instances operational commanders would not have this luxury, especially during the early stages of a naval battle.[164] Thus for maximum effectiveness, any shipboard facility used to collect and correlate information obtained by other friendly units had to be a part of a communications system that was itself relatively immune to enemy intercept. The key to such a system was the development of "super-frequency" transmitters and receivers, since radio waves above the HF band (i.e., 3-30

---

[161] Vice Admiral Adolphus Andrews [Commander, Scouting Force], "Report on Radio Intelligence Work, BLACK Unit During Fleet Problem XX," circa March 1938, 24-26, NAMC, RRFP, Roll No. 25. With respect to plotted intercepts, Andrews observed that "the area of greatest density will give the OTC his best information." Ibid., 26. For an especially critical analysis of BLACK Fleet high frequency direction finding during Fleet Problem XX, see Commander, Submarine Force to Commander in Chief, U.S. Fleet, 29 March 1939, attached as Enclosure (B) to Commander in Chief, U.S. Fleet to Chief of Naval Operations, 8 May 1939, NAMC, RRFP, Roll No. 25.

[162] Fleet Problem XX simulated an effort by a hostile European power (WHITE) to reinforce a faltering insurgency in a hypothetical Latin American nation. These efforts were opposed by a North American power (BLACK) intent on preserving the legitimate government of the aforementioned Latin American country. Commander in Chief, U.S. Fleet, "Operation Order No. 13-38," 4 November 1938, and Idem, "Annex 'A' to U.S. Fleet Operation Order No. 13-38," 4 November 1938, 1-4, both on NAMC, RRFP, Roll No. 25.

[163] Commander, BLACK Fleet [Adolphus Andrews], "Fleet Problem XX, Estimate of the Situation," 6 February 1939, 10, and Idem, "Appendix '1' to Annex Affirm of BLACK Operation Plan 1S-39," circa January 1939, 2(b), 8(b), both on NAMC, RRFP, Roll No. 25.

[164] Ibid., Commander in Chief, U.S. Fleet to Secretary of the Navy, 3 August 1938, and Commander in Chief, U.S. Fleet to Secretary of the Navy, 4 August 1939, both on NAMC, ARFTF, Roll No. 10.

megahertz) tend to propagate on a line-of-sight trajectory. Barring unusual atmospheric conditions, the curvature of the earth thereby established a maximum distance at which such transmissions could be received. Fortunately for the Navy, by the late 1930s fleetwide adoption of super-frequency equipment already had begun.

Limited Range Radio

The tactical advantages of a limited range ship-to-ship communications system long had been recognized by American naval officers. As early as 1905, the Chief of the Bureau of Equipment expressed an interest in limited range wireless telephony,[165] and prior to American entry into World War I the Navy's General Board advocated development of radio-telephone apparatus for "short distance communication."[166] In the mid-1920s, the Commander-in-Chief of the United States Fleet informed the Secretary of the Navy that there was "need of some way to reduce transmission range to an approximately known distance,"[167] and that development of a limited range transmitter was "necessary if radio is to be permitted when cruising during wartime."[168] Aware of such long-standing sentiments, personnel

---

[165] To one individual the Bureau Chief wrote: "I wish to use wireless telephones for short distances . . . I do not care to have the distance covered by the telephone to exceed five miles." Chief, Bureau of Equipment to Bruce Cornwall, 17 May 1905, NADC, RG 19, BuEq, Box No. 34.

[166] President, General Board [George Dewey] to Secretary of the Navy, 19 January 1916, NADC, RG 80, GB, Subject File 419, Box No. 49.

[167] Commander in Chief, U.S. Fleet to Secretary of the Navy, 28 August 1924, NAMC, ARFTF, Roll No. 4.

[168] Commander in Chief, U.S. Fleet to Secretary of the Navy, 9 July 1925, NAMC, ARFTF, Roll No. 5. For similar comments see Captain A. Bronson [Commander, Submarine Divisions, Pacific], "War Diary, U.S.S. Camden, Problem of Panama, February 18-21, 1923," n.d., 1-2, NAMC, RRFP, Roll No. 1, and Rear Admiral William C. Cole, "Remarks by Chief of Staff,

at the Naval Research Laboratory sought to build a functioning super-frequency radio set, but they quickly discovered that the available components for frequency control, modulation, power generation, and reception were not yet reliable enough to ensure satisfactory performance.[169] Operational commanders therefore investigated other possibilities for limited range tactical communications.

A logical place for them to begin was with visual signalling, the fleet's primary method of short-range ship-to-ship communications. As the reader may recall from the previous chapter, the difficulties of communicating via visual methods during large-scale fleet maneuvers first became readily apparent in Fleet Problem Number One (1923). After that exercise, several commanders reported that semaphores, signal flags, and blinker tubes could not be read at distances greater than about five nautical miles,[170] and many officers complained about the lengthy delays that arose when repeating ships were used to relay messages.[171] Of the various visual signalling techniques employed during Problem Number One, searchlights evidenced the most potential. Rather inopportunely, however, the Navy discovered that the signal searchlights on its smaller vessels (i.e., primarily destroyers) did not possess adequate luminosity for distant signalling.[172]

U.S. Fleet, at Critique on Fleet Problem No. 5," 14 March 1925, 2, NAMC, RRFP, Roll No. 3.

[169] Gebhard, *Evolution of Naval Radio-Electronics*, 94.

[170] Commanding Officer, USS Yarborough to Commander in Chief, Battle Fleet, Commanding Officer, USS Sloat to Commander in Chief, Battle Fleet, both undated but known written in late February 1923. Located in Commander in Chief, U.S. Fleet, "Report on United States Fleet Problem Number One," 19 June 1923, 99, 102, NAMC, RRFP, Roll No. 1.

[171] See note 78 in Chapter Three.

[172] Commander, Destroyer Squadron Twelve to Commander in Chief, Battle Fleet, 27 February 1923, NAMC, RRFP, Roll No. 1.

Efforts to correct these deficiencies began almost imme-
diately, and continued throughout the 1920s. After Fleet
Problem Number One the Navy Department introduced competitive
drills "to stimulate interest in visual signalling" and encour-
aged commanding officers to select only the best personnel for
signalling duty.[173] A few years later the fleet adopted an im-
proved General Signal Book, while progressive officers like
Samuel S. Robison promoted closer integration of radio and vis-
ual communications systems.[174] Nevertheless, these steps could
not remedy the Navy's single biggest problem with respect to
visual communications; namely, the lack of an aggressive pro-
gram for acquiring and installing new equipment. Even as late
as 1927, less than fifteen percent of the fleet's destroyers
had received replacements for the searchlights deemed inade-
quate by the Navy's senior operational commander during Fleet
Problem Number One.[175] Other, less expensive equipment, such
as flag sets and spyglasses, sometimes were in short supply as
well.[176]

One reason the United States Navy's senior leadership
hesitated to invest their limited resources into upgrading the
fleet's visual signalling systems was because they believed new

---

[173] Annual Report of Commanding Officer, USS Pennsylvania for FY 1924,
circa July 1924, 4, NAMC, ARFTF, Roll No. 4. See also Commander in
Chief, U.S. Fleet to Secretary of the Navy, 9 July 1925, NAMC, ARFTF,
Roll No. 5.
[174] Annual Report of Commander in Chief, Battle Fleet for FY 1925, circa
July 1925, 48, 58, and Commander in Chief, U.S. Fleet to Secretary of
the Navy, 25 August 1926, both on NAMC, ARFTF, Roll No. 5.
[175] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 27 Sep-
tember 1927, NAMC, ARFTF, Roll No. 6.
[176] Ibid., Commander, Battleship Divisions, Battle Fleet to Commander in
Chief, Battle Fleet, 30 May 1925, and Commander in Chief, Scouting Fleet
to Commander in Chief, U.S. Fleet, 16 June 1925, both on NAMC, ARFTF,
Roll No. 5.

technologies might alleviate the need for such an investment.[177]
In the early-to-mid 1920s a number of American naval officers
hoped underwater sound signalling eventually would supplant, or
at least supplement, visual techniques as the preferred method
of short-range tactical communication between ships.[178] Even as
late as 1928, the Commander-in-Chief of the United States Fleet
wrote of his desire ". . . that the Bureau of Engineering will
evolve some method of underwater sound signalling of sufficient
range to permit tactical handling of the battle line."[179]

Despite these high hopes, the Bureau made little progress
toward this end. Operational experience revealed that sound
signals generally could not be received when the speed of ma-
neuvering ships exceeded five to ten knots,[180] and commanders
frequently complained about unreliable equipment and poorly-
trained operators.[181] Of even greater concern, the aspect of

[177] See, for example, William Pratt's comments in Commander in Chief,
U.S. Fleet to Chief of Naval Operations, 1 August 1930, NAMC, ARFTF,
Roll No. 8.

[178] Rear Admiral G. H. Burrage [Commander, Outguards (BLACK)] to Com-
mander in Chief, Battle Fleet, undated but known written in late
February 1923, located in Commander in Chief, U.S. Fleet, "Report on
United States Fleet Problem Number One," 19 June 1923, 93, NAMC, RRFP,
Roll No. 1, Commander in Chief, Scouting Fleet to Commander in Chief,
U.S. Fleet, 12 February 1924, NAMC, ARFTF, Roll No. 3, and Commander,
Battleship Divisions, Battle Fleet to Commander in Chief, Battle Fleet,
17 June 1924, NAMC, ARFTF, Roll No. 4. In the last of these documents,
for example the author argued that "sound installation appears to be a
fertile field for desirable improvements. Equipment designed for di-
rective signalling would result in practically secret communications
between ships of a battle fleet."

[179] Annual Report of Commander in Chief, U.S. Fleet for the period 8 No-
vember 1927 to 30 June 1928, 26 September 1928, 57, NAMC, ARFTF, Roll
No. 7. Similar comments are made in Commander in Chief, U.S. Fleet to
Chief of Naval Operations, 21 May 1929, NAMC, RRFP, Roll No. 7.

[180] University of Pittsburgh Historical Staff at ONR, *The History of
United States Naval Research and Development in World War II*, n.d. but
known written in the late 1940s or early 1950s, 1192f. This document
is available at the Navy Department Library in Washington, DC.

[181] Commander in Chief, U.S. Fleet to Secretary of the Navy, 28 August
1924, Commander in Chief, Battle Fleet to Commander in Chief, U.S.
Fleet, 22 July 1924, both on NAMC, ARFTF, Roll No. 4, Commander in
Chief, U.S. Fleet to Secretary of the Navy, 25 August 1926, NAMC, ARFTF,
Roll No. 5, Commander in Chief, Battle Fleet to Commander in Chief, U.S.
Fleet, 1 July 1927, Annual Report of Commander in Chief, Scouting Fleet

underwater sound communications limiting the range at which a message could be received – signal attenuation – was highly dependent upon little-understood and difficult-to-predict environmental conditions.[182] These dilemmas, when combined with promising trends in the development of limited range radio, ultimately led the U.S. Navy to abandon underwater sound signalling as a prospective means of short-range tactical communications.

Fortunately for American naval commanders, super-frequency radio offered considerably more promise as a system of secure tactical communications. As early as 1925 the fleet, in conjunction with the Naval Research Laboratory (NRL), conducted experiments involving super-frequency apparatus. Despite a game effort, however, nothing tangible came from these tests.[183] Research at NRL continued, and in late 1928 Stanford C. Hooper, who recently had been promoted to the rank of Captain and was then serving as the Director of Naval Communications,[184] informed the Navy Department that experiments with limited range radio appeared "very promising." Hooper went on to note that such a system, if successful, would "better serve the purpose

for FY 1927, 30 June 1927, 30, both on NAMC, ARFTF, Roll No. 6, and Annual Report of Commander in Chief, Scouting Fleet for the period 1 July 1928 to 31 March 1929, circa April 1929, 36-37, NAMC, ARFTF, Roll No. 7.
[182] For an overview of the U.S. Navy's efforts to understand sound propagation in the ocean environment, see Gary E. Weir, *An Ocean in Common: American Naval Officers, Scientists, and the Ocean Environment* (2001), 104-188, 292-315 passim.
[183] Commander in Chief, U.S. Fleet to Secretary of the Navy, 9 July 1925, NAMC, ARFTF, Roll No. 5. A year later one senior officer noted that: "Super-high frequency work has been almost at a standstill due to lack of apparatus, and no results worthy of mention have been obtained." Commander in Chief, Scouting Fleet to Commander in Chief, U.S. Fleet, 25 June 1926, NAMC, ARFTF, Roll No. 5.
[184] Hooper served as the Director of Naval Communications from August 1928 until July 1935. Howeth, *History of Communications-Electronics*, 420.

of communication during the approach and during periods of ra-
dio silence than underwater sound signalling."[185]

The following year NRL installed and tested experimental
super-frequency sets on two U.S. battleships.[186] The results
of these trials were encouraging, but Battle Fleet Commander
Frank H. Schofield cautioned that additional testing was nec-
essary before definite conclusions could be drawn regarding
the tactical utility of super-frequency radio.[187] As far as
operational commanders were concerned, the biggest drawback of
the NRL system was that it could only be used for telegraphic
communication. In order to resolve this issue, engineers at
the Naval Research Laboratory devised a way to incorporate
voice modulation into existing equipment,[188] and in March 1931
the Bureau of Engineering announced its intention to place all
super-frequency radio testing afloat in the hands of the Bat-
tle Fleet Commander-in-Chief.[189]

Shortly thereafter, the Battle Force[190] began service test-
ing several models of super-frequency radio equipment. Despite
optimistic expectations, however, none of this apparatus per-
formed particularly well.[191] Personnel at NRL and in the Bureau

[185] Recommendation made by Director of Naval Communications, contained in
"Comments on Report of Commander-in-Chief, U.S. Fleet, by Offices in Na-
val Operations," 5 November 1928, 16-17, NAMC, ARFTF, Roll No. 7.
[186] A. Hoyt Taylor, Radio Reminiscences: A Half Century (1948), 244, and
University of Pittsburgh Historical Staff, United States Naval Research
and Development in World War II, 1006o.
[187] Annual Report of Commander in Chief, Battle Fleet for the period 1
July 1929 to 30 April 1930, circa May 1930, 101, NAMC, ARFTF, Roll No.
8.
[188] Taylor, Radio Reminiscences, 244-245, and Gebhard, Evolution of Na-
val Radio-Electronics, 96.
[189] Chief, Bureau of Engineering to Chief of Naval Operations, 25 March
1931, NAMC, ARFTF, Roll No. 8.
[190] The Navy re-designated the Battle Fleet as the Battle Force in April
1931. For more on the fleet reorganization of 1931, see note 22 above.
[191] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 28 July
1931, Director of Naval Communications to Chief of Naval Operations, 2
October 1931, both on NAMC, ARFTF, Roll No. 8, Commander in Chief, U.S.
Fleet to Chief of Naval Operations, 10 June 1933, Commander, Battle

of Engineering apparently underestimated the difficulty of transitioning from laboratory to shipboard conditions, and several more years passed before reliable super-frequency equipment was available for fleet use.[192] Nevertheless, during this interregnum operational commanders continued to convey their enthusiasm for the new technology. For example, in 1932 the United States Fleet Commander-in-Chief expressed his belief that "[l] imited-range radio communications may prove so satisfactory as to eliminate the present necessity for blinker-tube signalling,"[193] and a few years later one of his successors commented that the absence of super-frequency equipment was one of the "most keenly felt needs of the Fleet."[194]

By 1935, the Navy determined that sufficient progress had been made to warrant the letting of contracts for the production of super-frequency radio equipment.[195] The following year naval personnel began the installation of model "CXL" super-frequency radios on warships throughout the fleet,[196] and a few commanding officers even succeeded in employing them during Fleet Problem XVII.[197] As more and more vessels received the new equipment, senior operational commanders began to consider the potential advantages of a system that combined limited

Force to Commander in Chief, U.S. Fleet, 15 May 1933, both on NAMC, ARFTF, Roll No. 9.

[192] Transmission line interference and vacuum tube unreliability were two of the biggest problems encountered. University of Pittsburgh Historical Staff, *United States Naval Research and Development in World War II*, 1006s-1006t, and Taylor, *Radio Reminiscences*, 285.

[193] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 21 July 1932, NAMC, ARFTF, Roll No. 9.

[194] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 11 October 1935, NAMC, ARFTF, Roll No. 10.

[195] Ibid., and Anonymous Author, "Memorandum for OP-20-A," 9 December 1935, NAMC, ARFTF, Roll No. 10.

[196] Commander, Battle Force to Commander in Chief, U.S. Fleet, 21 May 1936, and Annual Report of Commander, Scouting Force for the period 1 July 1935 to 24 June 1936, circa June 1936, 24, both on NAMC, ARFTF, Roll No. 10.

range radio with the broadcast method of communication. Writing in the summer of 1936, United States Fleet Commander-in-Chief Joseph M. Reeves discussed just such a possibility. With respect to the fleet commander's "no receipt" circuit, which was then in the HF band, the admiral remarked:

> It is believed that eventually, for tactical use, this circuit will have to be placed in the superfrequency band, and under such circumstances will become the most important and useful communication channel of the Fleet. By using limited range radio, capable of being restricted to the limits of a Fleet disposition, the Commander-in-Chief will have available the most satisfactory method, (even superior to flag hoists and other systems), for the instantaneous dissemination of signals, orders and information to all ships of the disposition without danger of intercept by an alert enemy intelligence organization. With a channel of this nature available, encrypting of signals will not be necessary, relays will be eliminated, and 24-hour operation, unaffected by darkness or low visibility, will be available.[198]

Unfortunately for the Navy, Reeves's vision could not be realized with the CXL radio. Although the model was of a reliable design, experience revealed that radio waves from CXLs sometimes could be intercepted well beyond the horizon. This held true even for frequencies up to 60 megahertz, which corresponded to the maximum frequency setting on the CXL trans-

---

[197] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 14 June 1936, NAMC, RRFF, Roll No. 21.
[198] Commander in Chief, U.S. Fleet to Chief of Naval Operations, 24 June 1936, NAMC, ARFTF, Roll No. 10. This excerpt is from pages 34 and 35 of this document. Battle Force Commander William D. Leahy was equally enthusiastic about the new equipment. Commander, Battle Force to Commander in Chief, U.S. Fleet, 21 May 1936, NAMC, ARFTF, Roll No. 10.

mitter.[199] Operational commanders therefore called for equipment that could be operated at even higher frequencies.[200]

The Bureau of Engineering answered this call in 1939 when it introduced the "TBS" radio transceiver into the fleet.[201] Developed by NRL and manufactured by the Radio Corporation of America, the TBS had a frequency range of 60 to 80 megahertz, which meant that its transmissions were considerably more secure than those of the CXL.[202] Initially installed on submarines and destroyers,[203] TBS provided American naval officers with a superior method of short-range tactical communications. By 1941, the Navy had installed TBS transceivers on nearly all its major warships, and this equipment served as the fleet's primary system of tactical ship-to-ship communications for the entirety of the Second World War.[204]

---

[199] Thomas B. Inglis, "Analysis of Military Communications of Fleet Problem XIX," 20 March 1939, 19-21, NAMC, RRFP, Roll No. 23.

[200] Commander in Chief, Asiatic Fleet [Harry E. Yarnell] to Chief of Naval Operations, 11 June 1937, NAMC, RRFP, Roll No. 23, and Annual Report of Commander, Scouting Force for FY 1937, circa July 1937, 24, NAMC, ARFTF, Roll No. 10.

[201] Commander in Chief, U.S. Fleet to Secretary of the Navy, 27 July 1940, NAMC, ARFTF, Roll No. 10.

[202] F. C. Kahler and John M. Coe, "Report on Test of Preliminary Model TBS Transmitting Equipment," 25 January 1939, and H. G. Lindner and S. A. Greenleaf, "Report of Test on Model TBS Receiver," 25 January 1939. Both of these reports are available at the Ruth H. Hooker Research Library, located at the Naval Research Laboratory in Anacostia, Maryland. A discussion of radio wave propagation characteristics for the frequencies under discussion is available in Gebhard, *Evolution of Naval Radio-Electronics*, 94-99. See also Norman Friedman, *Naval Radar* (1981), 119-120.

[203] The first CXLs had been installed on battleships, primarily for use on the "Battle Line" circuit. Although not entirely secure, they were considered adequate for fleet use. Because submarines and destroyers traditionally evidenced the most difficulty with short-range tactical communications, they were the first to receive TBS equipment. Inglis, "Analysis of Military Communications of Fleet Problem XIX," 23, NAMC, RRFP, Roll No. 23, and Commander in Chief, U.S. Fleet to Secretary of the Navy, 27 July 1940, NAMC, ARFTF, Roll No. 10.

[204] Captain Charles F. Horne, "Report of a Board Convened by the Commander in Chief U.S. Pacific Fleet, to Make Recommendations on Radio Equipment Based on Experience in the War which Resulted in the Defeat of Japan," 1 November 1945, NOA, World War II Histories and Historical

*   *   *

The United States Navy adopted more new shipboard command
and control systems during the 1930s than it had in any previ-
ous era. To a large extent, the service's ability to acquire
such systems stemmed from improvements in electrical and elec-
tronics technologies; however, these improvements did not take
place in a vacuum. Practical experience revealed that coordi-
nated naval operations were extremely difficult, and that the
naval force which best mastered this "most complex problem"[205]
was likely to achieve victory.

Whether partial to carriers, battleships, or submarines,
naval commanders of the late interwar period uniformly recog-
nized that information about enemy and own units was critical
to the coordination of naval forces. Not by coincidence were
explicit discussions about the importance of information more
prevalent after Fleet Problem IX, since that exercise starkly
illuminated the increasingly difficult task of command in an
environment of geographically-dispersed and dimensionally-di-
verse naval forces. The 1930s thus witnessed aggressive ef-
forts by the United States Navy to create shipboard systems
that would provide commanders with access to accurate, timely,
and secure information.

As they pursued this goal, operational commanders, working
in conjunction with the Navy's shore establishment, created for
themselves shipboard environments noticeably different from
those of the previous generation. In these new environs, ef-

Reports, Entry No. 204. See also Gebhard, *Evolution of Naval Radio-
Electronics*, 96-97.
[205] See note 64 above.

fective commanders had to possess not only audacity and good seamanship skills, but also the ability to manage information in time-critical situations. Yet even with the numerous command and control systems developed by the U.S. Navy during the interwar period, a ship's commanding officer or the OTC still had sufficient time to make nearly all important tactical decisions. As the next chapter will show, the introduction of naval radar soon changed this situation.

FIGURE 4-1

USS Saratoga's historic raid on the Panama Canal
during Fleet Problem IX (January 1929) emphasized
the importance of information in the practice of
warfare at sea. This photo shows *Saratoga* tran-
siting through the very canal she had "destroyed"
five weeks earlier.

Potential situation at dusk – carrier forces unaware of location of enemy surface vessels

Battleship Forces

Effective Gunnery Range

Effective Cruising Radius of Carrier Aircraft

Carrier Forces

Distance in Nautical Miles

320   160   0

Effective Gunnery Range

Distance in Nautical Miles

320   160   0

Potential situation eight hours later – carrier forces likely to be annihilated

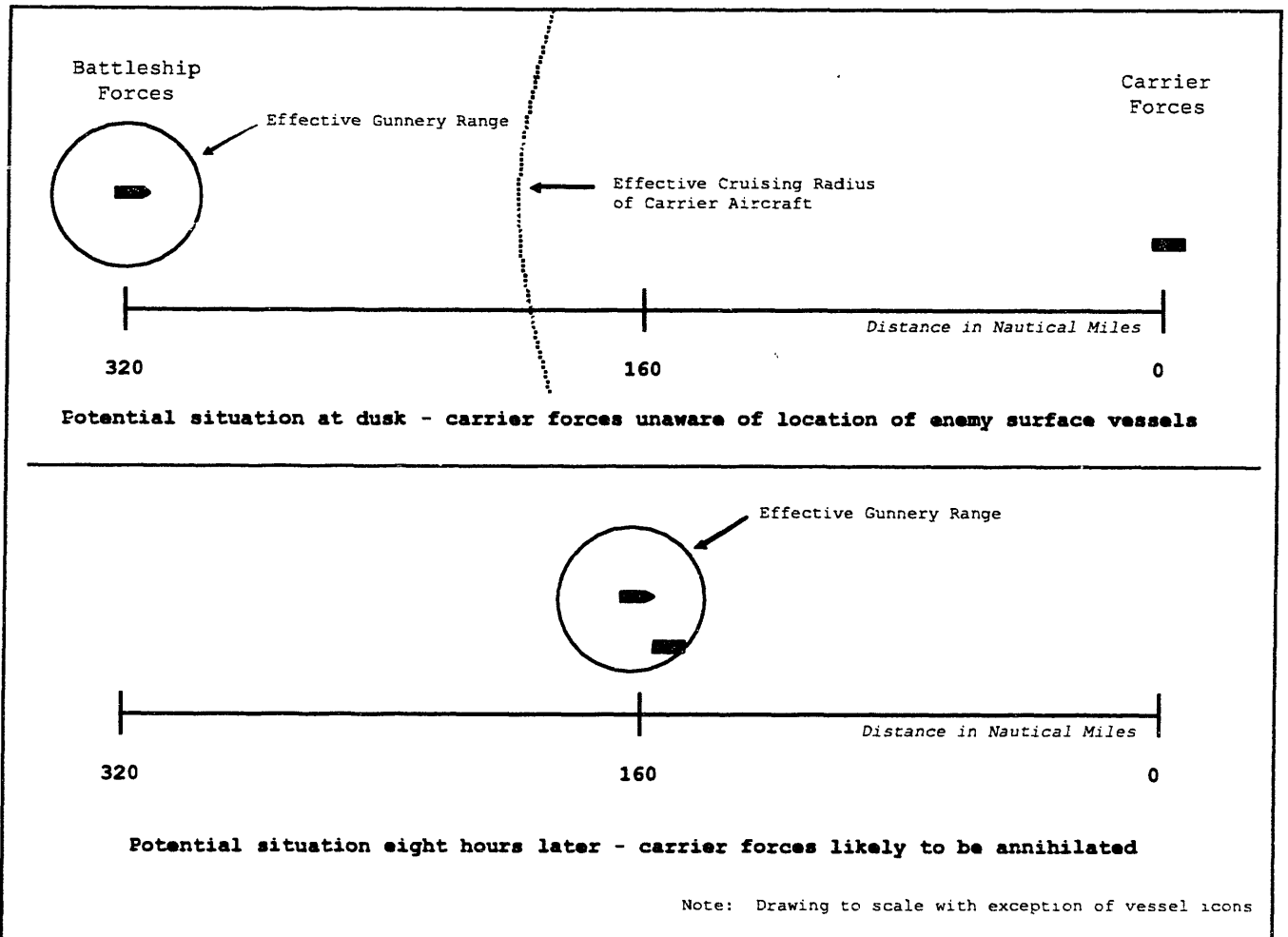Note: Drawing to scale with exception of vessel icons

FIGURE 4-2

Because carrier aircraft had limited cruising radii and did not routinely fly at night during the interwar period, flattops might easily be caught by surface warships that had been hundreds of miles away just hours before. This often held true even when opposing forces approached one another at different angles.

