

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OPM control number.
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (<i>DD-MM-YYYY</i>) xx-xx-2017	2. REPORT TYPE Book	3. DATES COVERED (<i>From – To</i>)
---	-------------------------------	--

4. TITLE AND SUBTITLE Torpedoes and Their Impact on Naval Warfare	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S) Arthur E. Burke	5.d PROJECT NUMBER 300000076492/0010
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Undersea Warfare Center Division 1176 Howell Street Newport, RI 02841-1708	8. PERFORMING ORGANIZATION REPORT NUMBER N/A
---	--

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Naval Undersea Warfare Center Division 1176 Howell Street Newport, RI 02841-1708	10. SPONSORING/MONITOR'S ACRONYM NUWC
	11. SPONSORING/MONITORING REPORT NUMBER

12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES First edition.
--

14. ABSTRACT This history of the torpedo traces the weapon's evolution from Robert Whitehead's invention of a self-propelled underwater missile in 1866 to the modern versions deployed and in development in the 1980s. The book describes precursors of the torpedo, the revolutionary impact it had on naval tactics and strategy, how it was used in major wars all over the world by the navies of many nations, and the development by national governments and industry of a wide variety of torpedos, including the modern weapon, for deployment from surface ships, submarines, and aircraft. The significant role of the torpedo in 19th and 20th century naval warfare is comprehensively documented in detailed descriptions of its effectiveness in naval campaigns, the radical changes made in fleet tactical doctrine and the design of new warships to counter the torpedo's threat, and the development of new ship and aircraft classes designed to exploit the new weapon's potential. The author researched and wrote this history after a distinguished career in torpedo research and development at the Naval Underwater Systems Center. His book is issued by the Undersea Warfare Weapons, Vehicles, and Defensive Systems Department of the Naval Undersea Warfare Center Division, Newport, as an educational and reference resource.
--

15. SUBJECT TERMS			
Acoustic Torpedo British Torpedoes Homing Torpedo Robert Whitehead Torpedo Development	Antisubmarine Warfare Destroyers Japanese Torpedoes Torpedo Aircraft Torpedo History	Antisurface Warfare Electric Torpedo Locomotive Torpedo Torpedo Boats U.S. Torpedoes	Automobile Torpedo German Torpedoes Naval Warfare Torpedo Business Wire-Guided Torpedo

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT (SAR)	18. NUMBER OF PAGES 196	19a. NAME OF RESPONSIBLE PERSON Brian T. McKeon
a. REPORT (U)	b. ABSTRACT (U)	c. THIS PAGE (U)			19b. TELEPHONE NUMBER (<i>Include area code</i>) 401-832-6097

INSTRUCTIONS FOR COMPLETING SF 298

1. REPORT DATE. Full publication date, including day, month, if available. Must cite at least the year and be Year 2000 compliant, e.g. 30-06-1998; xx-06-1998; xx-xx-1998.

2. REPORT TYPE. State the type of report, such as final, technical, interim, memorandum, master's thesis, progress, quarterly, research, special, group study, etc.

3. DATES COVERED. Indicate the time during which the work was performed and the report was written, e.g., Jun 1997 – Jun 1998; 1-10 Jun 1996; May – Nov 1998; Nov 1998.

4. TITLE. Enter title and subtitle with volume number and part number, if applicable. On classified documents, enter the title classification in parentheses.

5a. CONTRACT NUMBER. Enter all contract numbers as they appear in the report, e.g. F33615-86-C-5169.

5b. GRANT NUMBER. Enter all grant numbers as they appear in the report, e.g. AFOSR-82-1 234.

5c. PROGRAM ELEMENT NUMBER. Enter all program element numbers as they appear in the report, e.g. 61101A.

5d. PROJECT NUMBER. Enter all project numbers as they appear in the report, e.g. 1F665702D1 257; ILIR.

5e. TASK NUMBER. Enter all task numbers as they appear in the report, e.g. 05; RF0330201; T4112.

5f. WORKUNIT NUMBER. Enter all work unit numbers as they appear in the report, e.g. 001; AFAPL30480105.