GEOMETRY A

+/- 5 degrees error

+/- 5 degrees error

Cross-fixes labeled 1 - 4

GEOMETRY B

+/- 5 degrees error

+/- 5 degrees error
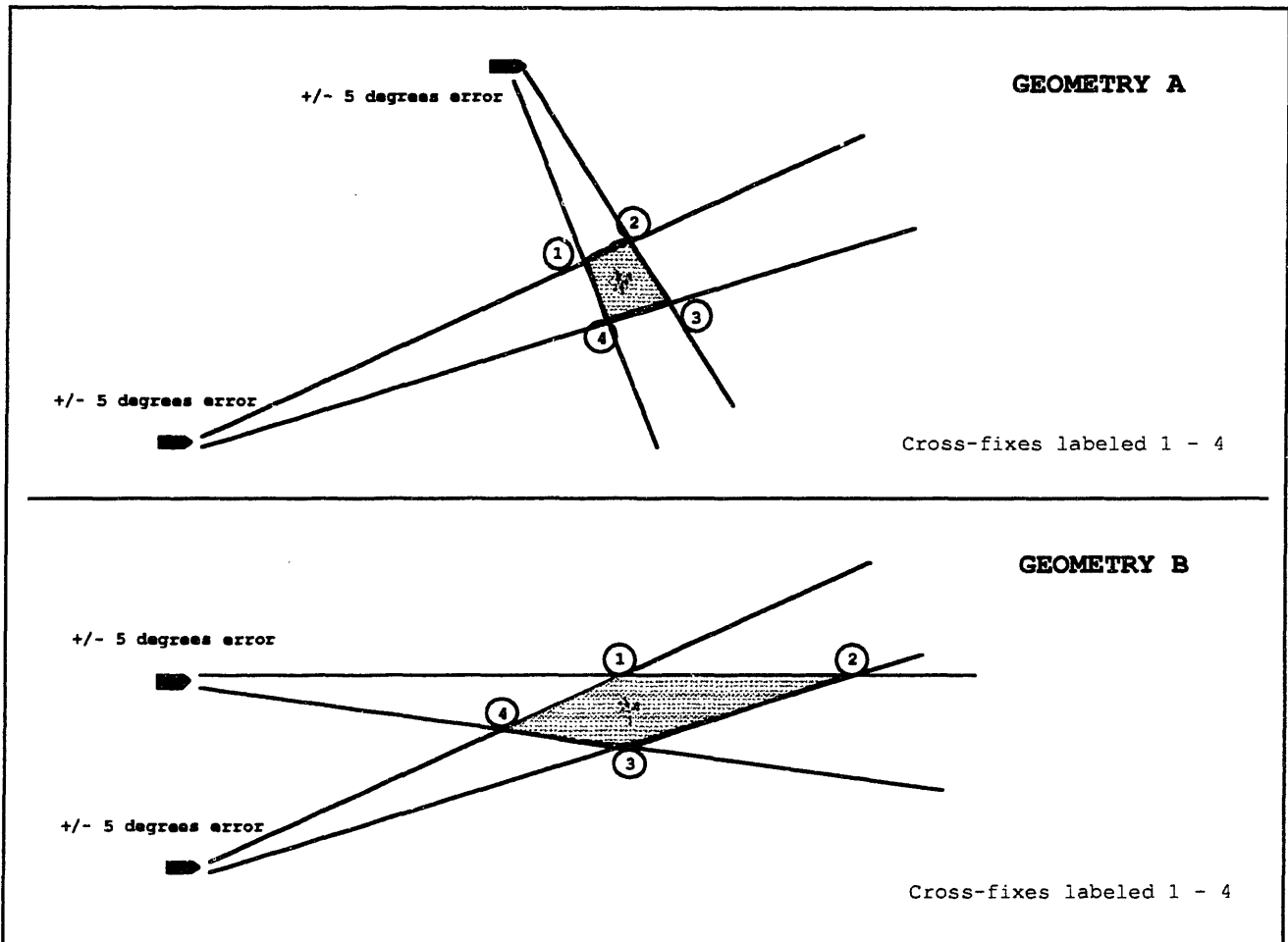
Cross-fixes labeled 1 - 4

FIGURE 4-3

For a given error in bearing, geometry made a big
difference in the accuracy of a cross-fix derived
from two intercepting direction finders. Note how
much further apart the cross-fixes are in Geometry
B as compared to Geometry A. Also note the
greater area in which a contact could possibly be
located (shaded in gray).

FIGURE 4-4

Admiral Arthur J. Hepburn, shown here with Captain
Robert L. Ghormley aboard the battleship *USS Nevada*
in 1936, was one of the Navy's biggest proponents
of centralized high frequency direction finding
facilities.

Citations for Figures

Figure 4-1: Courtesy of the Naval Historical Center.

Figure 4-2: Diagram created by the author.

Figure 4-3: Diagram created by the author.

Figure 4-4: Courtesy of the Naval Historical Center.

THIS PAGE INTENTIONALLY LEFT BLANK

CHAPTER FIVE
RADARS AND RADAR PLOTS:
ORIGINS OF THE CIC

Something Completely Out of the Ordinary[1]

For citizens of the United States, probably no event of
the twentieth century is more infamous than the Japanese at-
tack on Pearl Harbor. Less well known, at least by the pub-
lic, is the fact that immediately prior to the attack Ameri-
can forces on and around Oahu had several indications some-
thing was amiss. More than an hour before the first bombs
fell on battleship row, the destroyer *USS Ward* sighted and
sank a Japanese midget submarine.[2] Approximately fifteen
minutes later, at 7:02 AM, two enlisted operators at the
Opana radar station on the northern tip of Oahu picked up
"something completely out of the ordinary."[3] What they had

---

[1] The description of events that follows is taken from several sources,
including: *Report of the Joint Committee on the Investigation of the
Pearl Harbor Attack*, 79th Congress, 1st session, 16 July 1946, Samuel
Eliot Morison, *History of United States Naval Operations in World War
II: The Rising Sun in the Pacific, 1931 - April 1942*, Vol. III (1948),
Roberta Wohlstetter, *Pearl Harbor: Warning and Decision* (1962), Gordon
W. Prange, *At Dawn We Slept: The Untold Story of Pearl Harbor* (1981),
Idem, *Pearl Harbor: The Verdict of History* (1986), and Idem, *December
7, 1941: The Day the Japanese Attacked Pearl Harbor*. Other works con-
sulted include Edwin T. Layton, Roger Pineau, and John Costello, "*And I
Was There*": *Pearl Harbor and Midway - Breaking the Secrets* (1985), and
Henry C. Clausen and Bruce Lee, *Pearl Harbor: Final Judgement* (1992).
[2] *Ward* had been alerted to the midget submarine's presence on two sepa-
rate occasions, first by the minesweeper *USS Condor* (at 3:42 AM), and
later by a U.S. Navy patrol plane (at 6:33 AM). Only in August 2002
was this sinking confirmed, when a team of underwater archaeologists
from the University of Hawaii discovered the sunken wreckage of the
midget sub. This wreckage revealed a large hole in the submarine's
sail, which almost certainly was the result of a well-aimed shell from
the *Ward*. Burl Burlingame, "Midget Sub Found at Pearl," *United States
Naval Institute Proceedings*, vol. 128, no. 10 (2002), 94-95.
[3] George Elliott, from testimony given in *Hearings before the Joint
Committee on the Investigation of the Pearl Harbor Attack*, Part 27,

detected was the first wave of more than 180 Japanese aircraft, the majority of which were headed for the main U.S. naval base at Pearl Harbor.

After some hesitation, the radar operators at Opana reported their contacts, via telephone, to an "Information Center" thirty miles distant (located at Fort Shafter). Theoretically, this center stood at the heart of Oahu's air defense system. Within it, personnel could plot information received from any of six mobile radar stations positioned around the island's perimeter. In the event of an enemy raid, a Control Officer and his staff would direct pursuit planes to intercept the attacking aircraft. While such a raid might not be stopped, one knowledgeable officer later remarked that effectively-directed defending aircraft likely would have been able ". . . to break up, to a large extent, a raid of the sort that came in on December 7 [1941]."[4]

Of course, no intercepting defenders were there to meet the attacking Japanese aircraft on that fateful Sunday morning. Instead, an embarrassment of errors led to tragic failure. To begin, the Information Center was not fully manned.[5] Only two individuals were still on duty when the radar operators phoned in their report, and the senior officer present,

---

520. Quoted in Wohlstetter, *Warning and Decision*, 11, and Prange, *December 7, 1941*, 96.

[4] William Taylor, from testimony given in *Hearings before the Joint Committee on the Investigation of the Pearl Harbor Attack*, Part 26, 385. Quoted in Prange, *Verdict of History*, 375. At the time of the attack on Pearl Harbor, Taylor was one of the United States' foremost experts on fighter direction. A discussion of how Taylor became an authority in this area is available in Thomas Wildenberg, "An Eagle with Wings of Gold: The Remarkable Career of Bill Taylor," *Air Power History*, vol. 48, no. 3 (2001), 26-33.

[5] There was no need to man the Information Center after 7:00 AM, as the officer in charge of Hawaii's defense (Major General Walter Short) had ordered operation of the Army's coastal radars only during what he considered the most dangerous hours for an air attack (i.e., 4:00 to 7:00 AM). Only by chance was the Opana radar station still in operation at the time the initial detection was made.

Lieutenant Kermit Tyler, had stood his first watch only four days previously. Tyler remembered that a flight of Army Air Corps bombers from the mainland was due to arrive that morning, so he told the radar operators not to worry about the incoming planes.[6] Because Tyler believed the inbound planes were American, he saw no need to telephone the operations officer at the pursuit wing tasked to defend Oahu in the event of an attack. Forty-five minutes later, Japanese dive bombers destroyed the aircraft of that wing while they still were parked on the tarmac.

In defense of Tyler, he was part of a system almost predestined for failure. Personnel within the Information Center had no way of determining whether radar reports were of friendly or hostile aircraft, in part because there existed no movement reporting system for aircraft. Inadequate lines of communication between the Army and the Navy meant that no one in the Army, least of all Tyler, knew about *Ward*'s early-morning encounter with a Japanese submarine.[7] Finally, even if Tyler had telephoned the pursuit wing operations officer, as he was supposed to do, it probably would have made little difference since the Army's existing alert condition was not sufficient to permit a rapid sortie of available aircraft.[8]

One of the few things that did not go wrong that calamitous morning was the performance of the United States Army's

---

[6] Because movements of aircraft from the United States to the Southwest Pacific were classified secret, Tyler did not inform the operators of his reason for dismissing their report. Had he done so, it is possible they would have informed him that the radar blips were too big for only one flight of aircraft. For more on this point, see Prange, *At Dawn We Slept*, 500-501.

[7] Poor cooperation between the two services also prevented the Army from taking advantage of the Navy's expertise in fighter direction. Prange, *Verdict of History*, 367-370.

[8] In this recounting I have focused on tactical and operational errors. For a further discussion of the strategic and intelligence errors that led to Pearl Harbor, the reader is invited to consult the works cited in note 1 above.

radar. The SCR-270 equipment that detected the inbound Japanese aircraft was a long-wave, air-search radar, the first sets of which had entered operational service in May 1940.[9] Pre-service testing performed by the Signal Corps indicated that the SCR-270 reliably could detect approaching aircraft at distances of up to 150 miles,[10] and the operators at Opana picked up the Japanese raid very near this maximum range.[11]

The point here is that even though the Army possessed a reliable air-search radar, it did not lead directly to operational success. The dismal performance of Oahu's air defense system was the result of many factors, including poor preparedness, limited inter-service cooperation, bad judgment, and insufficient training. Yet at the very heart of this failure were inadequate methods and procedures for managing information. Much of the problem stemmed from the fact that Oahu's air defense system was under the control of the Signal Corps at the time of the attack on Pearl Harbor. This interim arrangement had been in effect for months, primarily because the Hawaiian Department's senior Signal Corps officer refused to turn his radars over to the Air Corps until he was certain that all equipment was functioning properly.[12] Unfortunately, because the Air Corps ultimately was going to assume responsibility for the air defense system, the Signal Corps spent little energy exploring how to use radar information in an

---

[9] The acronym SCR stood for "Signal Corps Radio." The Signal Corps was the Army branch responsible for the design and development of radar.
[10] Dulany Terret, *The Signal Corps: The Emergency* (1994 [1956]), 128-129.
[11] *Investigation of the Pearl Harbor Attack*, 140-141, Wohlstetter, *Warning and Decision*, 11, and Prange, *December 7, 1941*, 96-97.
[12] The Army Air Corps had been pushing to acquire operational control, but Short, who was satisfied with existing arrangements, deferred to the Signal Corps. Prange, *Verdict of History*, 370-372.

operational environment. The Army was thus ill-prepared to employ radar effectively when war arrived.[13]

<center>*   *   *</center>

In contrast to the Army, the United States Navy experienced little bureaucratic infighting over the adoption of radar. In fact, quite the opposite was true, as the service's technical organizations worked closely with the operating forces on this matter. Still, the Navy's ability to employ radar effectively was limited by two factors unique to warfare at sea. First, the physical facilities used to process radar information (i.e., the naval equivalent to the Information Center at Fort Shafter) had to be built within the confines of warships that already were extremely crowded.[14] Second, *air* defense was but one aspect of *ship* defense. For naval commanders, information obtained from radar could be used to help protect against air, surface, or sub-surface attacks.[15]

Furthermore, radar information came in the form of images, not words. These images had to be translated by operators and integrated with information from existing shipboard command and control systems in order to be of use to operational commanders. This process required the observa-

---

[13] I base this conclusion on the capabilities of the Army's air defense system in Hawaii (as of December 1941). The Army also had air defense systems in Panama and the Philippines, but there is little evidence to indicate that these facilities were superior to those on Oahu. See especially William H. Bartsch, *Doomed at the Start: American Pursuit Pilots in the Philippines, 1941-1942* (1992), and Terret, *The Emergency,* 251-306.

[14] For more on the issue of over-crowding, see Chapter Three.

[15] In 1941 onar was the only effective method for detecting a submerged submarine, but radar could be (and was) employed against *surfaced* submarines. Eventually, as radar resolution improved even periscopes became vulnerable to detection.

<center>207</center>

tion of analogue representations (i.e., blips on an oscillo-scope), converting this information to a digital format and transmitting it to a plot, where it could be presented to decision-makers as a more intelligible analogue representation. Needless to say, this analogue-to-digital-to-analogue conversion process appreciably increased the possibility that important information might be "lost in translation."

Individually and together, these issues greatly complicated the Navy's efforts to design and construct command and control facilities for the employment of shipboard radar. Nevertheless, by late 1941 the service had made considerable progress developing radar technology and integrating it into the practice of warfare at sea: training programs had been initiated, new tactics had been developed, and improved equipment was on the way. Yet solutions to the problems created by shipboard space constraints and three-dimensional threat axes were not easy to achieve, and much work remained to be done before American naval commanders could exploit the full potential of seaborne radar.

This chapter examines the Navy's efforts to integrate radar technology into fleet operations from 1937 to 1941.[16] Such an examination reveals that radar created an information management problem of considerable complexity, and that operational success required the adoption of new techniques, devices, and facilities for the command and control of naval forces. Although it took considerable time to make these

---

[16] During most of this period the Navy had no significant operational experience with fire control radar, the first sets of which were not installed on American warships until the summer of 1941. As such, my analysis concentrates on the service's efforts to integrate search radar into naval warfare. For more on the U.S. Navy's adoption of fire control radar, see Buford Roland and William B. Boyd, *U.S. Navy Bureau of Ordnance in World War II* (1953), 368-432, and David A. Mindell, *Between Human and Machine: Feedback, Control, and Computing Before Cybernetics* (2002), 260-275.

systems highly-effective, to a large extent their efficacy in World War II derived from the initiatives begun during those final years of peace.

Radar at the Naval Research Laboratory

Like many technologies, radar possesses its own set of creation myths.[17] The British government granted the first patent for a radio reflection device in 1904, but not until 1922 would the idea be given a practical test in the United States.[18] In September of that year two U.S. Navy engineers, Leo C. Young and Albert Hoyt Taylor,[19] were conducting tests with experimental high frequency radio apparatus when they observed that passing vessels created unusual interference patterns. Realizing that this phenomenon might have useful applications, Taylor wrote the Bureau of Engineering to ask for further support. Despite its potential utility, however, the Bureau concluded that a practical radio detection system could not be constructed with existing electronic components. Taylor and Young thus went on to other projects, and the U.S.

---

[17] "RADAR" is an acronym for "Radio Detection and Ranging." During its developmental years, radar was referred to variously as "Radio Ranging Equipment," "Radio Detection Equipment," "Radio Echo Equipment," and "Pulse Radio Equipment." The Navy officially adopted the term radar in late 1940. Chief, Bureau of Ships to Chief of Naval Operations, 28 October 1940, U.S. Navy Operational Archives, Washington, DC (NOA), Post-1946 Command File (P46), Documentary Analysis of New-Weapon Development Programs (DANWDP), Section A-1, and Chief of Naval Operations to Chief, Bureau of Ships (and others), 18 November 1940, National Archives, Washington, DC (NADC), Record Group 80 – General Records of the Department of the Navy, Records of the General Board, Subject File 419, Box No. 50.
[18] Henry E. Guerlac, *Radar in World War II*, vol. 1 (1987 [1947]), 40-42.
[19] Taylor was a physicist by training. A. Hoyt Taylor, *Radio Reminiscences: A Half Century* (1948), 10-72.

Navy took no direct steps toward the development of radar for nearly another decade.[20]

Renewed interest in the possibilities of radio detection began in the summer of 1930, when Young, who was now employed by the Naval Research Laboratory (NRL), discovered that airplanes reflected enough high frequency radiation to cause a noticeable interference pattern in a distant receiver.[21] After several months of investigation, Young's superior notified the Bureau of Engineering that NRL might be able to build a practical radio detection system. The Bureau agreed to sponsor further research, but allocated little in the way of new funds. For the next several years NRL engineers made limited progress, so in late 1933 Young recommended a new approach. Whereas previous efforts had attempted to detect objects on the basis of the Doppler Effect,[22] Young suggested a pulsed system; that is, one in which the time difference between the transmission of a radiated signal and the receipt of its echo is used to determine the distance to an object.[23]

Work on a pulsed system began in earnest the following year, about the same time NRL elevated the radar project to "urgent" priority.[24] The head of NRL's Radio Research Division tasked one of his brightest employees, a young engineer by the name of Robert M. Page, to spearhead the pulsed radar

[20] Ibid., 156, Guerlac, *Radar in World War II*, 42-44, and David Kite Allison, *New Eye for the Navy: The Origin of Radar at the Naval Research Laboratory* (1981), 39-41.

[21] Young made this discovery while working with Lawrence A. Hyland, another NRL engineer.

[22] Doppler Effect is the apparent frequency shift that results from relative motion. The archetypal example of this is a moving train. As the train approaches a stationary observer, its whistle seems to blow at a higher frequency; as the train passes and moves away from the observer it seems to blow at a lower frequency. In actuality, of course, the frequency of the sound waves coming out of the whistle is constant.

[23] Taylor, *Radio Reminiscences*, 267-271, Guerlac, *Radar in World War II*, 64-73, and Allison, *New Eye for the Navy*, 61-83.

[24] This represented the highest level of importance for any NRL program.

project. Page worked hard to construct a functioning device, and by the end of the year he had demonstrated the feasibility of a pulsed radar system. Nevertheless, Page's experimental apparatus evidenced numerous shortcomings. The main difficulty was with the receiver, which became saturated by the high-power pulse and could not recover in time to detect a returning echo. Page therefore spent most of 1935 redesigning the receiving unit, during which time he developed a circuit to reduce feedback and permit rapid recovery from high-voltage signals. By early 1936, Page was ready for a practical test of his new system.[25]

That test finally came the last week of April, and was successful beyond even Page's expectations. The redesigned apparatus revealed clear and distinct echoes from planes up to nine miles away, a distance NRL engineers were able to double after some "fruitful tinkering."[26] In early June, NRL demonstrated its pulsed radar system to representatives from the Bureau of Engineering, who made an enthusiastic report back to the Bureau Chief, Rear Admiral Harold G. Bowen. After receiving the encouraging news, Bowen immediately requested that the Naval Research Laboratory direct its efforts toward the design and construction of a practical system for shipboard use.[27]

The existing prototype was unsuitable for shipboard use for two principal reasons. First, it operated at a frequency

[25] Robert M. Page, *The Origin of Radar* (1962), 73, 89-105. NRL personnel also made changes to the transmitter (through the incorporation of a self-quenching circuit) and to the display unit, which they modified from a circular time sweep to a linear sweep on a logarithmic scale (i.e., an A-scope). See also Allison, *New Eye for the Navy*, 78-97.
[26] Guerlac, *Radar in World War II*, 75-76.
[27] Chief, Bureau of Engineering to Director, Naval Research Laboratory, 12 June 1936, NADC, Record Group 19 - Records of the Bureau of Ships (RG 19), Naval Research Laboratory General Files (Confidential) (NRL-C), Box No. 31.

of only 28.6 megahertz, which meant that the transmitting an-
tenna was too big for installation on board naval warships.[28]
Naturally, Page had been aware of this limitation from the
outset, but he believed the initial tests should be conducted
at a frequency for which electronic components were readily
available. After these tests proved successful, the young
engineer shifted his efforts toward the design and construc-
tion of a 200-megahertz set. Page selected this particular
frequency because he believed it to be the maximum one prac-
ticable with state-of-the-art vacuum tube technology.[29]

The second reason the existing prototype was unsuitable
for shipboard installation was that it required two antennas,
one for transmission and one for reception. Page believed
this would be an acceptable arrangement once the 200-mega-
hertz equipment had been developed, but Taylor, his superior,
thought a single antenna could be used for both transmitting
and receiving. Although Page greeted this idea with consid-
erable skepticism, Taylor persisted. So the young engineer
went to work, and remarkably, within a matter of months he
had developed a device that permitted the use a common an-
tenna.[30]

The new device, referred to as a duplexer, and the 200-
megahertz radar set were given their initial tests in July
1936. The duplexer worked splendidly, but the new receiver
had difficulty picking up reflected signals from aircraft.
To solve this problem, Page sought a more powerful transmit-

---

[28] As a general rule for radio equipment, lower frequencies require
larger antennas.

[29] Allison, *New Eye for the Navy*, 99, and Louis A. Gebhard, *Evolution of
Naval Radio-Electronics and Contributions of the Naval Research Labora-
tory* (1979), 172-173.

[30] Page, *The Origin of Radar*, 106-125, Guerlac, *Radar in World War II*,
79-80, and Allison, *New Eye for the Navy*, 100-101.

ter.[31] This he accomplished by: (1) adopting a new type of vacuum tube that became commercially available in late 1936, and (2) re-configuring the transmitter circuitry into a ring design.[32] In early 1938, NRL engineers successfully tracked planes out to a distance of fifty miles, which was the maximum possible at that time due to the limit of the sweep on the display scope.[33] Satisfied with these results, on February 17th Page recorded in his notebook: "This completes the entire 200 [MHz] development of radio echo equipment."[34] Radar was ready to make the transition from the laboratory to the fleet.

Radar Goes to Sea

Even while the development of NRL's 200-megahertz radar was still on-going, senior American naval officers expressed considerable interest in the new technology. During the summer of 1936, Page and his staff demonstrated their 28.6-megahertz equipment to a number of high-ranking officers from the Washington area, including the Chief of Naval Operations. In December, they demonstrated NRL's new 200-megahertz equipment to United States Fleet Commander-in-Chief Arthur J. Hepburn,

---

[31] Because the signal strength at a receiver decreases at a rate proportional to the fourth-root of the power of the transmitted pulse, very large increases in transmitter power are necessary to achieve relatively small increases in maximum detection range. To wit, a doubling of transmitter power increases a radar's maximum detection range by only nineteen percent. Radar School Staff at the Massachusetts Institute of Technology, *Principles of Radar* (1946), Chapter I, 12-18.

[32] For further details, see Page, *The Origin of Radar*, 129-133.

[33] Guerlac, *Radar in World War II*, 80-83, and Allison, *New Eye for the Navy*, 100-104.

[34] Robert M. Page, Laboratory Notebook No. 346, vol. IV, 73. Quoted in Guerlac, *Radar in World War II*, 83, and Allison, *New Eye for the Navy*, 103.

who immediately called for shipboard tests of a practical nature.[35] Although Page believed that the apparatus was not yet ready to go to sea, Taylor, who felt that NRL's radar program would benefit from the operational exposure, overruled him.[36]

The U.S. Navy's first test of seaborne radar took place the following April, when the Naval Research Laboratory installed a 200-megahertz set on the destroyer *USS Leary*. During the two weeks *Leary* was underway this equipment performed satisfactorily, although the need for more powerful transmitting apparatus again was apparent.[37] As discussed above, Page and his staff did not produce a sufficiently-powerful transmitter until early 1938, at which time the Navy Department chose to "freeze" development of NRL's 200-megahertz radar.[38] This decision was made in late February after representatives from NRL, the material bureaus,[39] and the Office of the Chief of Naval Operations met and concluded that radar equipment should be provided to the fleet at "the earliest practicable date."[40] On March 4th, NRL informed the Bureau of Engineering it would have a 200-megahertz "radio echo detector" ready for shipboard installation within six months.[41]

---

[35] Hand-written letter from A. J. Hepburn to H. M. Cooley [Director, Naval Research Laboratory], 29 December 1936, Director, Naval Research Laboratory to Commander in Chief, U.S. Fleet, 7 January 1937, both in NADC, RG 19, NRL-C, Box No. 31, and Gebhard, *Evolution of Naval Radio-Electronics*, 172-176. Hepburn was a forceful proponent of integrating radio-electronics into naval operations. For more on his efforts toward this end, see Chapter Four.
[36] Taylor, *Radio Reminiscences*, 299-300.
[37] Allison, *New Eye for the Navy*, 101-102.
[38] Taylor, *Radio Reminiscences*, 323-325. NRL already was in the process of developing higher frequency radars. Chief, Bureau of Engineering to Director, Naval Research Laboratory, 2 March 1938, NADC, RG 19, Naval Research Laboratory General Files (Secret) (NRL-S), Box No. 4.
[39] The material bureaus consisted of Construction & Repair, Engineering, Ordnance, and Aeronautics.
[40] J. M. Irish [Acting Chief, Bureau of Engineering], "Record of Conference in Connection with Bureau of Engineering SECRET Problem W5-2S," 28 February 1938, NADC, RG 19, NRL-S, Box No. 4.
[41] Director, Naval Research Laboratory to Chief, Bureau of Engineering, 4 March 1938, NADC, RG 19, NRL-S, Box No. 4.

Because of delays in the procurement of an antenna support structure, the Naval Research Laboratory failed to meet this deadline. Nevertheless, by the end of 1938 Page and his assistants had supervised the installation of a 200-megahertz radar, designated the "XAF," on board the battleship *USS New York*.[42] Fearful of having all eggs in one basket, the Bureau of Engineering also contracted with the Radio Corporation of America (RCA) for a second radar set.[43] This equipment, designated the "CXZ," was a 385-megahertz pulsed radar that RCA had developed independently from the NRL radar program.[44] On January 4, 1939, only a few weeks after *New York* received her XAF, the Navy installed RCA's CXZ on board the battleship *USS Texas* so that comparative tests could be conducted during the fleet's upcoming annual maneuvers.[45]

As carried out, these tests revealed that the XAF and the CXZ were far from comparable. RCA had rushed the CXZ into production (largely in response to pressure from the Navy), with disappointing results. Returns frequently were weak and inconsistent, exposed parts deteriorated when exposed to moisture, and the apparatus could not withstand the vibrations created by the discharge of *Texas'* s fourteen-inch

[42] Director, Naval Research Laboratory to Chief, Bureau of Engineering, 4 August 1938, Chief of Naval Operations to Commander, Atlantic Squadron, 2 December 1938, and Louis A. Gebhard, "Memorandum for Dr. Taylor (Subject: Radio Ranging Equipment, 200 megacycles)," 6 February 1939, all in NADC, RG 19, NRL-S, Box No. 4. See also Assistant Chief, Bureau of Engineering to Director, Naval Research Laboratory, 5 December 1938, NADC, RG 19, NRL-C, Box No. 31.

[43] BuEng Contract NOs-59870, dated 26 March 1938, NOA, P46, DANWDP, Section D-2.

[44] Prior to 1939, RCA and NRL exchanged surprisingly little information about their respective radar programs. Allison, *New Eye for the Navy*, 105-107.

[45] Arthur A. Varela to Director, Naval Research Laboratory, 28 March 1939, NADC, RG 19, NRL-S, Box No. 4. These tests were conducted both before and during Fleet Problem XX.

guns.[46] For surface contacts, the maximum detection range of the CXZ was roughly half that of the XAF, and CXZ operators rarely succeeded in detecting aircraft at distances of more than five nautical miles.[47] Disappointed with the CXZ's performance, the Commanding Officer of the *Texas* remarked that RCA's equipment "would be of very little value in war,"[48] while his boss informed the Bureau of Engineering that "the XAF equipment was in all respects (except size) markedly superior to the CXZ."[49]

Perhaps the most dramatic indication of the XAF's potential came on the night of January 16th, when a special tactical exercise pitted four darkened destroyers against the *New York*. As described by Page, the exercise proceeded as follows:

> [Destroyer Squadron] spotted 19,500 yards, 350° [relative bearing] . . . Range observed to be increasing slowly . . . Search lights were turned on at 9000 yards, 60°. First light fell dead on leading destroyer, as reported later by Comdesron. Range was too great for observers on NEW YORK to see the destroyers. At 9000 yards, 120° the destroyers turned on their lights, and they appeared to be exactly where indicated by the XAF. The defense was considered successful.[50]

---

[46] Commanding Officer, USS Texas to Commander, Atlantic Squadron, 24 March 1939, NADC, RG 19, NRL-S, Box No. 4.

[47] For example, the CXZ detected capital ships at a maximum range of 15,000 yards, and destroyers at a maximum range of 9,000 yards. The corresponding distances for the XAF were 29,000 and 19,000 yards, respectively. Robert M. Page to Commander, Atlantic Squadron, 3 April 1939, and Commanding Officer, USS Texas to Commander, Atlantic Squadron, 19 March 1939, and both in NADC, RG 19, NRL-S, Box No. 4.

[48] Commanding Officer, USS Texas to Commander, Atlantic Squadron, 24 March 1939, NADC, RG 19, NRL-S, Box No. 4.

[49] Commander, Atlantic Squadron to Chief, Bureau of Engineering, 4 April 1939, NADC, RG 19, NRL-S, Box No. 4.

[50] Robert M. Page to Commander, Atlantic Squadron, 3 April 1939, NADC, RG 19, NRL-S, Box No. 4. "Comdesron" refers to the Destroyer Squadron Commander.

Other tests provided similarly impressive results. For example, XAF operators discovered that fourteen-inch shells could be tracked in flight, and that even partially submerged submarines could be detected.[51] With respect to approaching aircraft, *New York*'s Commanding Officer remarked that such units "could be reliably reported, day or night, up to twenty miles distant,"[52] and Page himself rated the XAF's ability to detect airplanes as "outstanding."[53] The NRL engineer also noted how senior officers present during the tests had been "especially pleased with our equipment and its operation."[54]

In spite of these encouraging reports, indications of the challenges to come with respect to the management of radar information were evident as well. For example, during a destroyer attack exercise conducted late at night on February 21st, the XAF again succeeded in picking up and tracking the approaching vessels. This time, however, the *New York* failed to illuminate the destroyers in time to prevent damage from a simulated barrage of torpedoes. Although no one recorded the precise reason for this failure, almost certainly the searchlight operators either failed to receive or misunderstood the information passed to them from the operators in the XAF control station.[55] The Navy thus learned in 1939 what the Army would discover two years later at Pearl Harbor: that opera-

---

[51] Ibid. With respect to submarines, Page wrote: "Submergence of the hull made no difference in signal as long as the conning tower was above water. . . . Signal disappeared about the same time the conning tower went out of sight. No signal could be observed from the periscope alone."

[52] Commanding Officer, USS New York to Commander, Atlantic Squadron, 24 March 1939, NADC, RG 19, NRL-S, Box No. 4.

[53] Robert M. Page to Commander, Atlantic Squadron, 3 April 1939, NADC, RG 19, NRL-S, Box No. 4.

[54] Personal letter from Robert M. Page to Leo C. Young, 3 March 1939, NADC, RG 19, NRL-S, Box No. 4. Page wrote this letter while underway on the *New York*.

[55] Robert M. Page to Commander, Atlantic Squadron, 3 April 1939, NADC, RG 19, NRL-S, Box No. 4.

tional success derived not only from dependable radar equipment, but also from an effective system for managing information.

*   *   *

In the aftermath of Fleet Problem XX, NRL's radio-ranging device became a subject of even greater interest to the Navy's senior leadership. On May 1st, 1939, a conference was held in the offices of the Chief of Naval Operations (OPNAV) to determine a course of action with respect to the procurement of XAF equipment. Present at the conference were representatives from NRL, OPNAV, and each of the Navy's material bureaus. After briefly discussing the advantages and limitations of the XAF,[56] these men agreed unanimously that ten to twenty devices should be procured immediately. In order of priority, they recommended that five fleet carriers, three battleships, and seven cruisers be the first to receive the new equipment.[57]

Less than two weeks later, the Chief of Naval Operations directed the Bureau of Engineering to procure ten radio ranging devices for installation on vessels of the United States Fleet.[58] Soon thereafter, representatives from both Western Electric and RCA visited NRL to learn more about the XAF and

[56] According to the memorandum from this meeting, the main limitations of the XAF were: "(a) large size; (b) lack of desired range against surface targets; (c) lack of desired accuracy in bearing indication." The memo went on to note that ". . . these limitations are a matter of degree only. The instrument in its present form is useful and valu-able." Anonymous Author, "Memorandum for File: Conference on Special Project No. 1," 8 May 1939, NADC, RG 19, NRL-S, Box No. 4.
[57] Ibid. The Navy at this time had only five fleet carriers in commission. Norman Friedman, *U.S. Aircraft Carriers: An Illustrated Design History* (1983), 31-100.
[58] Chief of Naval Operations to Chief, Bureau of Engineering, 12 May 1939, NOA, P46, DANWDP, Section D-1.

to discuss potential contract specifications.[59] Similar meetings took place throughout the summer, until finally in October the Bureau announced that RCA had won a contract to build the first production-model 200-megahertz search radars, now re-designated the model "CXAM."[60] Because NRL engineers were continuing to make rapid advances in their development of radar equipment, however, the Bureau of Engineering lowered the initial production run to only six units.[61]

Contract approved, the Naval Research Laboratory supplied RCA with a complete set of blueprints for the XAF and turned its attention toward other issues.[62] One of the most important of these was the development of an improved visual display system for radar information. The existing display on the XAF's receiving unit consisted of an A-scope, which provided the operator with an amplitude spike on an oscilloscope calibrated to indicate range (Figure 5-1), and an electro-mechanical bearing indicator to show the azimuth of the antenna at the time of detection. During Fleet Problem XX, anti-air exercises revealed that operators often had difficulty correlating information from the bearing indicator and the A-scope, so NRL undertook development of an indicating system that could provide both bearing and range on the same

[59] Louis A. Gebhard, "Record of Consultative Services, 5/19/39," and Idem, "Record of Consultative Services, 5/26/39," both in NADC, RG 19, NRL-S, Box No. 4.

[60] Louis A. Gebhard, "Record of Consultative Services, 6/26/39," and Idem, "Record of Consultative Services, 10/17/39," Chief, Bureau of Engineering to Director, Naval Research Laboratory and Inspector of Naval Material, 25 October 1939, and Director, Naval Research Laboratory to Chief, Bureau of Engineering, 26 February 1940, all in NADC, RG 19, NRL-S, Box No. 4.

[61] In part, this decision was based on estimates from Western Electric and RCA engineers, who indicated that it would take nearly a year to complete the first production model. Louis A. Gebhard, "Record of Consultative Services, 6/21/39," NADC, RG 19, NRL-S, Box No. 4.

[62] Receipt for "one complete set of blueprints of the Model XAF Radio Ranging Equipment," 16 October 1939, signed by J. E. Love of the RCA Manufacturing Company, NADC, RG 19, NRL-S, Box No. 4.

display.[63] Eventually this work led to the Plan Position In-
dicator (PPI), which afforded operators a 360-degree "birds-
eye" view of the tactical situation (Figure 5-2).

In addition to the display problem, NRL scientists and
engineers worked to solve other difficulties related to the
tactical employment of radar at sea. After Fleet Problem XX,
the Navy shipped *New York's* XAF back to NRL, where Page and
his staff made a number of minor improvements to increase ac-
curacy and extend maximum detection ranges.[64] Laboratory per-
sonnel also continued their efforts to develop an adequate
recognition system for shipboard use.[65] Like the PPI, suc-
cessful adoption of such a device was about two years away;
however, that success stemmed directly from these early ef-
forts.

Lastly, NRL investigated thoroughly the problem of how
best to distribute radar information throughout a warship.
Existing shipboard arrangements for information distribution
relied on verbal reports, passed either by telephone, voice
tube, or messenger.[66] Yet because radar information came in
the form of electronic images, not words, American naval of-
ficers believed that remote indicators were essential. Imme-
diately after Fleet Problem XX, for example, the Navy's sen-
ior operational commander in the Atlantic stated that the in-
formation obtained by radar was "of such immediate vital in-
terest to a number of ship and fire control stations . . .

---

[63] Director, Naval Research Laboratory to Chief, Bureau of Engineering,
26 February 1940, NADC, RG 19, NRL-S, Box No. 4. Although signed by
Bowen, this document was written by Page.
[64] Ibid.
[65] Ibid.
[66] The Navy adopted the sound-powered telephone as standard equipment
for shipboard inter-communication in 1939. Undocumented commentary
found in NOA, P46, DANWDP, Section D-8. For an explanation of why
details regarding the historical development of U.S. Navy interior
communication systems remain imprecise, see note 72 in Chapter One.

that the development of a repeater system is extremely desirable."[67] By early 1940, not only had NRL engineers determined that such a system would be relatively easy to build, they also were considering what to them seemed like the next logical step. As Page described the situation:

> In some uses . . . it may be desirable for the echo pattern as observed on one ship to be repeated on another or other ships. There should be no particular difficulty in operating remote indicator stations by wire on the same ship. Several methods of providing a radio link to extend this to remote indicating stations on other ships have been discussed but no work has been started on this project.[68]

The system proposed by Page would not be developed until after World War II, but the very fact that he suggested it before the war is indicative of the naval establishment's constant pursuit of improved systems for shipboard command and control.

<p style="text-align:center">*   *   *</p>

The Naval Research Laboratory was not the only organization seeking solutions to the information management problems created by the U.S. Navy's adoption of radar technology. Individuals within OPNAV and the Bureaus of Engineering, Construction and Repair,[69] Ordnance, and Aeronautics all had

---

[67] Commander, Atlantic Squadron to Chief, Bureau of Engineering, 4 April 1939, NADC, RG 19, NRL-S, Box No. 4.

[68] Director, Naval Research Laboratory to Chief, Bureau of Engineering, 26 February 1940, NADC, RG 19, NRL-S, Box No. 4.

[69] The Bureau of Engineering and the Bureau of Construction & Repair merged in June 1940 to form the Bureau of Ships. Paul J. Strayer and Edward J. Pope, *An Administrative History of the Bureau of Ships During World War II* , vol. 1 (1947), 1-48, and Julius A. Furer, *Administration of the Navy Department in World War II* (1959), 217-222.

ideas and suggestions concerning the tactical employment of radar, but ultimately the operating forces were the ones that had to make the new device an effective tool of war. Little surprise, then, that when RCA finally delivered the first six 200-megahertz radars in mid-to-late 1940, it was the officers and men of the fleet who developed some of the most effective means for managing radar information.

Of the initial six production-model CXAMs, the U.S. Navy installed one on the carrier *USS Yorktown*, one on the battleship *USS California*, and four on cruisers.[70] Although the exact reason for this distribution remains a bit of a mystery, extant documentation suggests that the Navy wanted to test the new apparatus on each type of major warship.[71] As events unfolded, it was the officers and men of the *Yorktown* and the *California* who would have the most impact on the development of techniques, devices, and facilities for radar employment.

In a curious twist of fate, *USS California*, the vessel from which Admiral Samuel S. Robison had introduced numerous improvements in tactical radio communications during the mid-1920s, was the first warship to receive the CXAM radar. From the moment Puget Sound Navy Yard installed the new device, *California's* Commanding Officer, Captain H. M. Bemis, and his Communications Officer, Lieutenant Commander Henry E. Bernstein, took considerable initiative to integrate the CXAM into existing shipboard command and control systems. In his

[70] This four cruisers were: *USS Chicago, USS Chester, USS Pensacola,* and *USS Northampton.* Chief, Bureau of Engineering and Chief, Bureau of Construction & Repair to Commandant, Navy Yard, Mare Island, Commandant, Navy Yard, Puget Sound, and Commandant, Navy Yard, Pearl Harbor, 6 May 1940, NADC, RG 19, NRL-S, Box No. 4.
[71] Chief of Naval Operations to Commander in Chief, U.S. Fleet, 13 April 1940, NOA, P46, DANWDP, Section D-2. Cruisers likely were provided with four of six sets because of their role as scouts and also because an improved CXAM (designated the CXAM-1) was already on order. BuShips Contract NOs-79414, dated 30 November 1940, NOA, P46, DANWDP, Section D-2.

first report on the CXAM's performance, Bemis informed United States Fleet Commander-in-Chief James O. Richardson that the CXAM operator was too isolated and that he must be integrated more completely into the ship's existing system of interior communications.[72] In order to facilitate this, Bemis authorized Bernstein to create a radar plotting room containing the CXAM receiving unit, two voice-radios, a horizontal plotting table, a radio direction finder, and several intra-ship telephones. Apparently believing that he would be spending a lot of time in this new facility, Bemis also made sure to install a bunk for the Communications Officer.[73]

Bernstein's "radar plot"[74] was completed by November 1940, after which time the young officer turned his attention to another difficulty; namely, how to distinguish between friendly and enemy units on the CXAM display console. This was a problem on which NRL engineers had been working for some time, but Bernstein was the one who developed the first practicable solution. In May 1941, Bernstein and several of his subordinates completed work on a recognition device for use with the CXAM, and in August, Bemis reported to the Bureau of Ships that the device was ready for immediate production.[75] Less than ten days after receiving this report, the

[72] Commanding Officer, USS California to Commander in Chief, U.S. Fleet, 2 October 1940, NADC, RG 19, NRL-S, Box No. 4. Also available in NOA, P46, DANWDP, Section D-8.

[73] Undocumented commentary found in NOA, P46, DANWDP, Section E-1.

[74] As indicated in note 17 above, the Navy did not officially adopt the word radar until late November. Until then (and presumably afterwards as well), the men on the California referred to the CXAM as "the Geep." Hence, Bernstein initially called his extemporized room the "Geep Plot." Henry E. Guerlac, Radar in World War II, vol. 2 (1987 [1947]), 929-930.

[75] Commanding Officer, USS California to Chief, Bureau of Ships, 10 August 1941, NOA, P46, DANWDP, Section D-5. This device automatically "keyed" when swept by the beam of a CXAM antenna, which caused it to send out a signal that caused an image of a predetermined width to appear at a predetermined spot on the radar screen. The Navy eventually awarded Bernstein a commendation medal for his work on this recognition

Pacific Fleet Commander-in-Chief[76] directed his Battleship and Air Force Commanders to build eighteen recognition devices for further testing, noting that "the problem of recognizing friendly vessels and aircraft is preventing full use being made of [available] radar equipment."[77] Although the Navy eventually shifted to a recognition system that employed separate frequency channels,[78] Bernstein's initiatives nevertheless reveal the innovative approaches taken by the U.S. Navy's operating forces with respect to shipboard command and control technology.

California was not the only vessel whose personnel aggressively strove to integrate radar technology into the practice of warfare at sea. For example, the Commanding Officer of the *Chester* sought authorization to install makeshift repeaters at various locations throughout his ship,[79] while *Northampton*'s Commanding Officer informed the Pacific Fleet Commander-in-Chief that direct telephone communication from the CXAM control station to the anti-aircraft director was essential.[80] The frequency of these types of recommendations only increased after the Navy began to take delivery of

---

device. Irving L. McNally, "Radar Reflections," 1 July 1975, 3. This document is available at the Navy Department Library in Washington, DC.
[76] Effective February 1, 1941, Navy Department General Order No. 143 reorganized the United States Fleet into an Atlantic, an Asiatic, and a Pacific Fleet. Commander in Chief, U.S. Pacific Fleet to Secretary of the Navy, 15 August 1941, National Archives Microfilm Collection, "Annual Reports of Fleets and Task Forces of the U.S. Navy, 1920-1941," Roll No. 3.
[77] Commander in Chief, U.S. Pacific Fleet to Commander, Aircraft, Battle Force and Commander, Battleships, Battle Force, 23 August 1941, NOA, P46, DANWDP, Section D-5.
[78] Gebhard, *Evolution of Naval Radio-Electronics*, 253-256.
[79] Commanding Officer, USS Chester to Chief, Bureau of Ships, 9 August 1940, NOA, P46, DANWDP, Section D-8. These were not repeaters of the oscilloscope, but rather of the antenna bearing/elevation indicator.
[80] Commanding Officer, USS Northampton to Commander in Chief, U.S. Pacific Fleet, 4 June 1941, NOA, P46, DANWDP, Section C-1.

improved 200-megahertz search radars, designated the CXAM-1, in June 1941.[81]

Even before the CXAM-1s started to arrive, however, the officers and crew of the *Yorktown* took another important step toward integrating radar into existing shipboard command and control systems. Like the *California, Yorktown* was the only ship of her type to receive a CXAM radar, the installation of which had been completed in November 1940. Unlike the *California, Yorktown* had no armored protection, which meant that she had little margin for error with respect to time-late or inaccurate information.[82] After just five months of experimenting with the CXAM, *Yorktown's* Commanding Officer therefore expressed his views in no uncertain terms:

> It has been increasingly apparent that separate and complete plotting facilities must be provided in order that full and intelligent use may be made of the information which is obtainable from radar. As at present installed and operated, a mass of unrelated and heterogeneous ranges and bearings is sent from radar by telephone . . . It is manifestly impossible for any person receiving this information to form from it a mental picture which will show him incipient air attacks or approaching targets for gun fire. Furthermore, such a mass of unrelated information is likely to confuse the picture of the tactical situation obtained from other means such as contact reports and reports from lookouts.[83]

---

[81] Chief of Naval Operations to Commander in Chief, U.S. Pacific Fleet and Commander in Chief, U.S. Atlantic Fleet, 14 June 1941, NOA, P46, DANWDP, Section D-2.
[82] See Chapter Four for a further discussion about the issue of carrier vulnerability.
[83] Commanding Officer, USS Yorktown to Commander-in-Chief, U.S. Pacific Fleet, 28 March 1941. NOA, P46, DANWDP, Section E-1.