6. AUTHOR(S). Enter name(s) of person(s) responsible for writing the report, performing the research, or credited with the content of the report. The form of entry is the last name, first name, middle initial, and additional qualifiers separated by commas, e.g. Smith, Richard, J, Jr.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES). Self-explanatory.

8. PERFORMING ORGANIZATION REPORT NUMBER. Enter all unique alphanumeric report numbers assigned by the performing organization, e.g. BRL-1234; AFWL-TR-85-4017-Vol-21-PT-2.

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES). Enter the name and address of the organization(s) financially responsible for and monitoring the work.

10. SPONSOR/MONITOR'S ACRONYM(S). Enter, if available, e.g. BRL, ARDEC, NADC.

11. SPONSOR/MONITOR'S REPORT NUMBER(S). Enter report number as assigned by the sponsoring/monitoring agency, if available, e.g. BRL-TR-829; -215.

12. DISTRIBUTION/AVAILABILITY STATEMENT. Use agency-mandated availability statements to indicate the public availability or distribution limitations of the report. If additional limitations/restrictions or special markings are indicated, follow agency authorization procedures, e.g. RD/FRD, PROPIN, ITAR, etc. Include copyright information.

13. SUPPLEMENTARY NOTES. Enter information not included elsewhere such as; prepared in cooperation with; translation of; report supersedes; old edition numbers, etc.

14. ABSTRACT. A brief (approximately 200 words) factual summary of the most significant information.

15. SUBJECT TERMS. Key words or phrases identifying major concepts in the report.

16. SECURITY CLASSIFICATION. Enter security classification in accordance with security classification regulations, e.g. U, C, S, etc. If this form contains classified information, stamp classification level on the top and bottom of this page.

17. LIMITATION OF ABSTRACT. This block must be completed to assign a distribution limitation to the abstract. Enter UU (Unclassified Unlimited) or SAR (Same as Report). An entry in this block is necessary if the abstract is to be limited.

TORPEDOES

AND THEIR IMPACT ON NAVAL WARFARE



BY

ARTHUR E. BURKE

**TORPEDOES
AND
THEIR IMPACT
ON
NAVAL WARFARE**

by

Arthur E. Burke

**First Edition
2017**

Approved for public release; distribution is unlimited.

FOREWORD

This book contains the efforts of the late Arthur Burke Jr. in tracing the history of torpedoes and their use in warfare. He was a mechanical engineer and served in a number of positions at the Naval Underwater Systems Center (currently the Naval Undersea Warfare Center), Newport, Rhode Island, and its predecessor organizations—from hands-on engineer to senior manager—from the mid-1950s to 1982, when he retired. He devoted his professional life to the research, development, and testing of torpedoes and to undersea warfare. He was a mentor for many engineers and was one of the most respected individuals at the Center during his tenure. He was the recipient of many awards and commendations and served on a number of committees and panels directed at improving both torpedoes and the processes associated with their development. He volunteered to serve in the Naval Science Advisor Program during the Vietnam War and participated in several dangerous positions. Mr. Burke also attended the Naval War College's College of Naval Warfare (senior class) Newport, Rhode Island, and, while there, published a paper entitled "The Torpedo's Role in the Weapon System (Head or Tail)" in 1975. He was also an Armed Forces veteran, having served in the Army, the Navy, and the Coast Guard, and was a proud member of the Warren Fire Department, Engine 6. Mr. Burke died in 2010 at the age of 82.



Arthur E. Burke

A lifelong torpedo history enthusiast, he generated this unreferenced manuscript subsequent to his retirement from the Naval Underwater Systems Center. It represents his research into the subject and contains material from an extensive number of sources and documents that he was exposed to over the years. Written in the late 1980s, it traces the history of the torpedo and its use in warfare. As such, it reflects developments and use up to that time and does not discuss more recent history. It was his intent to have it published as an educational and reference resource but this was not accomplished during his lifetime. Unfortunately, any list of references or bibliography that Mr. Burke may have generated has been lost to time and it is not known to what extent he used or quoted specific material.

The book is therefore dedicated to him in appreciation of his diligence in putting the history together, the lasting memory of him by all those who worked with him and for him, and for the many, many friends he accumulated during his lifetime.