He went on to recommend the formation of radar plotting teams and the creation of adequate physical facilities where vital information could be segregated and assimilated.[84] Based on *Yorktown's* reports and several important letters deriving from them,[85] the Chief of Naval Operations in August 1941 authorized the installation of radar plots on all aircraft carriers,[86] concurring with the Interior Control Board's recommendation that such facilities would serve as ". . . the brain of the organization which protects the fleet or ships from air attack."[87]

Very quickly, the Navy recognized that the creation of radar plotting facilities presented its own set of difficulties, probably the most significant of which was the problem of training. At first, the Navy's need for sufficient numbers of trained operators and maintenance men presented the most pressing issue. In September 1941 one internal report estimated that as many as 2,000 maintenance men and 10,500 operators would be needed by July 1st, 1942.[88] The Bureau of Navigation projected that existing facilities could train only about 930 maintenance men by that date, although it viewed the training of radar operators as less of a problem

---

[84] Ibid., and Commanding Officer, USS Yorktown to Commander-in-Chief, U.S. Pacific Fleet, 14 June 1941, NOA, P46, DANWDP, Section E-1.
[85] Chief, Bureau of Aeronautics to Chief, Bureau of Ships, 2 July 1941, and Chief, Bureau of Ships to Senior Member, Interior Control Board, 19 July 1941, and Senior Member, Interior Control Board to Secretary of the Navy (via the Chief of Naval Operations), 22 July 1941, all in NOA, P46, DANWDP, Section E-1.
[86] Chief of Naval Operations to Chief, Bureau of Ships, 21 August 1941, NOA, P46, DANWDP, Section E-1.
[87] Senior Member, Interior Control Board to Secretary of the Navy (via the Chief of Naval Operations), 22 July 1941, NOA, P46, DANWDP, Section E-1. Shortly after the attack on Pearl Harbor, the Chief of Naval Operations authorized the construction of radar plots on battleships and cruisers as well.
[88] E. T. Short to Chief, Bureau of Navigation, 19 September 1941, NOA, P46, DANWDP, Section G-1.

since this could be done aboard ship.[89] For those officers who had firsthand experience with the CXAM, however, this latter supposition was highly questionable. After being made aware of this consensus, in October 1941 the commander of the Pacific Fleet's battleships called for the immediate establishment of a radar operators' school at Pearl Harbor.[90] Based in part on this request, in late November the Bureau of Navigation finally agreed to the creation of a training school for enlisted radar operators.[91]

The first organization within the Navy to promote specialized radar training for officers was the Bureau of Aeronautics. In April 1941, the bureau created a "Training Devices Section" and tasked it with the development of synthetic training instruments,[92] including devices for radar operation.[93] Just two months later, the Chief of the Bureau of Aeronautics recommended the establishment of a school on each coast so that officers could receive formal instruction in radar-controlled fighter direction.[94] The Chief of Naval Operations approved the Bureau's request,[95] and the Navy soon

[89] Chief, Bureau of Navigation to Commander-in-Chief, U.S. Pacific Fleet, and Commander-in-Chief, U.S. Atlantic Fleet, 10 October 1941, NOA, P46, DANWDP, Section E-1.

[90] Commanding Officer, USS California to Commander, Battleships, Battle Force, 2 October 1941, and Commander, Battleships, Battle Force to Commander in Chief, U.S. Pacific Fleet, both in NOA, P46, DANWDP, Section G-1.

[91] Chief, Bureau of Navigation to Chief of Naval Operations, 27 November 1941, NOA, P46, DANWDP, Section G-1.

[92] The Navy used synthetic training devices to simulate real-world conditions. These devices gave operators the illusion of performing actual physical and/or mental tasks. Interestingly, the U.S. Navy may have been the first organization to use the term "synthetic training." *Oxford English Dictionary*, on-line ed., s.v. "synthetic."

[93] Undocumented commentary found in NOA, P46, DANWDP, Section G-1.

[94] Chief, Bureau of Aeronautics to Chief of Naval Operations, 23 June 1941, NOA, P46, DANWDP, Section G-1.

[95] Chief of Naval Operations to Chief, Bureau of Aeronautics, 10 July 1941, NOA, P46, DANWDP, Section G-1.

opened fighter director schools in both San Diego and Norfolk.[96]

In San Diego, the officer-in-charge of the new school was Lieutenant Commander Jack Griffin, one of several American officers who had been sent by the Navy Department to observe British methods of fighter direction.[97] As early as 1936, the Royal Air Force had initiated a series of special exercises "to determine the possibility of intercepting hostile aircraft with fighters whose navigation was controlled from the ground" (Figure 5-3),[98] and by 1940 their personnel almost certainly were the best in the world at this task.[99] Yet because British techniques were highly classified, his majesty's government provided full access to U.S. observers only after Britain and America agreed in the summer of 1940 to a full exchange of scientific and technical information.[100] Griffin was one of the first American citizens to be granted

[96] The Fighter Director School in Norfolk opened in September; the one in San Diego opened in October. William C. Bryant and Heith I. Hermane, "History of Naval Fighter Direction," undated but probably written in late 1945, 88, Office of Naval Aviation History, Washington, DC, Fast Carrier Task Force(s) File, Entry No. 4.

[97] Other officers sent to England who also were instrumental in establishing the U.S. Navy's system of fighter direction include Henry A. Rowe, and Robert J. C. Maulsby. Guerlac, *Radar in World War II*, 925-926, 989, and Jeffrey G. Barlow, "Arthur W. Radford: Aviation Trainer and Combat Commander," 162-164, in *The Human Tradition in the World War II Era* (2001), ed. Malcolm Muir.

[98] "Minutes of Conference Held at Headquarters Fighter Command on Friday 7th August 1936 to Discuss Questions Concerning Special Interception Experiments at Biggin Hill During August and September 1936," Wing Commander, R.A.F. Station, Biggin Hill to Secretary, Air Ministry, 5 August 1936, and Anonymous Author, "Note on the Special Interception Exercises, Biggin Hill, 1936 (Draft)," 12 August 1936, all in Public Record Office, Kew, Richmond, Surrey (PRO), "Air Ministry and Ministry of Defence, Registered Files, 1887-1985," (AIR 2), File No. 2625. The passage quoted is from "Agenda for the Meeting to Discuss a Programme for Biggin Hill Experiments to be Held at 1600 Hours, on 21st April, 1937, in Room 374 at Air Ministry," PRO, AIR 2/2625.

[99] David Zimmerman, *Britain's Shield: Radar and the Defeat of the Luftwaffe* (2001), especially 109-117, 122-131, 156-162, 175-210.

[100] For more on the formulation of this agreement, which eventually led to the famous Tizard Mission, see David Zimmerman, *Top Secret Exchange: The Tizard Mission and the Scientific War* (1996).

this level of access, and while in England he had the oppor-
tunity to observe interception techniques as practiced by
both the Royal Air Force and the Royal Navy.[101] These expe-
riences made him one of the U.S. Navy's foremost experts in
fighter direction, and thus a logical choice to head the new
school.

Griffin's first class consisted of twenty-five ensigns,
all of whom had graduated from the U.S. Naval Reserve Mid-
shipmen's School at Northwestern University only a few weeks
earlier.[102] One of Griffin's initial tasks was to acquire
equipment for the new school, including plotting instruments,
publications, radio telephones, and specially-manufactured
tricycles for practice intercepts.[103] Classes were conducted
in a converted airplane hangar, with control stations for the
tricycle interceptions located on the roof of the same han-
gar.[104]

Though ostensibly founded to produce competent fighter
director officers, the new school's curriculum covered all

---

[101] "Reminiscences of Nicholas J. Hammond, H. Stanwood Foote, and Charles
D. Ridgway (Final Draft)," 22 July 1988, 1. Hammond, Foote, and Ridgway
were all in this original class. In the late 1980s, apparently at Ham-
mond's initiative, they decided to write about their experiences during
World War II; however, they never found a publisher for their work. I
am indebted to David Boslaugh for providing me with a copy of this docu-
ment.
[102] Ibid., 1-5.
[103] The specially-manufactured tricycles were large enough for grown men
to ride, and the practice intercepts were conducted on a spacious flat
field. The tricycles simulated both friendly and enemy aircraft, and
the "pilots" used magnetic compasses for navigation and walkie-talkies
to communicate with the "shipboard" fighter directors. Each tricycle
also had a "blinder" so that pilots could not use their vision to fa-
cilitate interceptions. Griffin had observed British use of training
tricycles while in England, and had brought the idea back with him.
Hammond, Foote, and Ridgway, "Reminiscences," 5-8, and "Radar Center
Trains Thousands for the Pacific War," C.I.C., vol. 1, no. 7, 34-46.
C.I.C. was a confidential magazine published by OPNAV. Articles pub-
lished in the magazine rarely contained a byline.
[104] R. G. Gray, "History of CIC School, Fleet Training Center, Oahu" 15
September 1945, 1-3, NOA, World War II Histories and Historical Reports
(HHR), Entry No. 311.

aspects of radar employment, including theory, recognition, navigation, plotting, interception, and radio-telephone procedures.[105] Like an increasing number of his fellow officers, Griffin believed strongly that well-trained personnel were critical for translating the new technology into wartime success. Writing in early 1942, Griffin expressed his views:

> I feel that the operator is an extremely important cog in the system and incline to the belief that our people should receive training in operating the R. [radar] since so much depends on proper "interpretation" of what is seen. Recently I have confirmed this by talking to Jimmy Flatley exec. of VF-2. He says . . . under the influence of the officers [from school] all hands advanced further.[106]

Griffin's opinions were highly-regarded within the Navy Department, and a little over a year later the service would place him in charge of the newly-built Pacific Fleet Radar Center at Camp Catlin (Hawaii), a facility in which nearly 20,000 radar operators were trained over the course of the war.[107]

* * *

The United States Navy's early recognition that formal training – both for the maintenance *and* operation of radar technology – was one of the principal reasons the service, after a few growing pains, so successfully employed search radar during World War II. Three other reasons stand out as

---

[105] Ibid., 2.
[106] Jack H. Griffin to Red Morse, 6 March 1942, attached as Appendix II to Gray, "History of CIC School." For a further discussion of Flatley, see Steve Ewing, *Reaper Leader: The Life of Jimmy Flatley* (2002).
[107] Anonymous Author, "Radar Operators School History," circa September 1945, NOA, HHR, Entry No. 311.

well. First, the American naval establishment not only tol-
erated, but in many instances actively encouraged, innovative
ideas from the operating forces. Indeed, this institutional
ethos dated back at least to the adoption of radio itself.[108]
For radar specifically, this environment led directly to the
creation of devices and facilities that could assist opera-
tional commanders in managing the tactical information made
available by the new technology. Second, the Navy's opera-
tional commanders, over time and as a group, had developed
numerous shipboard systems to deal with the escalating com-
plexity of warfare at sea. To these men, the idea that radar
should be employed as part of a command and control system,
rather than as an isolated electronic device, was thus read-
ily apparent. Without such an appreciation, the radar plot
likely would not have been conceived and built as early as it
was, and its direct descendent, the Combat Information Center
(CIC), may well have looked very different than in did during
World War II.[109] Finally, the Naval Research Laboratory
played an essential role integrating radar technology into
the practice of warfare at sea, a fact sometimes overshadowed
by the Laboratory's technical exploits. In the four years
preceding the attack on Pearl Harbor, Page and his cohorts
displayed a remarkable ability to think in both technical and
operational terms.[110] As events soon would reveal, the fleet

---

[108] The reader is invited to consult Chapter Two for more on this point.
[109] During World War II, the British Royal Navy was the only other navy
to develop dedicated shipboard facilities for the processing and fil-
tering of all shipboard electrical and electronic information. Desig-
nated the Action Information Centre (AIC), it was similar to the U.S.
Navy Combat Information Center. These similarities were more than co-
incidental, as Great Britain and the United States shared considerable
information about their respective AIC and CIC programs.
[110] For example, of Page and his associates New York's Commanding Officer
wrote after Fleet Problem XX: "We found them very agreeable shipmates
and cooperative at all times, so much so in fact that I came to look
upon them as regular members of the ship's company and called on them

benefited tremendously from their ability to accomplish this feat.

for service just as I would any other officer of the ship. . . . It was with reluctance that we saw them depart carrying their very excellent device. We will be glad to have them back at any time. . . ." Commanding Officer, USS New York to Director, Naval Research Laboratory, 4 May 1939, NADC, RG 19, NRL-S, Box No. 4.
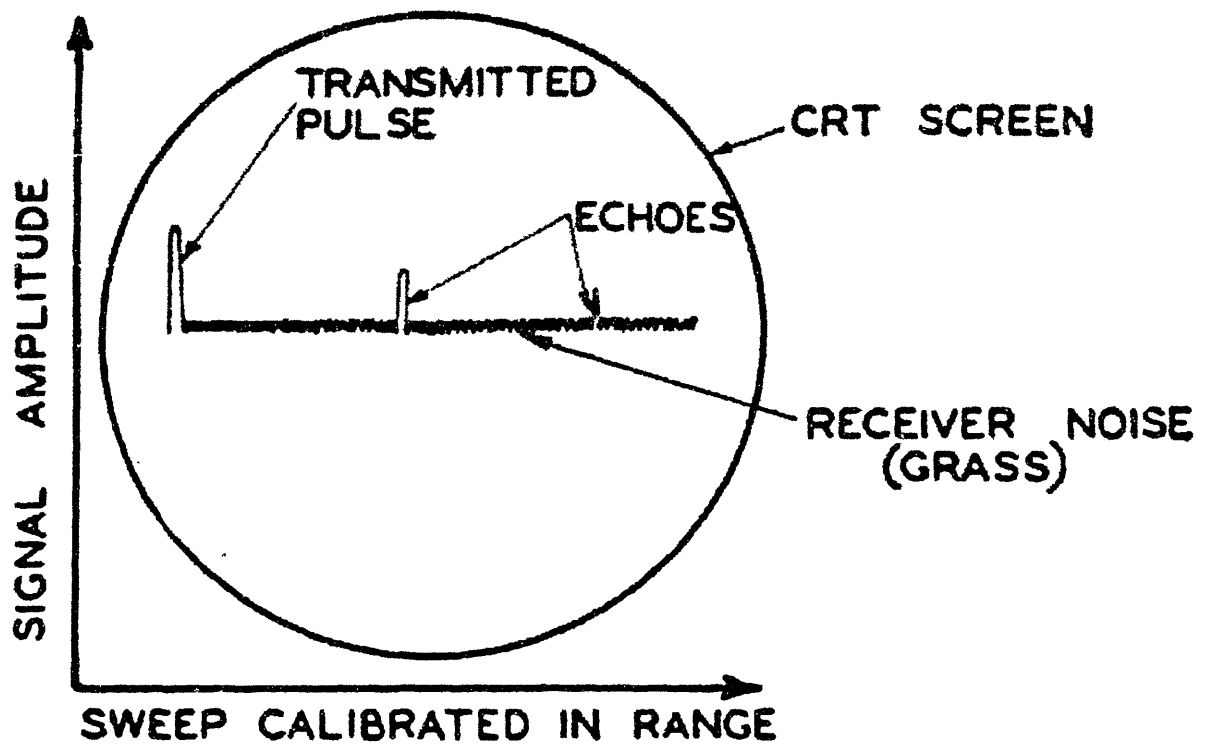
FIGURE 5-1

An A-scope provides the radar operator only with range and a rough estimate of the size of the target.
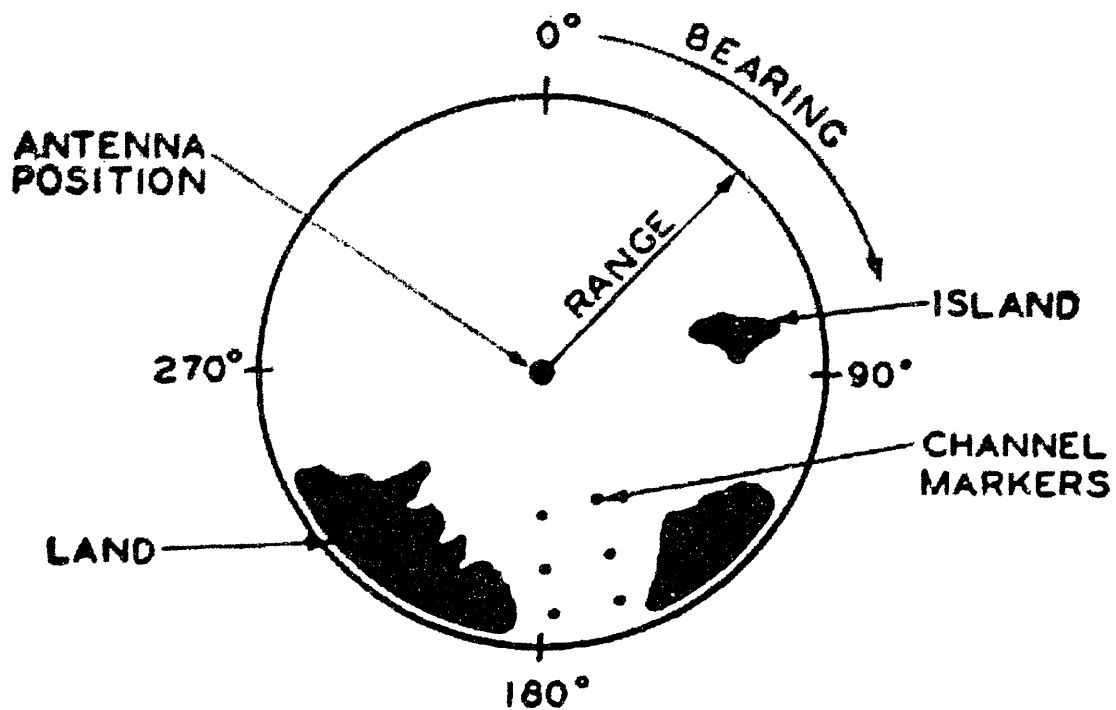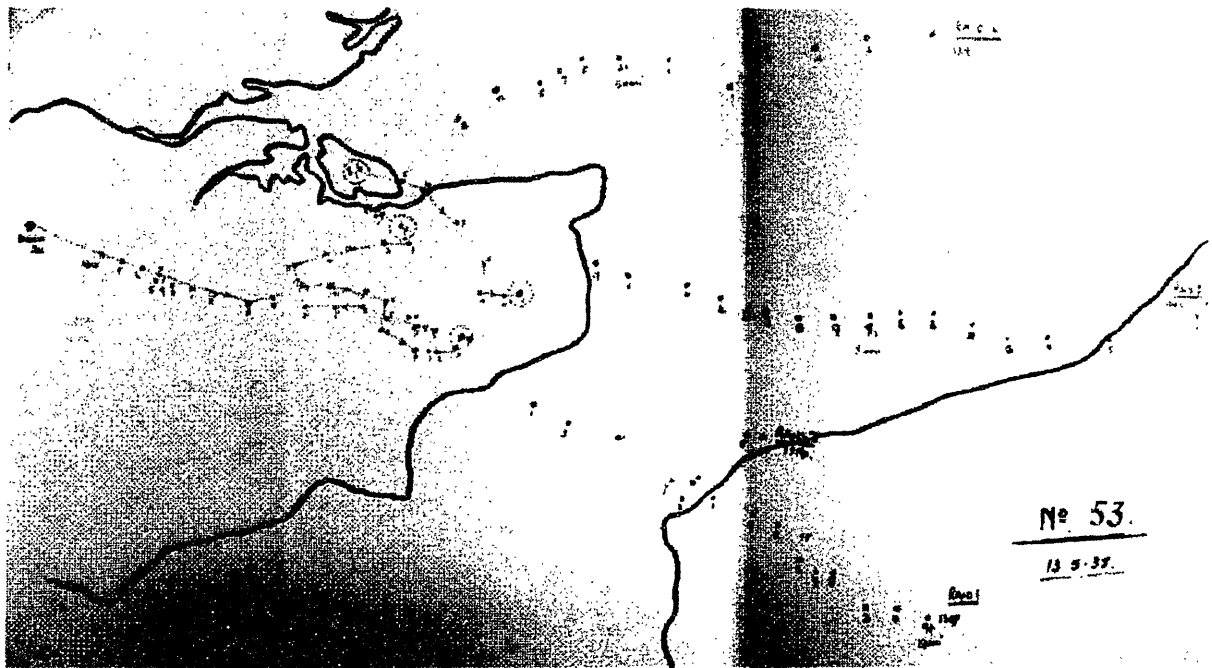
FIGURE 5-2

A Plan Position Indicator (PPI) provides the radar operator with both bearing and range to a target. Unlike an A-scope, however, the PPI does not provide an estimate of target size.

FIGURE 5-3

The U.S. Navy learned much from British expertise in fighter direction. This plot of a May 1938 special interception exercise shows that the Royal Air Force already was practicing the techniques it would employ two years later during the Battle of Britain.

Citations for Figures

Figure 5-1:   Bureau of Ships, *Radar System Fundamentals*
(NAVSHIPS 900,017), April 1944, 29.

Figure 5-2:   Bureau of Ships, *Radar System Fundamentals*
(NAVSHIPS 900,017), April 1944, 30.

Figure 5-3:   Table and Plot included as enclosures to Wing
Commander, R.A.F. Station, Biggin Hill to
Headquarters, Fighter Command, 23 May 1938,
PRO, AIR 16/180.

CHAPTER SIX
CONCLUSION

By and large, the shipboard command and control systems developed by the United States Navy in the first four decades of the twentieth century were the ones employed by the service during the Second World War. To be sure, in late 1941 the Navy still had a steep learning curve in front of it. Destruction of the U.S. battle line at Pearl Harbor meant that senior officers had to adapt hurriedly to tactical realities none of them had anticipated. Like a chess player who has lost his or her queen, the Navy had to use its remaining pieces more effectively. Adept coordination of naval forces was the key to this effectiveness. Fortunately for the United States, forty years of continuous experimentation with shipboard command and control systems meant that the American fleet had the means to accomplish this end.

While a comprehensive discussion of U.S. Navy shipboard command and control during the Second World War is beyond the scope of this dissertation, a brief examination of the subject is instructive because it reveals just how extensively the nature of command at sea had changed since the days of Farragut and Dewey.[1] Between 1941 and 1945, American naval commanders continued to adopt systems that improved the way information was acquired, displayed, and processed. The most important of these was the Combat Information Center (CIC), a shipboard fa-

---

[1] The U.S. Navy's development of shipboard command and control systems during World War II warrants a more thorough investigation than is possible here. The section that follows should therefore be viewed not as a definitive analysis, but rather as a prospective research agenda.

cility that provided operational commanders with an ideal in-
strument for managing the sea of information that surrounded
them. Indeed, the Navy's creation of the CIC signified an ex-
plicit recognition by the service's senior leaders that social-
ly-distributed cognition was the cornerstone of success in bat-
tle. To put it in more colorful terms, operational decision-
making was no longer a one-man show.[2]

---

[2] As one official publication described the situation: "[H]ow complex a
captain's life used to be, and how relatively simple it can be now . . .
the vast number of items that once went only to the captain, who had to
weigh each bit of data for himself and decide whether to use it, discard
it, or file it in the back of his mind for future use . . . the Combat
Information Center is now the agency whose primary function is to filter
and evaluate nearly all of this material for him. The captain receives
the information he needs when he needs it; and he is free to concentrate
on his decisions and to carry the burden of command. He has, in addi-
tion, in the C.I.C., an organization to which he can delegate secondary
decisions and control duties as the occasion may require." This passage
is taken from the second page of the U.S. Navy's first CIC manual. For
complete citation information, see note 28 below.

Part I:

SHIPBOARD COMMAND AND CONTROL IN WORLD WAR II

On December 11th, 1941, Nazi Germany declared war on the United States, and the nation finally confronted the two-ocean war it had been anticipating since the late 1930s.[3] In the Atlantic, the main problem for the U.S. Navy was that of preventing commerce-raiding German submarines from sinking allied merchantmen. Indeed, the service had been fighting an undeclared war against the U-boat menace for some time, a situation made painfully evident by the torpedoing of two American destroyers in October 1941.[4] In the Pacific, the sudden destruction of all seven battleships moored at Pearl Harbor meant an end not only to Pacific Fleet Commander-in-Chief Husband E. Kimmel's career, but also an end to plans for a decisive fleet engagement against the Imperial Japanese Navy.[5]

The calamity which befell the U.S. Navy's battle line did not, however, diminish the importance of shipboard command and control. As in World War I, convoy escort duty required reliable ship-to-ship voice communications, and the Navy's new TBS transceivers were a marked improvement over the CW 936s of the

---

[3] Adolf Hitler's reasons for declaring war on the United States remain one of the great mysteries of the Second World War. For an examination of this issue, see Gerhard L. Weinberg, "Why Hitler Declared War on the United States," 343-350, in *America at War: An Anthology of Articles from MHQ, the Quarterly Journal of Military History* (1995), ed. Calvin L. Christman.

[4] For more on this undeclared naval war between Germany and the United States, see Samuel Eliot Morison, *History of United States Naval Operations in World War II: The Battle of the Atlantic, 1939 - 1943*, Vol. I (1947), 17-113.