Brian T. McKeon
Head, USW Weapons, Vehicles, and Defensive Systems Department
Naval Undersea Warfare Center Division, Newport
March 2017

PREFACE

The torpedo is the most destructive naval weapon ever employed, yet its role in modern naval warfare is largely ignored by historians and naval professionals. It is incomprehensible that a weapon that has played such a major role in two World Wars would be ignored by writers and analysts, but the torpedo's significant impact on naval warfare remains a well-kept secret. The torpedo had a major influence on naval doctrine and on the design of warships. In two world wars, the torpedo influenced tactical and strategic decisions at the highest levels of government. Yet, in spite of the significant successes achieved with it, little mention is made of the torpedo in most contemporary military histories. Where there is mention of the torpedo, the statements are generally derogatory or consist of emotional comments about the weapon's ruthless application, low reliability, poor performance, or similar negative remarks.

There is a need for a rational and comprehensive review of the torpedo's role in 20th-century naval warfare in order to clearly document the torpedo's significant impact on modern naval warfare. It is not the intent of this book to glorify a weapon that has caused such immense suffering and destruction but rather to trace the torpedo's evolution and examine its remarkable influence on modern naval warfare. As the first "guided missile" used on a large scale in modern warfare, the torpedo's major impact on naval warfare may be a harbinger of what will occur if guided missiles are employed on a grand scale in future wars.

The torpedo, invented in 1866 by Robert Whitehead, an English engineer working in Austria, was a freakish weapon built by an artisan genius long before the theoretical base to support the scientific design of underwater missiles was developed. Whitehead originated the concept and, after an extended period of brilliant trial and error experimentation, he succeeded in developing a revolutionary new self-propelled underwater missile. At the turn of the century, when Whitehead's son John incorporated the new gyroscope mechanism into the torpedo, it became the first modern guided missile. Whitehead kept the design details secret but sold large numbers of torpedoes to the major naval powers; the freakish new weapon had an immediate impact on traditional naval thinking.

Although the torpedo was not used in any large-scale conflicts during the 19th century, this remarkable new weapon had a profound impact on naval theoreticians. The torpedo threatened the classic concept of close blockades, and radical changes were made in fleet tactical doctrine to counter the torpedo's threat. The torpedo also strongly influenced the design of new warships, and new ship classes, such as the destroyer and submarine, were designed to exploit the new weapon's potential.

When torpedoes were employed in large numbers during World Wars I and II, the awesome destructive potential of the first guided missile was dramatically demonstrated. Employed by surface ships, submarines, and aircraft, the torpedo was used to destroy almost 50 million tons of ships, and it had a major impact both at the tactical and strategic levels. Destroyer-launched torpedoes posed a major threat to the classic battle line. The famous battle of Jutland during World War I was inconclusive because massed torpedo attacks forced the battle lines to break off their classic big-gun slugging duels and reduced the battle to a series of inconclusive skirmishes. Aircraft employing torpedoes demonstrated that they were effective giant killers. At Pearl Harbor, torpedo planes

provided an impressive demonstration that a fleet was vulnerable to a torpedo attack even when it was tied up in its protected home anchorage. The torpedo deployed from submarines in unrestricted warfare against merchant shipping to cut sea lines of communications forcefully demonstrated the strategic significance of the torpedo as England and Japan, both island nations, were brought to the brink of strategic defeat when supplies of critically needed food and raw materials were cut off.

This book attempts to present a rational, unbiased record of the torpedo's evolution and to document the significant impact that this weapon has had on modern naval warfare. It is projected that the torpedo will continue to play a major role in any future intercontinental conflict where sea lines of communication are important. Finally, it makes the point that, as the first guided missile used on a large scale in modern warfare, the torpedo has demonstrated an awesome destructive capacity.

The book is organized into chapters that cover the history of the torpedo, its use in major wars, its application to and use from various launch platforms, the business and industry that produced the many versions of the torpedo, and the recent evolution to the modern weapon. The chapters are structured to reflect the specific subtopic so that they may be read independently. Thus, material is sometimes repeated for completeness.

CONTENTS

Chapter		Page
	PREFACE	i
1	INTRODUCTION.....	1
2	OVERVIEW	7
3	GENESIS OF A WEAPON	13
4	THE FATHER OF THE TORPEDO	21
5	BIRTH OF THE TORPEDO.....	27
6	THE COMPETITORS AND THEIR PRODUCTS	36
7	THE EARLY YEARS.....	44
8	THE TORPEDO COMES OF AGE.....	54
9	WORLD WAR I	61
10	WORLD WAR II	70
	PHOTOGRAPHS.....	83 to 88
11	TORPEDOES FROM SURFACE COMBATANTS	89
12	TORPEDOES AND SUBMARINES	104
13	THE TORPEDO AND AIRCRAFT	121
14	OTHER APPLICATIONS OF THE TORPEDO.....	131
15	THE TORPEDO BUSINESS.....	139
16	20th-CENTURY EVOLUTION OF THE TORPEDO	153
17	THE MODERN TORPEDO	166
18	IN SUMMARY	176

Chapter 1

INTRODUCTION

It would seem inconceivable that, given the thousands of books that have been written about 20th-century warfare, a weapon that played a major role in both World Wars and forever changed the role of naval warfare could be largely ignored. Distinguished authors and historians have discussed in great detail the political aspects, the great battles, and the colorful political and military leaders that were involved, but little has been written about the significance of the individual weapons that were instrumental in determining the outcome of these conflicts. There have also been endless books written discussing grand strategy, tactics, and the accomplishments of various platforms such as battleships, aircraft carriers, cruisers, submarines, destroyers, and even torpedo boats and aircraft. Again, weapons get no more than a passing mention in these books, and the emphasis generally focuses on human factors such as the valor and bravery of the individuals involved because readers are more interested in this type of information.

During the past 100 years, a single naval weapon, the torpedo, influenced the evolution of modern navies, changed classical naval doctrines, and even played a major role at the strategic level in two world wars. The torpedo, largely ignored by most naval historians, had a major impact on naval warfare, but a review of scores of books about naval warfare found that the torpedo rarely rates a listing in the index at the back of the book; it is simply ignored. If torpedoes are mentioned, it is generally in a derogatory way to highlight instances in which they didn't work properly or malfunctioned.

Little has been written in a positive vein about torpedoes, nor have there been any open-minded evaluations of the impact of the torpedo on 20th-century naval warfare. Much has been written about submarines, destroyers, torpedo boats, and torpedo bombers and their accomplishments, but relevant discussion about the actual weapon that caused the awesome destruction is conspicuous by its absence. Almost any casual student of naval warfare is aware of the fact that the U.S. Navy had problems with its torpedoes early in World War II, but very few people have any comprehension of the immense damage inflicted by these very same torpedoes and the significant role they played in defeating Japan. The role of the torpedo in modern naval warfare is one of the best kept secrets in the annals of naval warfare. The purpose of this book is to correct this situation by tracing the evolution of this weapon and identifying its significant role in modern naval warfare.

In 1866, an English engineer named Robert Whitehead, while managing a factory in Fiume, Austria, designed a freakish new naval weapon called an automobile or fish torpedo that ultimately revolutionized naval warfare. The weapon that Whitehead invented was a self-propelled underwater projectile powered by a compressed-air engine with a modest 18-pound warhead in the nose. Although primitive by modern standards, the Whitehead torpedo, with its secret depth control system, represented a revolutionary new weapon concept that caused a furor in naval circles. In an era when sailing ships were still commonplace, here was a unique new weapon that traveled covertly beneath the surface of the water. In addition, the warhead exploded against the side of the target underwater, which greatly increased the effectiveness of the new weapon since a ship holed below the waterline stood a much greater chance of sinking as it filled with water. Obviously, if you

wanted to sink ships, filling them with water was far more effective than making holes above the waterline that let in only air.