[5] Evidence of Kimmel's intention to seek a decisive fleet engagement is circumstantial; however, surviving Pacific Fleet war plans indicate that this is what he and his staff had in mind. Edward S. Miller, *War Plan Orange: The U.S. Strategy to Defeat Japan* (1991), 286-322.

late 1910s. During World War II, warships assigned to convoy duty also had access to ULTRA information, as relevant aspects of decrypted German messages were passed via radio to seaborne commanders.[6] Complementing ULTRA was information obtained from shipboard high-frequency direction finding equipment, the first effective units of which became available for installation on escort vessels in early 1943,[7] and radar, of which airborne microwave sets proved especially valuable.[8]

In the war against Japan, the Navy literally and figuratively had to pick up the pieces after the disaster at Pearl Harbor.[9] Almost immediately, American submarines deployed to bring the fight forward to the Japanese,[10] and in early 1942 carrier task forces carried out a number of raids in the Marshalls and the Gilberts.[11] These raids gave American carriers, now the backbone of the fleet, valuable combat experience, especially in fighter direction and radar employment. These ex-

---

[6] Because of the extreme secrecy surrounding ULTRA, the source of this information generally was not divulged. For more on the role of signals intelligence in the Battle of the Atlantic, see Jürgen Rohwer, *The Critical Convoy Battles of March 1943: The Battle for HX.229/SC122* (1977), 229-244, trans. Derek Masters and A. J. Barker, David Syrett, *The Defeat of the German U-Boats: The Battle of the Atlantic* (1994), and Idem, ed., *The Battle of the Atlantic and Signals Intelligence: U-Boat Situations and Trends, 1941-1945* (1998), and W. J. R. Gardner, *Decoding History: The Battle of the Atlantic and Ultra* (1999). Particularly informative is Syrett's introduction to *The Battle of the Atlantic and Signals Intelligence.*

[7] Kathleen Broome Williams, *Secret Weapon: U.S. High-Frequency Direction Finding in the Battle of the Atlantic* (1996), 206-231.

[8] Henry E. Guerlac, *Radar in World War II*, vol. 1 (1987 [1947]), 318-352, and Idem, vol. 2 (1987 [1947]), 708-730, and Robert Buderi, *The Invention that Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution* (1996), 138-170.

[9] The day after the attack, for example, the Navy removed *USS California*'s undamaged CXAM radar and placed it on a hill high above Honolulu in order to serve as a back-up to the Army's radar. A. Hoyt Taylor, *Radio Reminiscences: A Half Century* (1948), 342.

[10] Theodore Roscoe, *United States Submarine Operations in World War II* (1949), 12-84, and Clay Blair, *Silent Victory: The U.S. Submarine War against Japan* (2001 [1975]), 106-122, 135-145.

[11] John B. Lundstrom, *The First Team: Pacific Naval Air Combat from Pearl Harbor to Midway* (1984), 32-135.

periences helped the U.S. Navy obtain a draw at Coral Sea and a victory at Midway in the first naval battles where the ships of the opposing fleets never came into visual contact with one another.[12]

Two months after America's historic victory at Midway, the Marines landed at Guadalcanal and the Navy confronted a different type of command and control problem. Coral Sea and Midway had been fleet engagements, but the Navy's principal responsibility in the Solomons was to support the invading U.S. forces. The primary duties of the vessels assigned to this campaign were shore bombardment and the interdiction of Japanese supply lines. The former required operating close to land, frequently under conditions of restricted maneuverability, while the latter usually involved nighttime operations.[13] Both scenarios taxed existing command and control arrangements, prompting the Navy to implement significant changes in tactics, facilities, and training.

Tactically, the biggest change with respect to shipboard command and control was the distribution of fighter direction capability throughout the fleet. During the Gilberts and Mar-

---

[12] Historians generally portray the Battle of Coral Sea as a strategic victory, but a tactical defeat, for the U.S. Navy. For example, see Samuel Eliot Morison, *History of United States Naval Operations in World War II: Coral Sea, Midway and Submarine Actions, May 1942 – August 1942*, Vol. IV (1949), 33-64, John Costello, *The Pacific War, 1941-1945* (1981), 253-263, and Ronald H. Spector, *Eagle Against the Sun: The American War with Japan* (1985), 158-165. For more on the Battle of Midway, see especially Morison, Vol. IV, 69-159, Mitsuo Fuchida and Masatake Okumiya, *Midway: The Battle that Doomed Japan – The Japanese Navy's Story* (2001 [1955]), Gordon W. Prange, *Miracle at Midway* (1982), and Edwin T. Layton, Roger Pineau, and John Costello, "*And I Was There": Pearl Harbor and Midway – Breaking the Secrets* (1985), 418-448. A recent article which calls into question some of the long-accepted views regarding Japanese actions during the battle is Dallas Woodbury Isom, "The Battle of Midway: Why the Japanese Lost," *Naval War College Review*, vol. 53, no. 3 (2000), 60-100.
[13] Samuel Eliot Morison, *History of United States Naval Operations in World War II: Struggle for Guadalcanal, August 1942 – February 1943*, Vol. V (1949).

shalls campaigns, as well as at Coral Sea and Midway, fighter directors operated almost exclusively from carriers.[14] At Guadalcanal the U.S. Navy initially intercepted defending Japanese aircraft with combat air patrols directed from the cruiser *USS Chicago*, thereby allowing American carriers to stay in deeper water away from the beachheads. Due mainly to inexperienced operators and poor ship-to-ship communications, however, this experiment failed and the Navy abandoned the scheme only two days into the landings.[15]

Nevertheless, combat experience in the Solomons indicated that fighter direction capabilities should be extended to warships other than aircraft carriers. Based on recommendations from his staff, in mid-1943 the Commander of the Pacific Fleet destroyer force, Rear Admiral Mahlon S. Tisdale, decided to establish fighter direction capabilities on his destroyers. Tisdale met with Jack Griffin, now sporting the three stripes of a full commander, and the two agreed to a test of destroyer-based fighter direction. Griffin loaned Tisdale two of his best students, who then conducted intercepts (from destroyers) during a carrier task group training exercise.[16] These intercepts demonstrated the feasibility of destroyer-based fighter direction, leading to the issuance of a fighter direction manual "for the use of destroyer, cruiser, and other surface vessel officers who may be designated as Fighter Director Officers."[17] Later in the war, destroyer-based fighter direction capabilities en-

---

[14] William C. Bryant and Heith I. Hermane, "History of Naval Fighter Direction," undated but probably written in late 1945, 13-25, Office of Naval Aviation History, Washington, DC, Fast Carrier Task Force(s) File, Entry No. 4.
[15] Ibid., 34-36, and Guerlac, *Radar in World War II*, 947-948.
[16] John Monsarrat, *Angel on the Yardarm: The Beginnings of Fleet Radar Defense and the Kamikaze Threat* (1985), 38-40.
[17] Air Force, Pacific Fleet, "Fighter Direction Manual (Tentative)," September 1943, Naval War College Archives, Newport, RI (NWC), Papers of Caleb Laning (PCL).

hanced greatly the Navy's ability to employ "radar pickets" for both offensive and defensive purposes.[18]

Experience in the Solomons also led the Navy to develop a new type of warship, the amphibious command ship (AGC). The first three AGCs, those of the *Appalachian*-class, were commissioned in the fall of 1943.[19] Each ship carried multiple teams of qualified fighter director officers and radar operators, and their mission was to provide the commander of any amphibious invasion force with adequate command and control facilities to carry out his assigned tasks.[20] On January 10th, 1944, Rear Admiral Richmond K. Turner, commander of the Fifth Amphibious Force, shifted his flag to the first AGC to arrive in the western Pacific (*USS Rocky Mount*), and from her he successfully directed the invasion of Kwajalein.[21] In all the Navy commissioned eighteen AGCs during the war, and these vessels saw action in every amphibious campaign for which they were available, including the allied invasion of Europe at Normandy (Figure 6-1).[22]

The use of amphibious command ships was one way of better coordinating the operations of naval forces. Another was the construction of improved command and control facilities on existing types of warships. As was the case with amphibious operations, the Solomons campaign highlighted some of the other

---

[18] For a detailed examination of the Navy's use of destroyers as radar pickets, see Theodore Roscoe, *United States Destroyer Operations in World War II* (1953).

[19] The reader is invited to consult http://www.hazegray.org/danfs/amphib/ for specific launch and commissioning dates. Viewed August 14, 2003.

[20] Bryant and Hermane, "History of Naval Fighter Direction," 65-66.

[21] Samuel Eliot Morison, *History of United States Naval Operations in World War II: Aleutians, Gilberts and Marshalls, June 1942 – April 1944*, Vol. VII (1951), 230-281.

[22] *USS Ancon* (AGC-4) served as the flagship of the landing forces at Normandy. Samuel Eliot Morison, *History of United States Naval Operations in World War II: The Invasion of France and Germany, 1944 – 1945*, Vol. XI (1957), 63-64.

weaknesses of existing shipboard facilities. Foremost of these was the lack of a central location ". . . in which information from all available sources can be received, assimilated, and evaluated with a minimum delay."[23]

Of course, central shipboard locations for the processing of tactical information had been created before. Prior to the First World War, the U.S. Navy built plotting rooms to improve its existing system of gunnery. In the 1920s, the service constructed communications control centers to process radio traffic more efficiently. In the 1930s, Admiral Arthur J. Hepburn pursued centralized radio direction finding facilities, and in 1940 the radar plot was created.[24] Yet these efforts primarily assisted a commander in managing one particular type of information. Combat experience revealed that the Navy needed a central facility for the processing of *all* tactical information.

Like the radar plot, this new facility – officially designated the Combat Information Center (CIC) in January 1943[25] – was designed "to maintain the necessary plots based on observations of the various radars so that a general picture would be presented continuously and systematically."[26] Unlike the radar plot, however, the CIC also was designed "to provide a

---

[23] Commander in Chief, U.S. Pacific Fleet, Tactical Bulletin No. 4TB-42, 26 November 1942. Quoted in University of Pittsburgh Programs Research Staff, *Administration of the Combat Information Center Program to 1947*, 30 January 1952, 136. This document is available at the Navy Department Library in Washington, DC.
[24] For more on the development of plotting facilities for naval gunnery, see especially David A. Mindell, *Between Human and Machine: Feedback, Control, and Computing Before Cybernetics* (2002), 19-44. The other facilities are covered in Chapters Three, Four, and Five, respectively.
[25] University of Pittsburgh Programs Research Staff, *Administration of the Combat Information Center Program*, 181-182.
[26] Captain H. A. McClure, "Destroyer PCO/PXO Lectures," April 1944, National Archives, College Park, Maryland (NACP), Record Group 38 – General Records of the Chief of Naval Operations, (RG 38), Records of the United States Fleet Commander in Chief (COMINCH), Box No. 1162. The passage quoted is from page 1-3 of this document.

procedure and technique for applying this information to tactics, shiphandling, and control of own weapons in order that the commanding officer can make full use of the capabilities of the equipment [and] to provide a filter center for miscellaneous information such as lookout reports, radio reports, and other information which flows to a ship and often is not digested or cannot be used directly by the commanding officer."[27] In short, CIC was to serve as the brain of the warship (Figure 6-2).

To assist in making this brain function effectively, the Navy in June 1943 published its first comprehensive statement of CIC doctrine. Written by several experienced officers on Tisdale's staff, this document became known throughout the fleet as the "CIC Handbook."[28] Within a year the service had distributed over 12,000 copies,[29] and both during and immediately after the war this document had a considerable influence on the Navy's thinking about shipboard command and control facilities.[30]

Fundamentally, the Combat Information Center provided naval commanders with an invaluable tool for dealing with the complexities of mid-twentieth century warfare at sea. For individual commanding officers and fleet commanders alike, it

---

[27] Ibid.

[28] Commander, Destroyers, Pacific Fleet, "CIC Handbook for Destroyers, Pacific Fleet," 24 June 1943, NWC, PCL. Despite its title, naval officers on all types of warship used this document. The individual primarily responsible for writing the CIC Handbook was Lieutenant Commander Joseph C. Wylie, who had been selected by Tisdale after distinguishing himself in surface actions off Gaudalcanal while serving as the Executive Officer of USS Fletcher. John B. Hattendorf, "Introduction," xiv-xv, in Joseph C. Wylie, Military Strategy: A General Theory of Power Control (1989 [1967]).

[29] Comments by Wylie attached to Joseph C. Wylie to Lieutenant Commander R. M. Lunny, 12 April 1948, NWC, PCL.

[30] University of Pittsburgh Programs Research Staff, Administration of the Combat Information Center Program, 276-288.

facilitated quick decision-making and helped make clearer information that was obscure or difficult to process mentally. Yet this end could be accomplished only by delegating unprecedented responsibility to junior officers and enlisted personnel. The CIC thus became a human-machine information processing system that not only enabled naval commanders to make more effective tactical decisions, it also distributed problem-solving more evenly up and down the chain of command.

Little surprise, then, that the development of Combat Information Centers created within the fleet a pressing need for skilled personnel to man the new shipboard facilities. In April 1943, Pacific Fleet Commander-in-Chief Chester W. Nimitz ordered the consolidation of most tactical schools into a single facility at Camp Catlin, Hawaii. Nimitz named the new facility the Pacific Fleet Radar Center, and selected Commander Jack Griffin to serve as the Officer-in-Charge. The Center had four main divisions, one of which was the Fighter Director and Combat Information Center School.[31]

As initially structured, the Fighter Director and Combat Information Center School had three regular courses – CIC Indoctrination, Advanced Fighter Direction, and Advanced Evaluation – and a "Special Intensive Course" for the officers of ships in port at Pearl Harbor.[32] After several months, however, Griffin expanded the curriculum to include six regular courses, numbered I through VI, and three special courses.

---

[31] Commander in Chief, U.S. Pacific Fleet to Commander Service Force, Pacific Fleet, 10 April 1943, Enclosure (C) to "Radar Operators School History," U.S. Navy Operational Archives, Washington, DC (NOA), World War II Histories and Historical Reports (HHR), Entry No. 311.

[32] Commander in Chief, U.S. Pacific Fleet to Pacific Fleet (Pacific Fleet Confidential Letter 13CL-43), 25 May 1943, Appendix X to R. G. Gray, "History of CIC School, Fleet Training Center, Oahu," 15 September 1945, NOA, HHR, Entry No. 311. This letter was signed by Raymond A. Spruance, Nimitz's Chief of Staff.

Courses I, II, and III were for officers with no experience at sea. In them students learned plotting techniques, radar theory and operation, communications systems, the basics of CIC operations, and the fundamentals of fighter direction. The next two courses were more advanced, and provided students with the opportunity to qualify as either CIC watch officers (IV) or as fighter directors (V). The final regular course (VI) was for commanding, executive, and other senior officers. Although the course included lectures on all phases of CIC organization and operations, its primary goal was to give senior officers the opportunity to study "recent advanced literature on C.I.C., action reports, [and the] latest C.I.C. design and developments for any type of ship."[33]

The expanded curriculum at the Fighter Director and Combat Information Center School also included three courses intended specifically for team training. These special courses gave commanding officers the means to exercise their CIC teams under simulated combat conditions while in port. The significance of this development cannot be underestimated, as it enabled commanders to maintain operational proficiency even as their vessels underwent extensive yard work. Indeed, the concept proved so successful that by the end of the year the Navy had established four other CIC team-training schools on the West Coast.[34]

---

[33] Commander in Chief, U.S. Pacific Fleet to Pacific Fleet (Pacific Fleet Confidential Letter 13CL-43), 25 May 1943, Appendix XI to Gray, "History of CIC School," NOA, HHR, Entry No. 311. This letter was signed by Preston V. Mercer, Nimitz's Assistant Chief of Staff.
[34] Vice Chief of Naval Operations [Frederick J. Horne] to Commander, Operational Training Command, Pacific Fleet, Chief, Bureau of Naval Personnel, Chief, Bureau of Ships, and Chief, Bureau of Aeronautics, 14 July 1943, Enclosure (1) to J. H. Lowe, "History and Development of C.I.C. Team Training Center NAAS - San Clemente Island, California," NOA, HHR, Entry No. 390. Similar efforts were undertaken in the Atlantic. Commander in Chief, U.S. Fleet to Vice Chief of Naval Operations, 27 August 1943, NACP, RG 38, COMINCH, Box No. 586. W. R. Purnell, the

* * *

These improvements in tactics, facilities, and training –
when combined with materiel advantages deriving from America's
vastly superior industrial capacity[35] – proved invaluable as
the U.S. Navy thrust westward across the Pacific in 1944 and
1945. In the spring of 1944, for example, the Imperial Navy
adopted an aggressive operational plan designed to entice the
American fleet into a decisive battle near Japanese fuel sup-
plies and land-based aircraft. A desperation move, the Japa-
nese commander, Vice Admiral Jisaburo Ozawa, had at his dis-
posal only two-thirds as many major combatants and less than
half as many carrier-based airplanes as his American counter-
parts.[36] Nevertheless, Ozawa believed that favorable winds and
the superior range of his carrier aircraft, in combination with
anticipated attrition of the American fleet caused by Japanese
land-based planes, would enable him to achieve a decisive vic-
tory. Although he grossly overestimated the land-based air

Assistant Chief of Staff, signed this letter. For a list of all Atlan-
tic Fleet CIC training facilities at the end of the war, see Commander,
Operational Training Command, Atlantic Fleet to Chief, Bureau of Naval
Personnel, 19 September 1945, NACP, RG 38, COMINCH, Box No. 1848.
[35] For a comparative look at the industrial production of all major com-
batants during the Second World War, see Alan S. Milward, *War, Economy,
and Society, 1939-1945* (1979).
[36] Ozawa was both the fleet commander and the tactical commander of all
Japanese carriers. On the U.S. side these functions were split, with
Admiral Raymond A. Spruance serving as the fleet commander (i.e., Fifth
Fleet) and Vice Admiral Marc A. Mitscher serving as the officer in tac-
tical command of all American carrier forces. Spruance had under his
command 43 major combatants (15 carriers, 7 battleships, and 21 cruis-
ers) and nearly 1,000 aircraft; Ozawa was in command of 28 major com-
batants (9 carriers, 5 battleships, and 13 cruisers) and less than 500
aircraft. Samuel Eliot Morison, *History of United States Naval Opera-
tions in World War II: New Guinea and the Marianas, March 1944 – August
1944*, Vol. VIII (1953), 233, and H. P. Willmott, "The Battle of the
Philippine Sea," 329, in *Great American Naval Battles* (1998), ed. Jack
Sweetman. Willmott's figures differ from Morison's only in the number
of available aircraft (listing approximately five percent fewer on each
side).

support he eventually would receive,[37] on the morning of June 19th Ozawa succeeded in attacking first with four consecutive waves of carrier-launched aircraft.[38]

In the not-too-distant past, this advantage likely would have meant doom for the American carriers.[39] Yet at the Battle of the Philippine Sea, the capabilities of U.S. Navy shipboard command and control systems contributed to a different outcome. As early as June 15th, American submarines employed their high frequency radios to inform fleet commander Raymond A. Spruance and his immediate subordinate (Marc A. Mitscher) of the whereabouts of the Japanese fleet, and on the evening of the 18th a report from a shore-based high frequency direction finding station correctly identified the general location of Ozawa's forces.[40] Exercising command from the cruiser *USS Indianapolis*, Spruance successfully utilized signal flags, blinker tubes, and limited range radio (i.e., TBS) to maintain communications with Mitscher and other senior subordinates both before and during the battle. Most critically, however, the fleet's new CIC facilities and fighter direction capabilities enabled American carrier pilots to decimate Ozawa's attacking aircraft.

The extent of the carnage at Philippine Sea was such that one U.S. Navy pilot likened the action to "an old-time turkey

---

[37] The commander of the Japanese Air Force in the Marianas (Vice Admiral Kakuji Kakuta) seriously misled Ozawa about the capabilities and accomplishments of his forces. See especially William T. Y'Blood, *Red Sun Settting: The Battle of the Philippine Sea* (1981), 42-106 passim.

[38] This description of events derives from Morison, Vol. VIII, 213-321, Paul S. Dull, *A Battle History of the Imperial Japanese Navy, 1941-1945* (1978), 303-311, Y'Blood, *Red Sun Setting*, and Willmott, "Battle of the Philippine Sea," 324-342.

[39] See especially Chapter Four and the works cited in note 12 above.

[40] Spruance later disregarded this information after a garbled report from a U.S. submarine misled him to conclude that part of Ozawa's fleet was elsewhere. Morison, Vol. VIII, 251-254, and Y'Blood, *Red Sun Setting*, 94-95.

shoot down home."[41] Out of 374 aircraft launched by Ozawa, 244 did not return,[42] and fewer than twenty succeeded in penetrating the American fleet's combat air patrols. Of these, anti-aircraft fire destroyed most, although several Japanese planes scored near misses and one managed to bomb the battleship *USS South Dakota*. Amazingly, no American carriers were hit.[43] For the time being, at least, the United States Navy had solved the problem of carrier vulnerability.[44]

Unfortunately, this solution lasted only until the Japanese developed a new tactic: the *kamikaze* attack. First implemented at Leyte Gulf in October 1944, these suicide tactics severely strained the American system of air defense.[45] Unlike a traditional raid, which generally involved dozens or even hundreds or planes, *kamikazes* frequently approached singly or in pairs.[46] This made them less susceptible to radar detection, a tendency further exploited by tactical doctrine that

---

[41] Comments of a U.S. pilot as quoted in Y'Blood, *Red Sun Setting*, 133. For this reason, the Battle of the Philippine Sea is often referred to as the "Great Marianas Turkey Shoot."
[42] Here I rely on Y'Blood's figures. Y'Blood, *Red Sun Setting*, 97-141. Morison puts the number of Japanese carrier aircraft destroyed at 192 out of 326 launched; Willmott puts the number at 219 out of 321. Morison, Vol. VIII, 263-274, and Willmott, "Battle of the Philippine Sea," 335-337.
[43] As Mitscher later stated: "It was the first time that a major enemy air blow has been made on our forces without loss or serious damage to one of our carriers." Commander, Task Force 58 to Commander in Chief, U.S. Fleet, 29 September 1944. Quoted in Guerlac, *Radar in World War II*, 967.
[44] At Philippine Sea, the American fleet also benefited from its ability to intercept the transmissions of the Japanese air coordinator. Morison, Vol. VIII, 274, and Y'Blood, *Red Sun Setting*, 110, 141.
[45] Despite their age, the most thorough accounts of Leyte Gulf remain C. Vann Woodward, The Battle of Leyte Gulf (1947), and Samuel Eliot Morison, *History of United States Naval Operations in World War II: Leyte, June 1944 - January 1945*, Vol. XII (1958).
[46] Like traditional air attacks, *kamikaze* raids also involved dozens or more aircraft; however, the *kamikazes* would approach singly or in small groups at various altitudes and from different directions. They therefore could be more evasive than large groups of aircraft flying in formation, and the number of fighters sent to intercept them had to be much greater. This greatly complicated the overall tactical picture. Bryant and Hermane, "History of Naval Fighter Direction," 82-83.

emphasized low-altitude runs with terminal "pop-up" maneuvers (Figure 6-3). Yet the biggest problem in defending against *kamikazes* was that they were considerably more accurate than bombs or torpedoes. In a traditional raid, many of the planes that penetrated an opposing fleet's combat air patrol inflicted little or no damage (e.g., Philippine Sea). *Kamikaze* attacks, on the other hand, were much more likely to hit their intended targets.[47]

In response to the *kamikaze* threat, the U.S. Navy adopted new tactics of its own. In late 1944 and early 1945 the service conducted a series of exercises, code-named "Moosetrap," to identify weaknesses in fleet defenses with respect to *kamikaze* attacks. Based on lessons learned during these exercises, the fleet began to make more extensive use of nighttime combat air patrols, anti-snooper fighters, advanced picket destroyers, and anti-aircraft cruisers.[48] Yet despite these tactics, *kamikazes* exacted a huge toll on American naval forces, especially during the Iwo Jima and Okinawa campaigns.[49] One senior U.S. naval officer described the situation off Okinawa as follows:

> Rarely have the enemy attacks been so cleverly
> executed and made with such reckless determi-
> nation. These attacks were generally by sin-
> gle or few aircraft making their approach with
> radical changes in course and altitude . . .
> Fighter Director teams and radar personnel op-

---

[47] For more on the *kamikaze*, see especially Rikihei Inoguchi and Tadashi Nakajima, *The Divine Wind: Japan's Kamikaze Force in World War II* (1958), trans. Roger Pineau, Raymond Lamont-Brown, *Kamikaze: Japan's Suicide Samurai* (1997), and Albert Axell and Hideaki Kase, *Kamikaze: Japan's Suicide Gods* (2002).

[48] Guerlac, *Radar in World War II*, 978.

[49] For details about American losses resulting from *kamikaze* attacks during these campaigns, see Samuel Eliot Morison, *History of United States Naval Operations in World War II: Victory in the Pacific, 1945*, Vol. XIV (1960), 10-75, 94-282. No doubt losses would have been even more severe had the Navy not possessed improved fire control systems and the proximity fuse.

erating in this task force were well trained
and experienced and every effort was made to
increase efficiency by practice and experi-
ence. Never before, however, have the limita-
tions of our present equipment become so pro-
nounced, and the enemy, fully aware of these
limitations gained by experience and other
means, made every effort to attack this force
under the cloak of these limitations and with
quite effective results.[50]

Painful as they were, the *kamikaze*-inflicted losses suf-
fered by the U.S. Navy did not exceed the nation's ability to
replace those losses. Nevertheless, the service certainly rec-
ognized that this was not a long-term solution to the problem
of fleet air defense. Jet aircraft and guided missiles were
going to be part of the postwar world, and these technologies
only would exacerbate the limitations made evident by the *ka-
mikaze* in late 1944 and 1945. Yet because American naval com-
manders previously had recognized and adapted to changes in the
nature of command at sea, the United States Navy was positioned
well to address these limitations. Indeed, the development of
Cold War naval command and control systems would make for a
fascinating story of its own.