Whitehead was a mechanical genius, and his fish torpedo was a triumph of experimental artisan skills. The technology and theoretical base to support the design of a torpedo simply did not exist in the 1860s, and Whitehead had to solve, experimentally, myriad problems involving hydrodynamic stability, control system designs, propulsion systems, and servo-control systems to design and build a new weapon that would revolutionize naval warfare. It is a tribute to his genius that he succeeded in this endeavor. He also proved to be a shrewd businessman by maintaining control of his new invention and competitively selling it to most of the major naval powers. During the last three decades of the 19th century, the Whitehead Company sold thousands of torpedoes to just about every naval power, and Robert Whitehead became a very wealthy man.

Though the torpedo did not play a major role in any great sea battles during the closing decades of the 19th century, it did have a significant impact on naval tactics and the evolution of modern warships. The influence of the early torpedo on ship designs and tactical doctrine tends to be overlooked or ignored by naval historians, but the evidence clearly documents the fact that the torpedo did have a major impact on both ship designs and tactical doctrine during the closing decades of the 19th century.

When the torpedo was originally introduced as a harbor and coastal defense weapon, it posed a major threat to any warship attempting to conduct a classic close blockade. The traditional tactic was to use a close blockade to seal off the enemy's harbors and keep the ships bottled up. Naval strategists agreed that, with the advent of the torpedo, it was too dangerous to conduct close blockades since the blockading warships would be exposed to surprise torpedo attacks and this presented an unacceptable risk due to the lethality of the torpedo. Without a shot being fired in anger, the humble torpedo forced the mighty British navy to conclude that close blockades were no longer tactically sound and that new techniques had to be developed to conduct blockades when strong torpedo defenses were in place.

Warships underwent extensive redesigns to reduce the vulnerability to torpedo warheads exploding below the waterline. These design innovations included double bottoms, underwater armored belts, extensive compartmentation, separate engine rooms, and damage control techniques, including controlled flooding to reduce the damage caused by the torpedo's underwater explosive charge. Much has been written about the evolution of modern warships and the improvements that were incorporated into them during the closing decades of the 19th century, but, again, the fact that the threat posed by the torpedo provided the motivation for the major design improvements is largely ignored by modern naval historians.

In addition to the design changes to reduce vulnerability to torpedo attacks, whole new classes of warships evolved, including torpedo boats, destroyers, and submarines, that were specifically designed to utilize this revolutionary new weapon. These new platforms resulted in major changes in tactical doctrine. At the turn of the century, a new scientific curiosity called a gyroscope (or "gyro") was incorporated into the torpedo to increase its directional accuracy, which dramatically increased the effectiveness of the torpedo as it became the first guided missile. Fuel was added to create hot gas combustion systems, resulting in dramatic increases in speed and range that further increased the

effectiveness of the new gyro-controlled torpedoes. A new *Dreadnought* class of big-gun super battleships was designed by the British to increase fleet engagement ranges beyond the ever increasing range of the new torpedoes, and a massive armaments race resulted as Britain and Germany rebuilt their navies in the years prior to World War I.

When World War I started, there was a reluctance to engage in pitched naval battles because the torpedo had introduced an unacceptable risk of uncertainty, and the admirals were reluctant to commit their precious battleships to such an engagement. When the famous battle of Jutland occurred in 1916 and the British Grand Fleet and the German High Seas Fleet finally met in a major engagement, it was an anticlimax. Every time the two battle lines got into a major big-gun action, a massed destroyer torpedo attack was used to break off the action. The battleships would break off the engagement to evade the torpedoes, and it became obvious that the big gun was no longer supreme. In fact, the only battleship sunk during the battle, the German pre-dreadnought battleship *Pommern*, was the victim of a British destroyer torpedo attack.

The torpedo posed a major threat to the battleships, and the conservative tactics employed to protect the expensive battleships from torpedo attacks clearly indicated that the days of great gun duels between battle lines were numbered and that the torpedo was a major new naval weapon. Naval historians, however, continued to discuss the big-gun engagements in great detail, and the impact of the torpedo was again largely ignored.

Perhaps of even greater impact was the significance of the torpedo when employed by submarines. The basic naval strategy was presence, and the function of the dominant naval force was to demonstrate its dominance by controlling the seas. The British Royal Navy was faced with a major crisis when, on September 22, 1914, three Royal Navy cruisers patrolling off the Dutch coast were torpedoed and sunk by a single German U-boat. The British had undisputed control of the surface of the sea. However, a torpedo fired from a submarine posed a major new threat. In a prolonged war, the British numerical superiority would be challenged if major warships continued to be used in the classic presence role on the high seas and exposed to a war of attrition by continuing submarine torpedo attacks.

Since the submarine could also penetrate anchorages to fire torpedoes at warships at anchor, the ships were at risk both at sea and when they were in port. Also, every time a submarine penetrated an anchorage, the fleet went to general quarters, raised steam, and went to sea to escape the submarine since the anchored ships were like sitting ducks. Add to this a high incidence of false alarms about submarines being in the anchorage, and the result was that the fleet was soon spending most of its time just steaming in and out of the anchorage to escape submarine torpedo attacks. The submarine torpedo presented a major problem that threatened the very strategic bedrock that the Royal Navy was built on. Unlikely as it may seem, the lowly submarine torpedo forced the mightiest battle fleet the world had ever seen to leave Britain undefended and seek refuge in remote anchorages along the Irish coast to escape the U-boats while a massive program was initiated to strengthen the defenses at British naval bases in England. The British fleet was not safe in their own home ports, and they were also at risk when they were on patrol in home waters adjacent to the British Isles. Although the historians make little mention of it, the torpedo had dramatically changed the classic concepts of naval warfare.

The torpedo's greatest impact occurred almost by accident when the Germans decided to counter the British blockade by using their U-boats to blockade England by sinking merchant ships and troopships. The world's mightiest sea power was brought to the brink of defeat by the unprecedented success of the unrestricted U-boat campaign as millions of tons of merchant shipping were torpedoed. The torpedo teamed with the submarine was a deadly combination, and Great Britain, as an island nation, was uniquely vulnerable to this new weapon system. Since the torpedoed ships carried the food, raw material, and supplies needed to carry on the war, when these seaborne lifelines were choked off, the British began to suffer serious shortages of critical materials urgently needed to support their war effort. The torpedo used from submarines to sink merchant ships was really being used to achieve a major strategic objective that would influence the outcome of the whole war. The torpedo was employed as a strategic weapon to defeat Great Britain, and it came perilously close to succeeding by isolating the British nation from their allies and essential imported raw materials. The use of the torpedo as a strategic weapon to isolate an island nation is seldom even mentioned, although much has been written about the role of submarines that employed this unique weapon.

When World War I was over, there was much bitterness about the U-boat campaign and the millions of tons of ships that had been sunk, but, again, the significance of the torpedo as a strategic weapon that was used to choke the seaborne arterial lifeline of the world's greatest sea power was largely ignored. Military theoreticians also ignored the fact that the torpedo represented the first large-scale use of a guided missile in war and that it was an immensely effective weapon. The true significance of the torpedo was largely ignored, and it was generally identified as a terror weapon used to kill unarmed defenseless people. In fact, even the naval professionals that employed the torpedoes had little to say about them other than to complain about their poor performance and erratic behavior. Everybody seemed to hate torpedoes; even the word "torpedo" took on an evil slang connotation when it was used to identify a criminal or a sneaky surprise attack. In spite of the torpedo's major impact on naval warfare and the massive damage that it inflicted during the war, the torpedo continued to be largely ignored by naval professionals and historians.

When, prior to the start of World War II, the torpedo was adapted to be launched from both land-based and carrier-based aircraft, its versatility as a weapon was further expanded. The effectiveness of this new weapon system was dramatically demonstrated on December 7, 1941, when a Japanese carrier strike force conducted a surprise attack at Pearl Harbor. Aircraft-dropped torpedoes decimated the U.S. Pacific Fleet while it was at anchor in a well-protected harbor. Much has been written about the role of the aircraft carriers and the planes that attacked Pearl Harbor, but little mention is made of the torpedo as the weapon that inflicted the major damage or of the fact that the battleships were resting on the bottom because torpedoes made large holes below the waterline that caused them to fill with water and sink.