---

[50] Action Report for Task Force 58, "Operations of TF 58 in Support of
Landings at Okinawa, 14 March through 28 May, 1945," n.d., as quoted in
Bryant and Hermane, "History of Naval Fighter Direction," 86. For an
especially informative firsthand recollection, see Monsarrat, *Angel on
the Yardarm*, 148-173.

Part II:

INFORMATION, TECHNOLOGY, AND NAVAL WARFARE

Tell a contemporary American naval officer that shipboard command and control technology is of only minor significance in the practice of naval warfare, and he or she likely will question your sanity. Yet as a group, those who study the United States Navy in the first half of the twentieth century consistently overlook or downplay the significance of tactical command and control. Are modern naval officers really that different from their brethren of several generations past?

In the United States, shipboard command and control became increasingly important to naval officers in the latter half of the nineteenth century. To be sure, the coordination of naval forces also was important in the age of sail, an era that witnessed the creation of some very effective visual signalling systems. Yet starting in the late nineteenth century, a confluence of technological developments led naval officers to seek new means for exercising command. The first of these developments was steam-driven screw propulsion, which enabled warships to cover greater distances in shorter amounts of time and introduced significant variations in speed among different warship types. Then the so-called gunnery revolution greatly extended the ranges at which ships could hit and be hit. While this revolution was underway, two new technologies – the submarine and the airplane – transformed naval warfare into a three-dimensional affair. Contemporaneously, navies gained access to radio as a method of inter-ship communication.

From the perspective of the naval commander, the net effect of these developments was to complicate greatly the task of command and control. In a world without wireless, seaborne commanders could worry about what was over the horizon, but from a tactical perspective there was not much they could do about it. Yet powerful long-range guns, torpedo-carrying submarines, and swift-moving aircraft meant that disaster could strike from any direction and at any moment. Radio offered naval commanders a way to deal with this uncertainty.

At first, the United States Navy's operational commanders did not embrace the new technology. This has led some scholars to conclude that the Navy was a conservative institution resistant to change. Yet this interpretation derives from a flawed premise; namely, that the Navy behaved as a monolithic entity. Closer analysis reveals that the service's technical branches aggressively pursued the adoption of radio, as was their responsibility under the Navy's bi-linear organizational structure. Then as now, operational commanders were concerned with present capabilities, not future possibilities. Until the naval shore establishment could provide them with apparatus that improved tactical capabilities, there was little reason to adopt the new technology.

By the early 1910s, improved wireless equipment had led to a change of tune. Naval officers did not suddenly become less conservative, but rather gained access to apparatus that potentially could improve operational capabilities. In 1912 the Commander-in-Chief of the Atlantic Fleet created a specialized staff billet for wireless communications, and during World War I the fleet obtained its first reliable voice radios. Nevertheless, because the immediate postwar period saw a mass exodus of qualified radiomen and significant cuts in naval appropria-

tions, the Navy initially had difficulty developing an efficient system of shipboard command and control for its radio equipment.

At no time did these difficulties manifest themselves more conspicuously than during the U.S. Navy's inaugural fleet problem in 1923. The service learned from these mistakes, however, and by the mid-1920s it had begun to incorporate radio into a broader system of shipboard command and control. The Navy developed radio-equipped aircraft, underwater sound signalling apparatus, and radio direction finders, all of which contributed to a shift in the cognitive experience of command. Whereas previously commanders spent most of their mental energy focusing on direct actions, increasingly they had to expend as much if not more effort coping with the growing amount of information available to them. In order to accomplish this end, operational commanders demanded new equipment and improved facilities for shipboard command and control. These officers then strove to create systems that would enable them to collect, evaluate, and disseminate relevant tactical information in the most effective possible manner.

The 1930s witnessed the adoption of more shipboard command and control technologies than the previous three decades combined. Fleet Problem IX, which included *Saratoga*'s daring raid on the Panama Canal, demonstrated resoundingly that success in naval warfare depended upon accurate, timely, and secure information. Operational commanders clearly understood this fact, and they devoted considerable effort toward developing shipboard systems for the management of information. Some of these systems, such as limited range radio equipment and improved methods of communications security, worked exceptionally well. Others, such as underwater sound signalling and the Air

Net, did not perform as well as expected. Yet a common theme emerged from these efforts: real-time, operational decision-making was no longer the exclusive provenance of a single individual.

Nothing illuminated this point more clearly than Navy's adoption of radar. Not only did this new technology provide commanders with vast quantities of tactical information, it did so primarily in the form of images, not words. These images then had to be translated by operators and integrated with information from existing shipboard command and control systems. To do this effectively, naval commanders had to develop better methods for shipboard information distribution. In late 1940 and 1941, innovative officers from the fleet created the Radar Plot expressly for this purpose. The Navy hoped this new facility would help to protect against air attack, and although progress toward this end had only just begun at the time of Pearl Harbor, operational commanders eventually would reap the benefits of these early efforts.

The Second World War witnessed the culmination of more than forty years of efforts by the United States Navy to develop shipboard command and control systems for the coordination of geographically-dispersed and dimensionally-diverse naval forces. The operational flexibility made possible by the availability of these systems allowed the fleet to function effectively after the disaster at Pearl Harbor, and combat experience led to further improvements, especially in fighter direction and amphibious assault. Yet the most important command and control system developed by the Navy during the war was the Combat Information Center. This new facility distributed problem-solving more evenly up and down the chain of command, thereby allowing naval commanders to make more effective

tactical decisions. Sixty years later, the Combat Information Center remains the shipboard location from which naval officers exercise command and control.

*   *   *

The answer to the question posited above, then, is that American naval officers in the first four decades of the twentieth century were deeply concerned with issues of command and control, just like their occupational descendants of today. This conclusion carries some significant implications not only for those interested in American history, but also for all of us who live and work in the so-called Information Age. To begin, conceptions of the U.S. Navy officer corps of this period as a conservative group resistant to technological change simply are flawed. Indeed, with respect to command and control technology the opposite was true, as operational commanders repeatedly demanded and employed new systems for the coordination of naval forces.

Why then has this myth of resistance persisted? One reason, as discussed in the first chapter of this study, is because the historical development of naval command and control systems has been little explored. This has led some historians to draw conclusions about technological change based solely upon reactions to changes in dominant warship type. Yet some of the battleship admirals who supposedly resisted technological change were among the most aggressive in pursuing and adopting command and control technologies.[51] This apparent discrepancy can be explained by the fact that improved command

---

[51] Samuel S. Robison and Arthur J. Hepburn are perhaps the two most notable examples.

257

and control systems offered a "win/win" situation for all operational officers, not just those who were partial to carriers, submarines, or battleships. Advocates of all warship types wanted the best possible technology, but in a world of scarce resources not all of them could have it. Labeling others as "conservative" or "resistant to change" was simply one way of competing in this environment of fiscal austerity. After all, in an innovative institution what epithets could possibly be more damning?

Beyond these issues of historical interpretation, the evolution of shipboard command and control systems in the decades prior to the Second World War is important because the men involved were pioneers of the Information Age, developing and operating real-time systems for the management and processing of information well before the rest of American society. Their legacy may be found today in facilities such as air traffic control centers, power-plant control stations, and robotic-assisted operating rooms. By studying the problems faced by these pioneers, and more importantly, by examining the solutions they pursued, we might very well come to grips with some problems of our own.
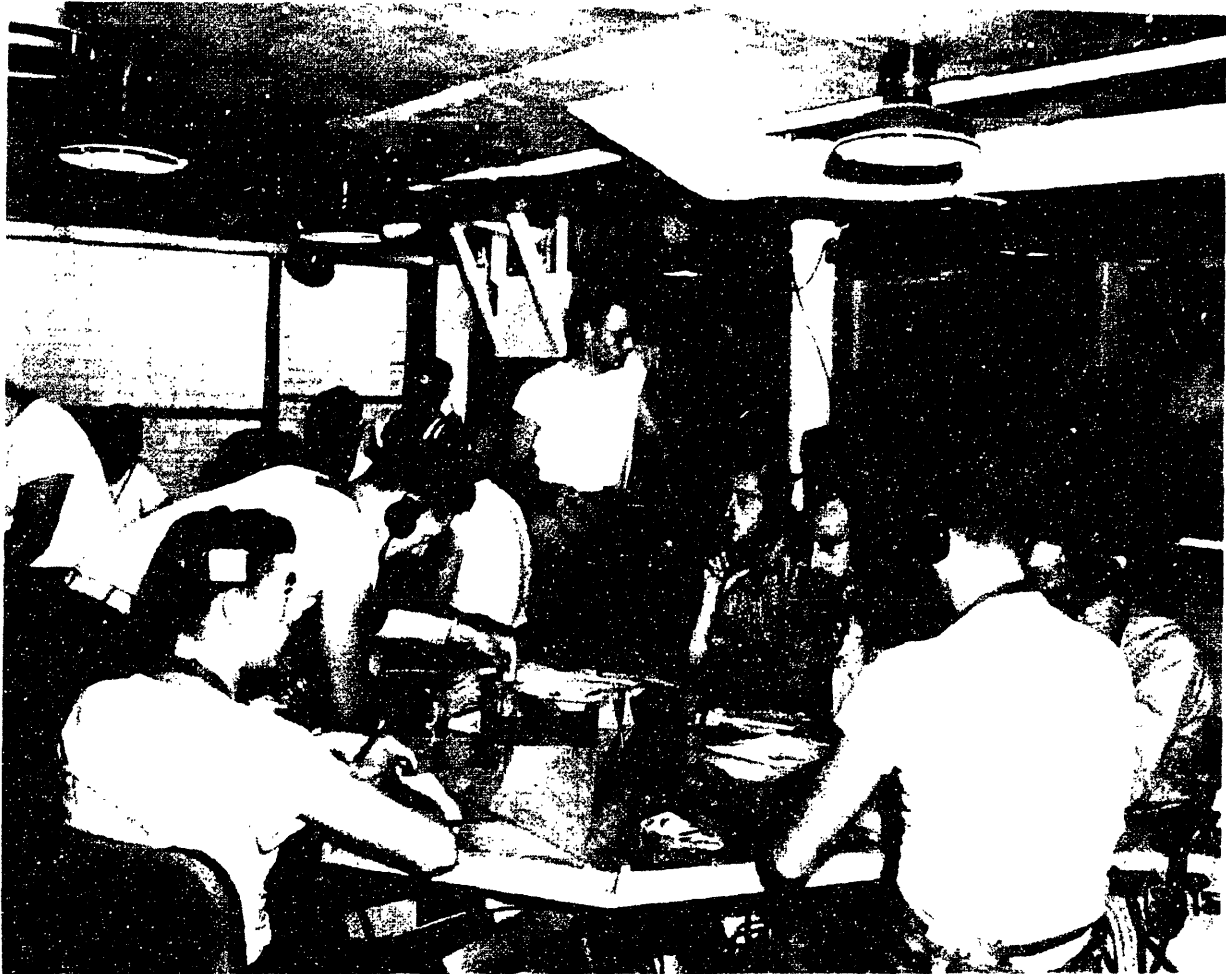
FIGURE 6-1

Personnel within the CIC of *USS Catoctin* (AGC-5)
perform their duties on the first day of the
allied invasion of southern France (August 15th,
1944). The U.S. Navy developed amphibious command
ships during World War II so that naval commanders
would have better shipboard facilities from which
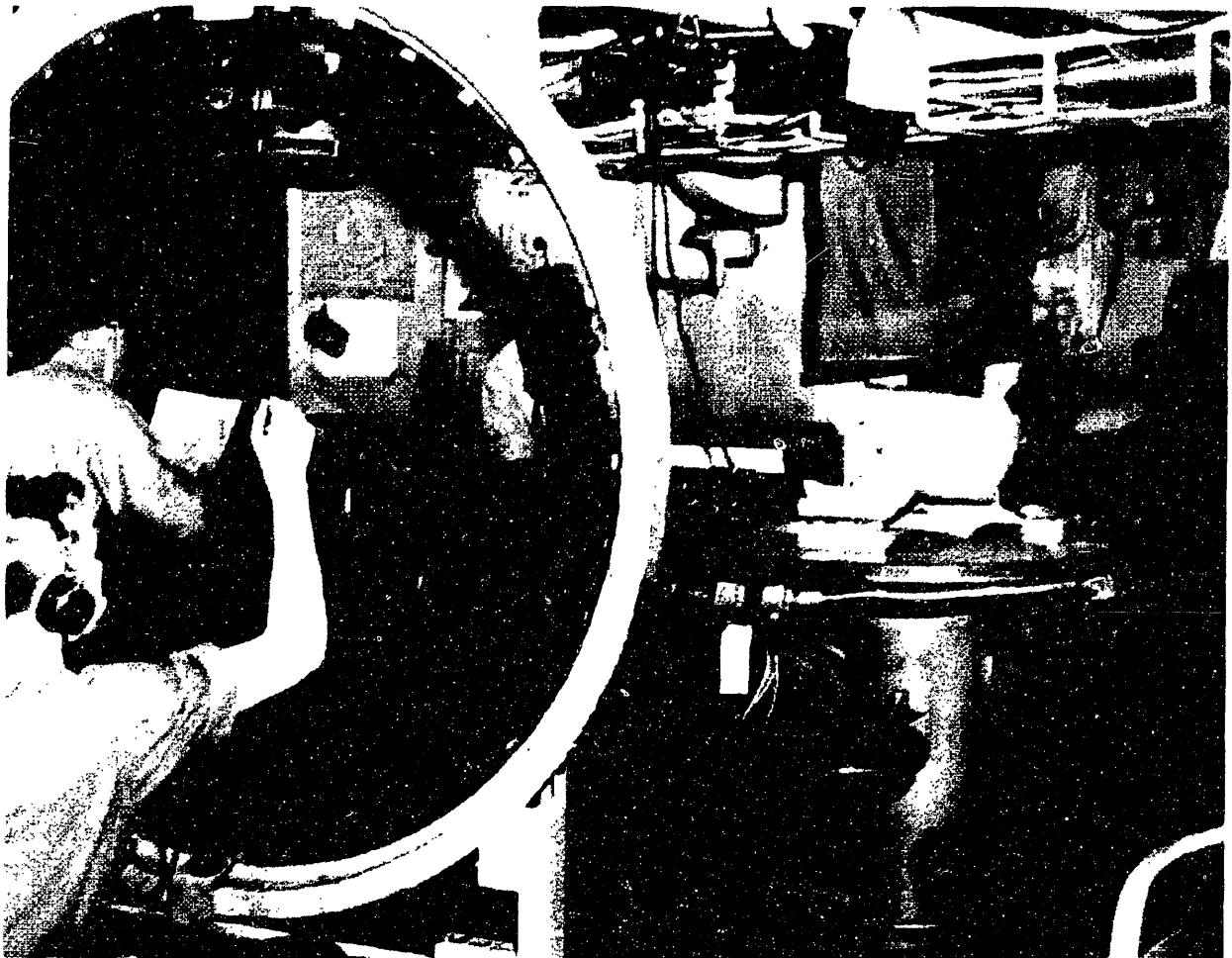to exercise command.

FIGURE 6-2

Developed by the U.S. Navy during World War II,
the Combat Information Center (CIC) provides
commanders with centralized shipboard information
processing facilities. Here, CIC team members
aboard the escort carrier USS Guadalcanal plot an
incoming air raid in June 1944.

ATTACK POINT

LOW-ALTITUDE APPROACH

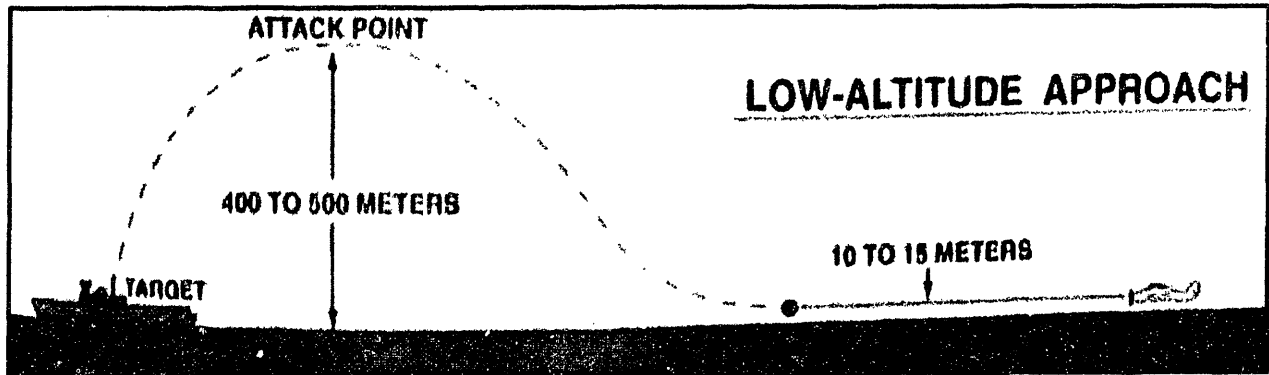400 TO 500 METERS

10 TO 15 METERS

TARGET

FIGURE 6-3

Because American radars had difficulty picking up low-flying aircraft, terminal "pop-up" maneuvers were an extremely effective *kamikaze* tactic.

Citations for Figures

Figure 6-1: Courtesy of the Naval Historical Center.

Figure 6-2: Courtesy of the Naval Historical Center.

Figure 6-3: Translated re-creation of a diagram in a Japanese tactics manual for *kamikaze* pilots. Albert Axell and Hideaki Kase, *Kamikaze: Japan's Suicide Gods*, fourth interleaf between 144-145.

SELECTED BIBLIOGRAPHY

This bibliography provides complete citation information for secondary sources. Citation information for primary sources may be found in the applicable footnotes. For a list of archival abbreviations, please consult page 11.

Abbate, Janet. *Inventing the Internet.* Cambridge, Massachusetts: MIT Press, 1999.

Adams, Stephen B., and Orville R. Butler. *Manufacturing the Future: A History of Western Electric.* Cambridge, UK: Cambridge University Press, 1999.

Aitken, Hugh G. J. *The Continuous Wave: Technology and American Radio, 1900-1932.* Princeton, New Jersey: Princeton University Press, 1985.

———. *Syntony and Spark: The Origins of Radio.* New York: John Wiley and Sons, 1976.

Alberts, David S., John J. Gartska, and Frederick P. Stein. *Network Centric Warfare: Developing and Leveraging Information Superiority.* Washington: C4ISR Cooperative Research Program, 1999.

Allard, Dean C., Martha L. Crawley, and Mary W. Edmison, eds. *U.S. Naval History Sources in the United States.* Washington: U. S. Government Printing Office, 1979.

Allard, Kenneth. "History, Technology, and the Structure of Command." *Military Review* 61 (1981): 3-9.

Allen, Marie B. "Annual Reports of Fleets and Task Forces of the U.S. Navy, 1920-1941." Washington: National Archives and Records Administration, 1974.

Allison, David Kite. *New Eye for the Navy: The Origin of Radar at the Naval Research Laboratory.* Washington: Naval Research Laboratory, 1981.

Amato, Ivan. *Pushing the Horizon: Seventy-Five Years of High Stakes Science and Technology at the Naval Research Laboratory.* Washington: U. S. Government Printing Office, 1998.

Andrade, Ernest. "Submarine Policy in the United States Navy, 1919-1941." *Military Affairs* 35, no. 2 (1971): 50-56.

Appleby, Joyce, Lynn Hunt, and Margaret Jacob. *Telling the Truth About History.* New York: W. W. Norton & Company, 1994.

Archer, Gleason L. *History of Radio to 1926.* New York: American Historical Society, 1938.

Aspray, William, ed. *Computing before Computers.* Ames, Iowa: Iowa State University Press, 1990.

Axell, Albert, and Hideaki Kase. *Kamikaze: Japan's Suicide Gods.* London: Pearson Education, 2002.

Baer, George W. *One Hundred Years of Sea Power: The U.S. Navy, 1890-1990.* Stanford, California: Stanford University Press, 1994.

Bailey, Thomas A. "The World Cruise of the American Battleship Fleet." *Pacific Historical Review* 1, no. 4 (1932): 389-423.

Baker, W. J. *A History of the Marconi Company.* London: Methuen and Company, 1970.

Barlow, Jeffrey G. "Arthur W. Radford: Aviation Trainer and Combat Commander." In *The Human Tradition in the World War II Era*, edited by Malcolm Muir, 159-175. Wilmington, Delaware: Scholarly Resources, 2001.

Bartsch, William H. *Doomed at the Start: American Pursuit Pilots in the Philippines, 1941-1942.* College Station, Texas: Texas A&M University Press, 1992.

Baxter, James Phinney. *The Introduction of the Ironclad Warship.* Hamden, Connecticut: Archon Books, 1968 [1933].

Beach, Edward L. *The United States Navy: 200 Years.* New York: H. Holt, 1986.

Beesly, Patrick. *Room 40: British Naval Intelligence, 1914-1918*. London: Hamilton, 1982.

Behe, Michael. *Darwin's Black Box: The Biochemical Challenge to Evolution*. New York: Free Press, 1996.

Bennett, Geoffrey M. *The Battle of Jutland*. London: B. T. Batsford, 1964.

Besch, Michael D. *A Navy Second to None: The History of U.S. Naval Training in World War I*. Westport, Connecticut: Greenwood Press, 2002.

Blair, Bruce G. *Strategic Command and Control: Redefining the Nuclear Threat*. Washington: Brookings Institution, 1985.

Blair, Clay. *Silent Victory: The U.S. Submarine War against Japan*. Annapolis, Maryland: Naval Institute Press, 2001 [1975].

Blake, George G. *History of Radio Telegraphy and Telephony*. London: Chapman & Hall, 1928.

Blumtritt, Oskar, Hartmut Petzold, and William Aspray, eds. *Tracking the History of Radar*. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, 1994.

Bolster, W. Jeffrey. *Black Jacks: African American Seamen in the Age of Sail*. Cambridge, Massachusetts: Harvard University Press, 1997.

Booker, Christopher B. *"I Will Wear No Chain!": A Social History of African American Males*. Westport, Connecticut: Praeger, 2000.

Boslaugh, David L. *When Computers Went to Sea: The Digitization of the United States Navy*. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, 1999.

Bracken, Paul J. *The Command and Control of Nuclear Forces*. New Haven, Connecticut: Yale University Press, 1983.

Braisted, William R. *The United States Navy in the Pacific, 1909-1922*. Austin, Texas: University of Texas Press, 1971.

Brittain, James E. *Alexanderson: Pioneer in American Electrical Engineering*. Baltimore: Johns Hopkins University Press, 1992.

Brodie, Bernard. *Sea Power in the Machine Age*. Revised 2nd ed. New York: Princeton University Press, 1943.

Brooks, John. *Telephone: The First Hundred Years*. New York: Harper and Row, 1976.

Brown, Charles H. *Dark Sky, Black Sea: Aircraft Carrier Night and All-Weather Operations*. Annapolis, Maryland: Naval Institute Press, 1999.

Brown, Louis. *A Radar History of World War II: Technical and Military Imperatives*. Philadelphia: Institute of Physics Publishing, 1999.

Buchwald, Jed Z. *The Creation of Scientific Effects: Heinrich Hertz and Electric Waves*. Chicago: University of Chicago Press, 1994.

Buderi, Robert. *The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution*. New York: Simon and Schuster, 1996.

Budiansky, Stephen. *Battle of Wits: The Complete Story of Codebreaking in World War II*. New York: Free Press, 2000.

Burlingame, Burl. "Midget Sub Found at Pearl." *United States Naval Institute Proceedings*, October 2002, 94-95.

Burns, Russell, ed. *Radar Development to 1945*. London: Peter Peregrinus, 1988.

Butterfield, Herbert. *The Whig Interpretation of History*. London: G. Bell and Sons, 1950 [1931].

Campbell, John. *Jutland: An Analysis of the Fighting*. New York: Lyons Press, 2000 [1986].

Campbell, Mark A. "The Influence of Air Power Upon the Evolution of Battle Doctrine in the U.S. Navy, 1922-1941." M. A., University of Massachusetts at Boston, 1992.

Campbell-Kelly, Martin, and William Aspray. *Computer: A History of the Information Machine*. New York: Basic Books, 1996.

Carr, Edward Hallett. *What Is History?* New York: Random House, 1961.

Case, Josephine Young, and Everett Needham Case. *Owen D. Young and American Enterprise: A Biography*. Boston: D. R. Godine, 1982.

Cebrowski, Arthur K., and John J. Gartska. "Network-Centric Warfare: Its Origin and Future." *United States Naval Institute Proceedings*, January 1998, 28-35.

Ceruzzi, Paul E. *Reckoners: The Pre-History of the Digital Computer, from Relays to the Stored Program Concept, 1935-1945*. Westport, Connecticut: Greenwood Press, 1983.

Chandler, Alfred D. *Strategy and Structure: Chapters in the History of the American Industrial Enterprise*. Cambridge, Massachusetts: MIT Press, 1962.

———. *The Visible Hand: The Managerial Revolution in American Business*. Cambridge, Massachusetts: Harvard University Press, 1977.

Clark, Andy. "Embodied, Situated, and Distributed Cognition." In *A Companion to Cognitive Science*, edited by William Bechtel and George Graham. Malden, Massachusetts: Blackwell, 1998.

Clausen, Henry C., and Bruce Lee. *Pearl Harbor: Final Judgement*. New York: Da Capo Press, 1992.

Coakley, Thomas P. *Command and Control for War and Peace*. Washington: National Defense University Press, 1992.

Cohen, Eliot A., and John Gooch. *Military Misfortunes: The Anatomy of Failure in War*. New York: Free Press, 1990.

Coletta, Paolo E. *American Secretaries of the Navy, 1775-1972*. 2 vols. Vol. 1. Annapolis, Maryland: Naval Institute Press, 1980.

———. *American Secretaries of the Navy, 1775-1972*. 2 vols. Vol. 2. Annapolis, Maryland: Naval Institute Press, 1980.

Corbett, Julian S. *Maritime Operations in the Russo-Japanese War, 1904-1905.* 2 vols. Vol. 1. Annapolis, Maryland: Naval Institute Press, 1994 [1914].

——. *Maritime Operations in the Russo-Japanese War, 1904-1905.* 2 vols. Vol. 2. Annapolis, Maryland: Naval Institute Press, 1994 [1915].

Cortada, James W. *Before the Computer: IBM, NCR, Burroughs, and Remington Rand and the Industry They Created, 1865-1956.* Princeton, New Jersey: Princeton University Press, 1993.

——. *The Computer in the United States: From Laboratory to Market, 1930 to 1960.* Armonk, New York: M. E. Sharpe, 1993.

Costello, John. *The Pacific War, 1941-1945.* New York: Quill, 1981.

Creighton, Margaret S., and Lisa Norling, eds. *Iron Men, Wooden Women: Gender and Seafaring in the Atlantic World, 1700-1920.* Baltimore: Johns Hopkins University Press, 1996.

Davidson, Joel R. *The Unsinkable Fleet: The Politics of U.S. Navy Expansion in World War II.* Annapolis, Maryland: Naval Institute Press, 1996.

Davis, Vincent. *The Admirals Lobby.* Chapel Hill, North Carolina: University of North Carolina Press, 1967.

Defense, Department of. *Joint Publication 1-02: Dictionary of Military and Associated Terms.* Washington: U. S. Government Printing Office, 2001.

Devereux, Tony. *Messenger Gods of Battle: Radio, Radar, Sonar - The Story of Electronics in War.* Washington: Brassey's, 1991.

Dewey, George. *Autobiography of George Dewey: Admiral of the Navy.* Annapolis, Maryland: Naval Institute Press, 1987 [1913].

Douglas, Susan J. *Inventing American Broadcasting, 1899-1922.* Baltimore: Johns Hopkins University Press, 1987.

———. *Listening In: Radio and the American Imagination, from Amos 'n' Andy and Edward R. Murrow to Wolfman Jack and Howard Stern*. New York: Times Books, 1999.

———. "Technological Innovation and Organizational Change: The Navy's Adoption of Radio, 1899-1919." In *Military Enterprise and Technological Change: Perspectives on the American Experience*, edited by Merritt Roe Smith, 118-173. Cambridge, Massachusetts: MIT Press, 1987.

Dreyer, Frederic C. *The Sea Heritage: A Study of Maritime Warfare*. London: Museum Press, 1955.

DuFoulon, Serge. *Les Gars De La Marine: Ethnologie D'un Navire De Guerre*. Paris: Editions Métailié, 1998.

Dull, Paul S. *A Battle History of the Imperial Japanese Navy, 1941-1945*. Annapolis, Maryland: Naval Institute Press, 1978.

Dunlap, Orrin L. *Marconi: The Man Ands His Wireless*. New York: Macmillan, 1938.

Dunnigan, James F., and Albert A. Nofi. *The Pacific War Encyclopedia*. New York: Checkmark Books, 1998.

Edwards, A. Trystan. *Three Rows of Tape: A Social Study of the Lower Deck*. London: W. Heinemann, 1929.

Edwards, Paul N. *The Closed World: Computers and the Politics of Discourse in Cold War America*. Cambridge, Massachusetts: MIT Press, 1996.

Evans, David C., and Mark R. Peattie. *Kaigun: Strategy, Tactics, and Technology in the Imperial Japanese Navy, 1887-1941*. Annapolis, Maryland: Naval Institute Press, 1997.

Ewing, Steve. *Reaper Leader: The Life of Jimmy Flatley*. Annapolis, Maryland: Naval Institute Press, 2002.

Fahey, James C. *The Ships and Aircraft of the United States Fleet: Two-Ocean Edition*. Annapolis, Maryland: Naval Institute Press, 1994 [1941].

Feuer, A. B. *The U.S. Navy in World War I: Combat at Sea and in the Air*. Westport, Connecticut: Praeger, 1999.

Fischer, Claude S. *America Calling: A Social History of the Telephone to 1940*. Los Angeles: University of California Press, 1992.

Fiske, Bradley A. *From Midshipman to Rear-Admiral*. New York: The Century Company, 1919.

Friedman, Norman. *Naval Radar*. Greenwich, UK: Conway Maritime Press, 1981.

——. *U.S. Aircraft Carriers: An Illustrated Design History*. Annapolis, Maryland: Naval Institute Press, 1983.

——. *U.S. Battleships: An Illustrated Design History*. Annapolis, Maryland: Naval Institute Press, 1985.

——. *U.S. Cruisers: An Illustrated Design History*. Annapolis, Maryland: Naval Institute Press, 1984.

——. *U.S. Destroyers: An Illustrated Design History*. Annapolis, Maryland: Naval Institute Press, 1982.

——. *U.S. Submarines through 1945: An Illustrated Design History*. Annapolis, Maryland: Naval Institute Press, 1995.

Frost, Holloway H. *The Battle of Jutland*. Annapolis, Maryland: United States Naval Institute, 1936.

Fuchida, Mitsuo, and Masatake Okumiya. *Midway: The Battle That Doomed Japan, the Japanese Navy's Story*. Annapolis, Maryland: Naval Institute Press, 2001 [1955].

Furer, Julius A. *Administration of the Navy Department in World War II*. Washington: U. S. Government Printing Office, 1959.

Gannon, Robert. *Hellions of the Deep: The Development of American Torpedoes on World War II*. University Park, Pennsylvania: Pennsylvania State University Press, 1996.

Garcia y Robertson, Rodrigo. "Failure of the Heavy Gun at Sea." *Technology and Culture* 28, no. 3 (1991): 539-557.

Gardner, W. J. R. *Decoding History: The Battle of the Atlantic and Ultra.* Annapolis, Maryland: Naval Institute Press, 1999.

———. "Intelligence Test: Evaluating Ultra in the Battle of the Atlantic." In *New Interpretations in Naval History: Selected Papers from the Fourteenth Naval History Symposium,* edited by Randy Carol Balano and Craig L. Symonds. Annapolis, Maryland: Naval Institute Press, 2001.

Gebhard, Louis A. *Evolution of Naval Radio-Electronics and Contributions of the Naval Research Laboratory.* Washington: Naval Research Laboratory, 1979.

Giedion, Siegfried. *Mechanization Takes Command: A Contribution to Anonymous History.* New York: W. W. Norton & Company, 1948.

Gillies, James, and Robert Cailliau. *How the Web Was Born: The Story of the World Wide Web.* New York: Oxford University Press, 2000.

Goldrick, James. "The Problems of Modern Naval History." In *Doing Naval History: Essays toward Improvement,* 11-23. Newport, Rhode Island: Naval War College Press, 1995.

Goldstine, Herman H. *The Computer from Pascal to Von Neuman.* Princeton, New Jersey: Princeton University Press, 1972.

Gordon, Andrew. *The Rules of the Game: Jutland and British Naval Command.* Annapolis, Maryland: Naval Institute Press, 1996.

Gray, Edwyn. *The Devil's Device: Robert Whitehead and the History of the Torpedo.* Revised 2nd ed. Annapolis, Maryland: Naval Institute Press, 1991.

Green, Venus. *Race on the Line: Gender, Labor, and Technology in the Bell System, 1880-1980.* Durham, North Carolina: Duke University Press, 2001.

Griffin, Robert S. *History f the Bureau of Engineering Navy Department During the World War.* Washington: U. S. Government Printing Office, 1922.

Grossnick, Roy A. *United States Naval Aviation, 1910-1995.* Washington: U. S. Government Printing Office, 1997.

Guerlac, Henry E. *Radar in World War II: Sections A-C*. 2 vols. Vol. 1. Woodbury, New York: Tomash Publishers, 1987 [1947].

———. *Radar in World War II: Sections D-E*. 2 vols. Vol. 2. Woodbury, New York: Tomash Publishers, 1987 [1947].

Hacker, Barton C. "Military Institutions, Weapons, and Social Change: Toward a New History of Military Technology." *Technology and Culture* 35, no. 4 (1994): 768-834.

Hackmann, Willem Dirk. *Seek & Strike: Sonar, Anti-Submarine Warfare and the Royal Navy, 1914-1954*. London: Her Majesty's Stationary Office, 1984.

Hagan, Kenneth J. *This People's Navy: The Making of American Sea Power*. New York: Free Press, 1991.

Halpern, Paul G. *A Naval History of World War I*. Annapolis, Maryland: Naval Institute Press, 1994.

Hamlyn, D. W. *In and out of the Black Box: On the Philosophy of Cognition*. New York: B. Blackwell, 1990.

Hancock, H. E. *Wireless at Sea: The First Fifty Years*. London: n.p., 1950.

Hattendorf, John B. "The Battle of Manila Bay." In *Great American Naval Battles*, edited by Jack Sweetman, 175-197. Annapolis, Maryland: Naval Institute Press, 1998.

———, ed. *Doing Naval History: Essays toward Improvement*. Newport, Rhode Island: Naval War College Press, 1995.

Headrick, Daniel R. *The Invisible Weapon: Telecommunications and International Politics, 1851-1945*. New York: Oxford University Press, 1991.

———. "The Sources of Technological Innovation in the Armed Forces: The Case of the U.S. Navy, 1865-1915." In *Critical Problems and Research Frontiers in History of Science and History of Technology*, 282-289. Madison, Wisconsin: n.p., 1991.

——. *The Tentacles of Progress: Technology Transfer in the Age of Imperialism, 1850-1940.* New York: Oxford University Press, 1988.

Heinrichs, Waldo H. "The Role of the United States Navy." In *Pearl Harbor as History: Japanese-American Relations, 1931-1941*, edited by Dorothy Borg and Shumpei Okamoto. New York: Columbia University Press, 1973.

Hertz, Heinrich. *Electric Waves: Being Researches on the Propagation of Electric Action with Finite Velocity through Space.* Translated by D. E. Jones. New York: Dover, 1962 [1893].

Herwig, Holger. "Innovation Ignored: The Submarine Problem - Germany, Britain, and the United States, 1919-1939." In *Military Innovation in the Interwar Period*, edited by Williamson Murray and Allan R. Millett. Cambridge, UK: Cambridge University Press, 1996.

Hezlet, Arthur. *Electronics and Sea Power.* New York: Stein and Day, 1975.

——. *The Submarine and Sea Power.* New York: Stein and Day, 1967.

Hijiya, James A. *Lee De Forest and the Fatherhood of Radio.* Bethlehem, Pennsylvania: Lehigh University Press, 1992.

Holley, Irving B. "Technology and Strategy: A Historical Overview." In *Technology, Strategy, and National Security*, edited by Franklin D. Margiotta and Ralph Sanders, 15-41. Washington: National Defense University Press, 1985.

Hone, Thomas C. "Battleships vs. Aircraft Carriers: The Patterns of U.S. Navy Operating Expenditures, 1932-1941." *Military Affairs* 41, no. 3 (1977): 133-140.

——. "Spending Patterns of the United States Navy, 1921-1941." *Armed Forces and Society* 8, no. 3 (1982): 443-462.

Hone, Thomas C., Norman Friedman, and Mark D. Mandeles. *American and British Aircraft Carrier Development, 1919-1941.* Annapolis, Maryland: Naval Institute Press, 1999.

Hone, Trent. "Building a Doctrine: U.S. Naval Tactics and Battle Plans in the Interwar Period." *The International Journal of Naval History* 1, no. 2 (2002): 1-39.

Hong, Sungook. "Syntony and Credibility: John Ambrose Fleming, Guglielmo Marconi, and the Maskelyne Affair." In *Scientific Credibility and Technical Standards in 19th and Early 20th Century Germany and Britain*, edited by Jed Z. Buchwald, 157-176. Boston: Kluwer, 1996.

——. *Wireless: From Marconi's Black-Box to the Audion*. Cambridge, Massachusetts: MIT Press, 2001.

Horowitz, Roger, and Arwen Mohun, eds. *His and Hers: Gender, Consumption, and Technology*. Charlottesville, Virginia: University Press of Virginia, 1998.

Hough, Richard. *The Great War at Sea, 1914-1918*. New York: Oxford University Press, 1983.

——. *The Longest Battle: The War at Sea, 1939-1945*. London: Cassell, 1986.

Howeth, Linwood S. *History of Communications-Electronics in the United States Navy*. Washington: U. S. Government Printing Office, 1963.

Howse, Derek. *Radar at Sea: The Royal Navy in World War 2*. Annapolis, Maryland: Naval Institute Press, 1993.

Hughes, Thomas P. *Elmer Sperry: Inventor and Engineer*. Baltimore: Johns Hopkins University Press, 1971.

——. *Networks of Power: Electrification in Western Society, 1880-1930*. Baltimore: Johns Hopkins University Press, 1983.

Hughes, Wayne P. *Fleet Tactics: Theory and Practice*. Annapolis, Maryland: Naval Institute Press, 1986.

Hugill, Peter J. *Global Communications since 1844: Geopolitics and Technology*. Baltimore: Johns Hopkins University Press, 1999.

Hutchins, Edwin. *Cognition in the Wild*. Cambridge, Massachusetts: MIT Press, 1995.

Inoguchi, Rikihei, and Tadashi Nakajima. *The Divine Wind: Japan's Kamikaze Force in World War II*. Translated by Roger Pineau. Annapolis, Maryland: United States Naval Institute, 1958.

Isom, Dallas Woodbury. "The Battle of Midway: Why the Japanese Lost." *Nasval War College Review* 53, no. 3 (2000): 60-100.

Israel, Paul. *From Machine Shop to Industrial Laboratory: Telegraphy and the Changing Context of American Invention, 1830-1920*. Baltimore: Johns Hopkins University Press, 1992.

Jolly, W. P. *Marconi*. New York: Stein and Day, 1972.

Jurens, W. J. "The Evolution of Battleship Gunnery in the U.S. Navy, 1920-1945." *Warship International* 28, no. 3 (1991): 240-271.

Karsten, Peter. *The Naval Aristocracy: The Golden Age of Annapolis and the Emergence of Modern American Navalism*. New York: Free Press, 1972.

Keegan, John. *The Face of Battle: A Study of Agincourt, Waterloo and the Somme*. New York: Penguin Books, 1976.

———. *The Mask of Command*. New York: Penguin Books, 1987.

Keller, Charles L. "The First Guided Missile Program: The Aerial Torpedo." *American Aviation Historical Society Journal* 20, no. 4 (1975): 268-273.

Keith, Francis Lovell. "United States Navy Task Force Evolution: An Analysis of United States Fleet Problems, 1931-1934." M. A., University of Maryland, 1974.

Kelly, Mary Pat. *Proudly We Served: The Men of the* USS Mason. Annapolis, Maryland: Naval Institute Press, 1995.

Kemp, Peter. *The British Sailor: A Social History of the Lower Deck*. London: Dent, 1970.

Kennedy, Paul M. "The Development of German Operational Plans against England, 1896-1914." In *The War Plans of the Great Powers, 1880-1914*, edited by Paul M. Kennedy. Boston: Allen & Unwin, 1979.

——. "Imperial Cable Communication and Strategy." In *The War Plans of the Great Powers, 1880-1914*, edited by Paul M. Kennedy. Boston: Allen & Unwin, 1979.

Kent, Barrie. *Signal! A History of Signalling in the Royal Navy*. Clanfield, UK: Hyden House, 1993.

Kevles, Daniel J. *The Physicists: The History of a Scientific Community in Modern America*. New York: Knopf, 1978.

Kingsley, F. A., ed. *The Development of Radar Equipments for the Royal Navy, 1935-1945*. Basingstoke, UK: Macmillan, 1995.

Kirsch, David A. *The Electric Vehicle and the Burden of History*. New Brunswick, New Jersey: Rutgers University Press, 2000.

Kirsch, David A., and Paul Maglio. "On Distinguishing Epistemic from Pragmatic Action." *Cognitive Science* 18, no. 4 (1994): 513-549.

Klachko, Mary. *Admiral William Shepherd Benson: First Chief of Naval Operations*. Annapolis, Maryland: Naval Institute Press, 1987.

Klado, Nicolas. *The Battle of the Sea of Japan*. Translated by J. H. Dickinson and F. P. Marchant. London: Hodder and Stoughton, 1906.

Knox, Dudley W. *A History of the United States Navy*. Revised 2nd ed. New York: G. P. Putnam's Sons, 1948.

Kruh, Louis. "An Armchair View of the Smithsonian Institution Cipher Machine Exhibit." *Cryptologia: A Quarterly Journal Devoted to Cryptology* 9, no. 1 (1985): 38-51.

Lambert, Nicholas A. "'Our Bloody Ships' or 'Our Bloody System'? Jutland and the Loss of the Battle Cruisers, 1916." *The Journal of Military History* 62, no. 1 (1998): 29-55.

———. *Sir John Fisher's Naval Revolution*. Columbia, South Carolina: University of South Carolina Press, 1999.

Lambi, Ivo Nikolai. *The Navy and German Power Politics. 1862-1914*. Boston: Allen & Unwin, 1984.

Lamont-Brown, Raymond. *Kamikaze: Japan's Suicide Samurai*. London: Arms and Armour, 1997.

Langley, Harold D. *A History of Medicine in the Early U.S. Navy*. Baltimore: Johns Hopkins University Press, 1995.

———. *Social Reform in the United States Navy, 1798-1862*. Urbana, Illinois: University of Illinois Press, 1967.

Lasky, Marvin. "A Historical Review of Underwater Acoustic Technology, 1916-1939, with Emphasis on Undersea Warfare." *Journal of Underwater Acoustics* 24, no. 4 (1974): 597-624.

———. "Historical Review of Underwater Acoustic Technology, 1939-1945, with Emphasis on Undersea Warfare." *Journal of Underwater Acoustics* 25, no. 4 (1975): 885-918.

———. "Review of Scientific Effort for Undersea Warfare." *Journal of Underwater Acoustics* 25, no. 3 (1975): 567-584.

———. "Review of World War I Acoustic Technology." *Journal of Underwater Acoustics* 24, no. 3 (1973): 363-385.

Latour, Bruno. *Science in Action*. Cambridge, Massachusetts: Harvard University Press, 1987.

Layton, Edwin T., Roger Pineau, and John Costello. *"And I Was There": Pearl Harbor and Midway - Breaking the Secrets*. New York: William Morrow and Company, 1985.

Levinson, Jeffrey L., and Randy L. Edwards. *Missile Inbound: The Attack on the Stark in the Persian Gulf*. Annapolis, Maryland: Naval Institute Press, 1997.

Lewis, Charles Lee. *David Glasgow Farragut: Our First Admiral*. Annapolis, Maryland: Naval Institute Press, 1943.

Lewis, Michael Arthur. *England's Sea-Officers: The Story of the Naval Profession*. London: G. Allen & Unwin, 1939.

——. *The Navy in Transition, 1814-1864: A Social History*. London: Hodder and Stoughton, 1965.

——. *The Navy of Britain: A Historical Portrait*. London: G. Allen & Unwin, 1948.

——. *The Ships and Seamen of Britain*. London: Longmans, Green & Company, 1946.

——. *A Social History of the Navy, 1793-1815*. London: Allen & Unwin, 1960.

Lipartito, Kenneth. *The Bell System and Regional Business: The Telephone in the South, 1877-1920*. Baltimore: Johns Hopkins University Press, 1989.

Lloyd, Christopher. *The British Seaman, 1200-1860: A Social Survey*. London: Collins, 1968.

Love, Robert W., ed. *The Chiefs of Naval Operations*. Annapolis, Maryland: Naval Institute Press, 1980.

——. *History of the U.S. Navy, 1942-1991*. 2 vols. Vol. 2. Annapolis, Maryland: Naval Institute Press, 1992.

Low, Morris F. "The Useful War: Radar and the Mobilization of Science and Industry in Japan." In *Science and the Pacific War: Science and Survival in the Pacific, 1939-1945*, edited by Roy M. MacLeod, 291-301. Boston: Kluwer, 2000.

Lundstrom, John B. *The First Team and the Guadalcanal Campaign: Naval Fighter Combat from August to November 1942*. Annapolis, Maryland: Naval Institute Press, 1994.

——. *The First Team: Pacific Naval Air Combat from Pearl Harbor to Midway*. Annapolis, Maryland: Naval Institute Press, 1984.

Macintyre, Donald. *Jutland*. London: Evans Brothers, 1957.

MacKenzie, Donald. *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance*. Cambridge, Massachusetts: MIT Press, 1990.

Mahan, Alfred T. *The Influence of Sea Power Upon the French Revolution and Empire, 1793-1812.* 2 vols. Vol. 1. Boston: Little, Brown and Company, 1893.

———. *The Influence of Sea Power Upon the French Revolution and Empire, 1793-1812.* 2 vols. Vol. 2. Boston: Little, Brown and Company, 1893.

———. *The Life of Nelson: The Embodiment of the Sea Power of Great Britain.* 2 vols. Vol. 1. Boston: Little, Brown and Company, 1897.

———. *The Life of Nelson: The Embodiment of the Sea Power of Great Britain.* 2 vols. Vol. 2. Boston: Little, Brown and Company, 1897.

Marconi, Degna. *My Father, Marconi.* New York: McGraw-Hill, 1962.

Marder, Arthur J. *From the Dreadnought to Scapa Flow: The Royal Navy in the Fisher Era, 1904-1919 - Jutland and After (May 1916-December 1916).* 5 vols. Vol. 3. New York: Oxford University Press, 1966.

———. *From the Dreadnought to Scapa Flow: The Royal Navy in the Fisher Era, 1904-1919 - Jutland and After (May 1916-December 1916).* Revised 2nd ed. 5 vols. Vol. 3. New York: Oxford University Press, 1978.

Marriott, Robert H. and Pratt, Haraden. "Radio Ancestors: An Autobiography by Robert H. Marriott." *IEEE Spectrum* 5, no. 6 (1968): 52-61.

Marvel, William. *The* Alabama *and the* Kearsarge: *The Sailor's Civil War.* Chapel Hill, North Carolina: University of North Carolina Press, 1996.

McBride, William M. "The 'Greatest Patron of Science'? The Navy-Academia Alliance and U.S. Naval Research, 1896-1923." *The Journal of Military History* 56, no. 1 (1992): 7-33.

———. "The Rise and Fall of a Strategic Technology: The American Battleship from Santiago Bay to Pearl Harbor, 1898-1941." Ph. D., Johns Hopkins University, 1989.

——. *Technological Change and the United States Navy, 1865-1945*. Baltimore: Johns Hopkins University Press, 2000.

McCully, Newton A. *The McCully Report: The Russo-Japanese War, 1904-1905*. Annapolis, Maryland: Naval Institute Press, 1977 [1906].

McNeill, William. *The Pursuit of Power: Technology, Armed Force, and Society since A.D. 1000*. Chicago: University of Chicago Press, 1982.

Melhorn, Charles M. *Two-Block Fox: The Rise of the Aircraft Carrier, 1911-1929*. Annapolis, Maryland: Naval Institute Press, 1974.

Miller, Edward S. *War Plan Orange: The U.S. Strategy to Defeat Japan, 1897-1945*. Annapolis, Maryland: Naval Institute Press, 1991.

Miller, Nathan. *War at Sea: A Naval History of World War II*. New York: Oxford University Press, 1995.

Miller, Sally M., ed. *Race, Ethnicity and Gender in Early Twentieth-Century American Socialism*. New York: Garland, 1996.

Milward, Alan S. *War, Economy, and Society, 1939-1945*. Los Angeles: University of California Press, 1979.

Mindell, David A. *Between Human and Machine: Feedback, Control, and Computing before Cybernetics*. Baltimore: Johns Hopkins University Press, 2002.

——. *War, Technology, and Experience Aboard the USS Monitor*. Baltimore: Johns Hopkins University Press, 2000.

Mitchell, Alastair. "The Development of Radar in the Royal Navy, 1935-1945: Part I." *Warship*, no. 13 (1980): 2-14.

——. "The Development of Radar in the Royal Navy, 1935-1945: Part II." *Warship*, no. 14 (1980): 117-134.

Monsarrat, John. *Angel on the Yardarm: The Beginnings of Fleet Radar Defense and the Kamikaze Threat*. Newport, Rhode Island: Naval War College Press, 1985.

Moretz, Joseph. *The Royal Navy and the Capital Ship in the Interwar Period: An Operational Perspective*. London: Frank Cass, 2002.

Morison, Elting E. *Admiral Sims and the Modern American Navy*. Boston: Houghton Mifflin, 1942.

——, ed. *The Letters of Theodore Roosevelt*. 8 vols. Vol. 4. Cambridge, Massachusetts: Harvard University Press, 1951.

——. *Men, Machines, and Modern Times*. Cambridge, Massachusetts: MIT Press, 1966.

Morison, Samuel Eliot. *History of United States Naval Operations in World War II: Aleutians, Gilberts and Marshalls, June 1942 - April 1944*. XV vols. Vol. VII. New York: Little, Brown and Company, 1951.

——. *History of United States Naval Operations in World War II: Coral Sea, Midway and Submarine Actions, May 1942 - August 1942*. XV vols. Vol. IV. New York: Little, Brown and Company, 1949.

——. *History of United States Naval Operations in World War II: Leyte, June 1944 - January 1945*. XV vols. Vol. XII. New York: Little, Brown and Company, 1958.

——. *History of United States Naval Operations in World War II: New Guinea and the Marianas, March 1944 - August 1944*. XV vols. Vol. VIII. New York: Little, Brown and Company, 1953.

——. *History of United States Naval Operations in World War II: Struggle for Guadalcanal, August 1942 - February 1943*. XV vols. Vol. V. New York: Little, Brown and Company, 1949.

——. *History of United States Naval Operations in World War II: The Battle of the Atlantic, 1939 - 1943*. XV vols. Vol. I. New York: Little, Brown and Company, 1947.

——. *History of United States Naval Operations in World War II: The Invasion of France and Germany, 1944 - 1945*. XV vols. Vol. XI. New York: Little, Brown and Company, 1957.

———. *History of United States Naval Operations in World War II: The Rising Sun in the Pacific, 1931 – April 1942.* XV vols. Vol. III. New York: Little, Brown and Company, 1948.

———. *History of United States Naval Operations in World War II: Victory in the Pacific, 1945.* XV vols. Vol. XIV. New York: Little, Brown and Company, 1960.

———. *The Two Ocean War: A Short History of the United States Navy in the Second World War.* New York: Little, Brown and Company, 1963.

Moy, Timothy. *War Machines: Transforming Technologies in the U.S. Military, 1920-1940.* College Station, Texas: Texas A&M University Press, 2001.

Mumford, Lewis. *Technics and Civilization.* New York: Harcourt, Brace, and Company, 1934.

Murfett, Malcolm H. "Admiral Sir Henry Bradwardine Jackson (1915-1916)." In *The First Sea Lords: From Fisher to Mountbatten*, edited by Malcolm H. Murfett. Westport, Connecticut: Praeger, 1995.

Nagy, Paul. "Network-Centric Warfare Isn't New." *United States Naval Institute Proceedings*, September 2001, 44-46.

Nakagawa, Yasuzo. *Japanese Radar and Related Weapons of World War II.* Laguna Hills, California: Aegan Park Press, 1997.

Navy, Department of the. *Naval Doctrine Publication 6: Naval Command and Control.* Washington: U. S. Government Printing Office, 1995.

Nenninger, Timothy K. "Records Relating to United States Navy Fleet Problems I to XXII, 1923-1940." Washington: National Archives and Records Administration, 1975.

Noble, David F. *America by Design: Science, Technology, and the Rise of Corporate Capitalism.* New York: Alfred A. Knopf, 1977.

Novick, Peter. *That Noble Dream: The "Objectivity Question" and the American Historical Profession.* Cambridge, UK: Cambridge University Press, 1988.

Novikoff-Priboy, Aleske. *Tsushima.* Translated by Eden and Cedar Paul. New York: Alfred A. Knopf, 1937.

Nye, David E. *American Technological Sublime.* Cambridge, Massachusetts: MIT Press, 1994.

————. *Electrifying America: Social Meanings of a New Technology.* Cambridge, Massachusetts: MIT Press, 1990.

O'Connell, Robert L. *Sacred Vessels: The Cult of the Battleship and the Rise of the U.S. Navy.* New York: Oxford University Press, 1991.

O'Rourke, Gerald G. *Night Fighters over Korea.* Annapolis, Maryland: Naval Institute Press, 1998.

O'Toole, George. *The Spanish War: An American Epic, 1898.* New York: W. W. Norton & Company, 1984.

Page, Robert Morris. *The Origin of Radar.* Garden City, New York: Doubleday & Company, 1962.

Papadopoulos, Sarandis. "Feeding the Sharks: The Logistics of Undersea Warfare, 1935-1945." Ph. D., George Washington University, 1999.

Passer, Harold C. *The Electrical Manufacturers, 1875-1900.* Cambridge, Massachusetts: Harvard University Press, 1953.

Patterson, A. Temple. *Jellicoe: A Biography.* New York: St. Martin's Press, 1969.

Paullin, Charles O. *Paullin's History of Naval Administration: A Collection of Articles from the U.S. Naval Institute Proceedings.* Annapolis, Maryland: Naval Institute Press, 1968.

Peattie, Mark R. *Sunburst: The Rise of Japanese Naval Air Power, 1909-1941.* Annapolis, Maryland: Naval Institute Press, 2001.

Porter, Glenn. *The Rise of Big Business, 1860-1920*. Revised
2nd ed. Arlington Heights, Illinois: Harlan Davidson,
1992.

Potter, E. B. *Nimitz*. Annapolis, Maryland: Naval Institute
Press, 1976.

———. *Sea Power: A Naval History*. Revised 2nd ed. Annapolis,
Maryland: Naval Institute Press, 1981.

Prados, John. *Combined Fleet Decoded: The Secret History of
American Intelligence and the Japanese Navy in World War
II*. Annapolis, Maryland: Naval Institute Press, 1995.

Prange, Gordon W. *At Dawn We Slept: The Untold Story of
Pearl Harbor*. New York: McGraw-Hill, 1981.

———. *December 7, 1941: The Day the Japanese Attacked Pearl
Harbor*. New York: McGraw-Hill, 1988.

———. *Miracle at Midway*. New York: McGraw-Hill, 1982.

———. *Pearl Harbor: The Verdict of History*. New York: McGraw-
Hill, 1986.

Price, Alfred. *The History of U.S. Electronic Warfare: The
Years of Innovation – Beginnings to 1946*. 2 vols. Vol.
1. Westford, Massachusetts: Association of Old Crows,
1984.

Pritchard, David. *The Radar War: Germany's Pioneering
Achievement, 1904-1945*. Wellingborough, UK: Patrick
Stephens, 1989.

Radar School Staff at the Massachusetts Institute of Technol-
ogy. *Principles of Radar*. New York: McGraw-Hill, 1946.

Ramold, Steven J. *Slaves, Sailors, Citizens: African Ameri-
cans in the Union Navy*. DeKalb, Illinois: Northern Illi-
nois University Press, 2002.

Ramsay, M. A. *Command and Cohesion: The Citizen-Soldier and
Minor Tactics in the British Army, 1870-1918*. Westport,
Connecticut: Praeger, 2002.

Rasor, Eugene L. *The Battle of Jutland: A Bibliography*.
Westport, Connecticut: Greenwood Press, 1992.

——. *Reform in the Royal Navy: A Social History of the Lower Deck, 1850-1880.* Hamden, Connecticut: Archon Books, 1976.

Rawles, Alan. "Jackson of the *Defiance.*" *Journal of the Institution of Electrical Engineers* 1, no. 12 (1955): 743-745.

Rawlins, Gregory J. E. *Slaves of the Machine: The Quickening of Computer Technology.* Cambridge, Massachusetts: MIT Press, 1997.

Reckner, James R. *Teddy Roosevelt's Great White Fleet.* Annapolis, Maryland: Naval Institute Press, 2001 [1988].

Reich, Leonard S. *The Making of American Industrial Research: Science and Business at GE and Bell, 1876-1926.* Cambridge, UK: Cambridge University Press, 1985.

Reynolds, Charles V. "America and a Two-Ocean Navy, 1933-1941." Ph. D., Boston University, 1978.

Reynolds, Clark G. *Admiral John H. Towers: The Struggle for Air Supremacy.* Annapolis, Maryland: Naval Institute Press, 1991.

——. *Famous American Admirals.* Annapolis, Maryland: Naval Institute Press, 2002 [1978].

——. *The Fast Carriers: The Forging of an Air Navy.* Revised 2nd ed. Annapolis, Maryland: Naval Institute Press, 1992.

——. *The Fast Carriers: The Forging of an Air Navy.* New York: McGraw-Hill, 1968.

Ring, Jim. *We Come Unseen: The Story of Britain's Cold War Submariners.* London: John Murray, 2001.

Ringle, Dennis J. *Life in Mr. Lincoln's Navy.* Annapolis, Maryland: Naval Institute Press, 1998.

Robison, Samuel S. *Manual of Wireless Telegraphy for the Use of Naval Electricians.* Revised 2nd ed. Annapolis, Maryland: United States Naval Institute, 1911.

———. *Robison's Manual of Radio Telegraphy and Telephony for Use of Naval Radiomen*. 7th ed. Annapolis, Maryland: United States Naval Institute, 1927.

———. *Robison's Manual of Radio Telegraphy and Telephony for Use of Naval Radiomen*. 8th ed. Annapolis, Maryland: United States Naval Institute, 1928.

Robison, Samuel S., and Mary L. Robison. *A History of Naval Tactics from 1530 to 1930: The Evolution of Tactical Maxims*. Annapolis, Maryland: United States Naval Institute, 1942.

Rodger, N. A. M. "Considerations on Writing General Naval History." In *Doing Naval History: Essays toward Improvement*, edited by John B. Hattendorf, 117-128. Newport, Rhode Island: Naval War College Press, 1995.

———. *The Wooden World: An Anatomy of the Georgian Navy*. Annapolis, Maryland: Naval Institute Press, 1986.

Rogers, Will, Sharon Rogers, and Gene Gregston. *Storm Center: The USS Vincennes and Iran Air Flight 655 - A Personal Account of Tragedy and Terrorism*. Annapolis, Maryland: Naval Institute Press, 1992.

Rohwer, Jürgen. *The Critical Convoy Battles of March 1943: The Battle for HX.229/SC122*. Translated by Derek Masters and A. J. Barker. London: Ian Allan, 1977.

Roland, Alex. "Science, Technology, and War." *Technology and Culture* 36, no. 2 (1995): 83-99.

———. *Underwater Warfare in the Age of Sail*. Bloomington, Indiana: Indiana University Press, 1978.

Roscoe, Theodore. *On the Seas and in the Skies: A History of the U.S. Navy's Air Power*. New York: Hawthorn Books, 1970.

———. *United States Destroyer Operations in World War II*. Annapolis, Maryland: United States Naval Institute, 1953.

———. *United States Submarine Operations in World War II*. Annapolis, Maryland: United States Naval Institute, 1949.

Rosenberg, Nathan. *Exploring the Black Box: Technology, Economics, and History*. Cambridge, UK: Cambridge University Press, 1994.

———. *Inside the Black Box: Technology and Economics*. Cambridge, UK: Cambridge University Press, 1982.

Rowland, Buford, and William B. Boyd. *U.S. Navy Bureau of Ordnance in World War II*. Washington: U. S. Government Printing Office, 1953.

Samuels, Martin. *Command or Control? Command, Training and Tactics in the British and German Armies, 1888-1918*. London: Frank Cass, 1998.

Schiffer, Michael Brian. *Taking Charge: The Electric Automobile in America*. Washington: Smithsonian Institution Press, 1994.

Schoenfeld, Maxwell P. *Charles Vernon Gridley: A Naval Career*. Erie, Pennsylvania: Erie County Historical Society, 1983.

Scott, Joan Wallach. *Gender and the Politics of History*. New York: Columbia University Press, 1988.

Scott, Lloyd N. *Naval Consulting Board of the United States*. Washington: U. S. Government Printing Office, 1920.

Showalter, Dennis E. "Toward a 'New' Naval History." In *Doing Naval History: Essays toward Improvement*, edited by John B. Hattendorf, 129-139. Newport, Rhode Island: Naval War College Press, 1995.

Shuffelton, Frank, ed. *A Mixed Race: Ethnicity in Early America*. New York: Oxford University Press, 1993.

Shulman, Mark Russell. *Navalism and the Emergence of American Sea Power, 1882-1893*. Annapolis, Maryland: Naval Institute Press, 1995.

Sims, William S. *The Victory at Sea*. Annapolis, Maryland: Naval Institute Press, 1984 [1920].

Singh, Simon. *The Code Book: The Science of Secrecy from Ancient Egypt to Quantum Cryptography*. New York: Random House, 1999.

Skolnikoff, Eugene B. *The Elusive Transformation: Science, Technology, and the Evolution of International Politics*. Princeton, New Jersey: Princeton University Press, 1993.

Smith, George David. *The Anatomy of a Business Strategy: Bell, Western Electric, and the Origins of the American Telephone Industry*. Baltimore: Johns Hopkins University Press, 1985.

Smith, Merritt Roe. *Harpers Ferry Armory and the New Technology: The Challenge of Change*. Ithaca, New York: Cornell University Press, 1977.

Spar, Deborah L. *Ruling the Waves: Cycles of Discovery, Chaos, and Wealth from the Compass to the Internet*. New York: Harcourt, 2001.

Spector, Ronald H. *Admiral of the New Empire: The Life and Career of George Dewey*. Baton Rogue, Louisiana: Louisiana State University Press, 1974.

———. *At War, At Sea: Sailors and Naval Warfare in the Twentieth Century*. New York: Viking, 2001.

———. *Eagle Against the Sun: The American War with Japan*. New York: Free Press, 1985.

Sprout, Harold, and Margaret Sprout. *The Rise of American Naval Power, 1776-1918*. Annapolis, Maryland: Naval Institute Press, 1990 [1939].

Stark, Suzanne J. *Female Tars: Women Aboard Ship in the Age of Sail*. Annapolis, Maryland: Naval Institute Press, 1996.

Staudenmaier, John M. *Technology's Storytellers: Reweaving the Human Fabric*. Cambridge, Massachusetts: MIT Press, 1985.

Steel, Nigel, and Peter Hart. *Jutland, 1916: Death in the Grey Wastes*. London: Cassell, 2003.

Stone, Ellery W. *Elements of Radiotelegraphy*. New York: D. Van Nostrand Company, 1919.

288

Strahan, Jerry E. *Andrew Jackson Higgins and the Boats That Won World War II*. Baton Rouge, Louisiana: Louisiana State University Press, 1994.

Strayer, Paul J., and Edward J. Pope. *Administrative History of the Bureau of Ships During World War II*. 4 vols. Vol. 1. Washington: Bureau of Ships Historical Section, 1947.

Sumida, Jon T. "'The Best Laid Plans': The Development of British Battle Fleet Tactics, 1919-1942." *The International History Review* 14, no. 4 (1992): 681-700.

———. *In Defence of Naval Supremacy: Finance, Technology, and British Naval Policy, 1889-1914*. 2nd ed. New York: Routledge, 1993.

———. *Inventing Grand Strategy and Teaching Command: The Classic Works of Alfred Thayer Mahan Reconsidered*. Baltimore: Johns Hopkins University Press, 1997.

———. "A Matter of Timing: The Royal Navy and the Tactics of Decisive Battle, 1912-1916." *The Journal of Military History* 67, no. 1 (2003): 85-136.

———. "The Quest for Reach: The Development of Long-Range Gunnery in the Royal Navy, 1901-1912." In *Tooling for War: Military Transformation in the Industrial Age*, edited by Stephen H. Chiabotti. Chicago: Imprint Publications, 1996.

Sumida, Jon T., and David Rosenberg. "Machines, Men, Manufacturing, Management, and Money: The Studies of Navies as Complex Organizations and the Transformation of Twentieth Century Naval History." In *Doing Naval History: Essays toward Improvement*, edited by John B. Hattendorf, 25-39. Newport, Rhode Island: Naval War College Press, 1995.

Süsskind, Charles. "The Early History of Electronics: The Experiments of Hertz." *IEEE Spectrum* 5, no. 12 (1968): 57-60.

Swanborough, Gordon, and Peter M. Bowers. *United States Navy Aircraft since 1911*. Annapolis, Maryland: Naval Institute Press, 1968.

Sweetman, Jack, ed. *The Great Admirals: Command at Sea, 1587-1945*. Annapolis, Maryland: Naval Institute Press, 1997.

Swords, Sean S. *Technical History of the Beginnings of Radar*. London: Peter Peregrinus, 1986.

Syrett, David, ed. *The Battle of the Atlantic and Signals Intelligence: U-Boat Situations and Trends, 1941-1945*. Brookfield, Vermont: Ashgate, 1998.

——. *The Defeat of the German U-Boats: The Battle of the Atlantic*. Columbia, South Carolina: University of South Carolina Press, 1994.

Tarrant, V. E. *Jutland: The German Perspective – A New View of the Great Battle, 31 May 1916*. Annapolis, Maryland: Naval Institute Press, 1995.

——. *The U-Boat Offensive, 1914-1945*. Annapolis, Maryland: Naval Institute Press, 1989.

Taylor, A. Hoyt. *The First Twenty-Five Years of the Naval Research Laboratory*. Washington: U. S. Government Printing Office, 1948.

——. *Radio Reminiscences: A Half Century*. Washington: Naval Research Laboratory, 1948.

Terraine, John. *The U-Boat Wars, 1916-1945*. New York: Putnam, 1989.

Terret, Dulany. *The Signal Corps: The Emergency*. Washington: U. S. Goverment Printing Office, 1994 [1956].

Till, Geoffrey. "Adopting the Aircraft Carrier: The British, American, and Japanese Case Studies." In *Military Innovation in the Interwar Period*, edited by Williamson Murray and Allan R. Millett, 191-226. Cambridge, UK: Cambridge University Press, 1996.

——. *Air Power and the Royal Navy, 1914-1945: A Historical Survey*. London: Jane's Publishing Company, 1979.

Tomes, Robert R. "Boon or Threat? The Information Revolution and U.S. National Security." *Naval War College Review* 53, no. 3 (2000): 39-59.

Trask, David F. *The War with Spain in 1898*. New York: Macmillan, 1981.

Turk, Richard W. "Edward Walter Eberle." In *The Chiefs of Naval Operations*, edited by Robert W. Love. Annapolis, Maryland: Naval Institute Press, 1980.

Turnbull, Archibald D., and Clifford L. Lord. *History of United States Naval Aviation*. New Haven, Connecticut: Yale University Press, 1949.

Uhlig, Frank. *How Navies Fight: The U.S. Navy and Its Allies*. Annapolis, Maryland: Naval Institute Press, 1994.

Utz, Curtis Alan. "Carrier Aviation Policy and Procurement in the U.S. Navy, 1936-1940." M. A., University of Maryland, 1989.

Valuska, David. *The African American in the Union Navy: 1861-1865*. New York: Garland, 1993.

Van Creveld, Martin L. *Command in War*. Cambridge, Massachusetts: Harvard University Press, 1985.

———. *Technology and War: From 2000 B.C. To the Present*. New York: Free Press, 1989.

Von Kroge, Harry. *GEMA: Birthplace of German Radar and Sonar*. Translated by Louis Brown. Philadelphia: Institute of Physics Publishing, 2000.

Walch, Timothy, ed. *Immigrant America: European Ethnicity in the United States*. New York: Garland, 1994.

Waugh, John C. *Last Stand at Mobile*. Abiline, Texas: McWhitney Foundation Press, 2001.

Weinberg, Gerhard L. "Why Hitler Declared War on the United States." In *America at War: An Anthology of Articles from MHQ, the Quarterly Journal of Military History*, edited by Calvin L. Christman. Annapolis, Maryland: Naval Institute Press, 1995.

Weinberg, Nathan. *Computers in the Information Society*. Boulder, Colorado: Westview Press, 1990.

Weir, Gary E. *Building American Submarines, 1914-1940.* Washington: U. S. Government Printing Office, 1991.

——. *An Ocean in Common: American Officers, Scientists, and the Ocean Environment.* College Station, Texas: Texas A&M University Press, 2001.

Welke, Barbara Young. *Recasting American Liberty: Gender, Race, Law and the Railroad Revolution, 1865-1920.* Cambridge, UK: Cambridge University Press, 2001.

Wells, John. *The Royal Navy: An Illustrated Social History, 1870-1982.* Dover, New Hampshire: A. Sutton, 1994.

Werrell, Kenneth P. *The Evolution of the Cruise Missile.* Maxwell, Alabama: Air University Press, 1985.

Westwood, J. N. *Witnesses of Tsushima.* Tokyo: Sophia University, 1970.

Wheeler, Gerald E. *Admiral William Veazie Pratt, U.S. Navy: A Sailor's Life.* Washington: U. S. Government Printing Office, 1974.

White, Lillian C. *Pioneer and Patriot: George Cook Sweet, Commander USN, 1877-1953.* Delray Beach, Florida: Southern Publishing Company, 1963.

Wildenberg, Thomas. *All the Factors of Victory: Admiral Joseph Mason Reeves and the Origins of Carrier Airpower.* Washington: Brassey's, 2003.

——. *Destined for Glory: Dive Bombing, Midway, and the Evolution of Carrier Airpower.* Annapolis, Maryland: Naval Institute Press, 1998.

——. "An Eagle with Wings of Gold: The Remarkable Career of Bill Taylor." *Air Power History*, Fall 2001, 26-33.

Willard, Robert F. "Rediscover the Art of Command and Control." *United States Naval Institute Proceedings*, October 2002, 52-54.

Williams, Kathleen Broome. *Secret Weapon: U.S. High-Frequency Direction Finding in the Battle of the Atlantic.* Annapolis, Maryland: Naval Institute Press, 1996.

Williams, Michael R. *A History of Computing Technology*. 2nd ed. Los Alamitos, California: IEEE Computer Society Press, 1997.

Willmott, H. P. "The Battle of the Philippine Sea." In *Great American Naval Battles*, edited by Jack Sweetman, 324-342. Annapolis, Maryland: Naval Institute Press, 1998.

Wilson, Eugene E. *Slipstream: The Autobiography of an Air Craftsman*. New York: McGraw-Hill, 1950.

Wimmel, Kenneth. *Theodore Roosevelt and the Great White Fleet: American Sea Power Comes of Age*. Washington: Brassey's, 1997.

Winner, Langdon. "Upon Opening the Black Box and Finding It Empty: Social Constructivism and the Philosophy of Technology." *Science, Technology, & Human Values* 18, no. 3 (1993): 362-378.

Wise, George. *Willis R. Whitney, General Electric, and the Origins of U.S. Industrial Research*. New York: Columbia University Press, 1985.

Wohlstetter, Roberta. *Pearl Harbor: Warning and Decision*. Stanford, California: Stanford University Press, 1962.

Woodward, C. Vann. *The Battle for Leyte Gulf*. New York: Macmillan, 1947.

Wylie, Joseph C. *Military Strategy: A General Theory of Power Control*. Annapolis, Maryland: Naval Institute Press, 1989 [1967].

Y'Blood, William T. *Red Sun Setting: The Battle of the Philippine Sea*. Annapolis, Maryland: Naval Institute Press, 1981.

Yates, Keith. *Flawed Victory: Jutland, 1916*. Annapolis, Maryland: Naval Institute Press, 2000.

Zimmerman, David. *Britain's Shield: Radar and the Defeat of the Luftwaffe*. Gloucestershire, UK: Sutton Publishing Limited, 2001.

———. *Top Secret Exchange: The Tizard Mission and the Scientific War*. Gloucestershire, UK: Sutton Publishing Limited, 1996.

Zorpette, Glenn. "The Edison of Secret Codes." *American Heritage of Invention & Technology*, Summer 1994, 34-43.

THESIS PROCESSING SLIP

FIXED FIELD: ill. _____ name _____

index _____ biblio _____

► **COPIES:** (Archives) Aero (Dewey) Barker Hum

Lindgren Music Rotch Science Sche-Plough

TITLE VARIES: ► ☐ _____

_____

_____

NAME VARIES: ► ☐ _____

_____

IMPRINT: (COPYRIGHT) _____

_____

► **COLLATION:** _____

_____

► **ADD: DEGREE:** _____ ► **DEPT.:** _____

► **ADD: DEGREE:** _____ ► **DEPT.:** _____

SUPERVISORS: _____

_____

NOTES:

cat'r: _____ date: _____

page: ► *545*

► **DEPT:** _STS_

► **YEAR:** _2003_ ► **DEGREE:** _Ph. D._

► **NAME:** _WOLTERS, Timothy Scott_