Similarly, when the British battleships *Repulse* and *Prince of Wales* were sunk by land-based Japanese aircraft, all the discussion centered on the vulnerability of surface combatants in forward areas and the value of land-based aircraft to counter naval forces. Again, the fact that both ships had been sunk by aircraft-launched torpedoes was largely ignored, and the significance of the torpedo as an aircraft-delivered weapon received scant attention. Shelves of books have been written about the impact of aircraft and aircraft carriers on naval warfare, but little mention is made of the fact that the

torpedo was the heavyweight weapon that made it possible for aircraft to successfully attack major surface combatants. Carrier-based torpedo planes had a major role in the attacks on Taranto and Pearl Harbor, in the battle of Cape Matapan, in bringing the mighty *Bismarck* to bay, and in sinking the world's mightiest battleship, the *Yamato*. The same torpedo that provided the carrier's striking power was also the carrier's archenemy, and most of the carriers sunk were the victims of torpedoes. In spite of these impressive accomplishments, the role of the torpedo is largely ignored, and most historians talk about "a carrier strike on Pearl Harbor" or write that "aircraft sank the *Yamato*."

Early in World War II, the U.S. Navy suffered severe losses during the battles of the Java Sea and Guadalcanal as the Japanese demonstrated the effectiveness of their high-performance Type 93 ("Long Lance") destroyer torpedoes. As the war progressed, U.S. destroyers became increasingly proficient in conducting torpedo attacks. The torpedoes deployed from surface ships took a heavy toll during the Pacific campaign. Names like "Iron Bottom Sound" at Guadalcanal testify to the fact that a large number of U.S. and Japanese warships went to the bottom, and most of them had large holes below the waterline made by torpedoes.

German U-boats conducted an aggressive campaign against Britain's sea lines of communications and again came perilously close to cutting off the seaborne flow of raw materials needed to continue the war. The torpedo was used as a strategic weapon to choke off seaborne trade by sinking millions of tons of critical war materiel and ships during the Battle of the Atlantic. It took a massive U.S. shipbuilding program to offset the losses and turn the tide by building thousands of merchant and warships to counter the U-boat threat. In the Pacific, U.S. Navy submarines waged a similar campaign against Japan, another island nation, and the Pacific Submarine Force (SUBPAC) succeeded in accomplishing what the German U-boats had failed to do in the Atlantic during two world wars. The SUBPAC submarines decimated the Japanese merchant fleet and achieved a strategic victory by effectively cutting off the flow of oil and raw materials that Japan needed to continue the war.

The dramatic introduction of the atomic bomb during the closing days of World War II completely overwhelmed everything else, so that few people are aware of the fact that the lowly torpedo, as the first guided missile, was instrumental in achieving a major strategic defeat. With the sinking of almost 6 million tons of ships, Japan's merchant fleet had been almost totally destroyed, and the flow of critically important oil, steel, rubber, and other raw materials had been effectively cut off. Even before the atomic bomb was dropped, the Japanese war machine was grinding to a halt, and defeat was inevitable since the island nation had been cut off from the essential raw materials needed to feed their industrial machine. The role of the torpedo in achieving this great victory is treated as a well-kept secret. Thousands of pages have been written about strategic aircraft and atom bombs, but precious little has been written about the role of the world's first guided missile.

In World War II, both the Germans and the United States engaged in highly classified programs to develop acoustic homing torpedoes. Both of these programs were successful, and, in 1943, the torpedo achieved another first in warfare when it became the first homing missile. The existence of homing torpedoes was a closely held secret during the war. Few people are aware of the fact that these torpedoes, as the first homing missiles used in combat, successfully sank or damaged over 100 surface ships and submerged submarines in the latter part of the war, conclusively demonstrating the potential effectiveness of these primitive new homing weapons. The acoustic torpedo opened a new

era in naval warfare as fully submerged submarines fired homing torpedoes at surface escort ships and as aircraft with acoustic sensors used homing torpedoes to attack submarines hiding in the ocean.

The homing torpedo radically changed the traditional concepts of submarine warfare. With the advent of the nuclear submarine and its essentially unlimited submerged endurance, the homing torpedo took on a new significance. The homing torpedo provided the nuclear submarine with a potent new weapon that was capable of attacking surface warships and convoys from the ocean depths without the submarine having to expose itself to counterattack to conduct periscope firings of conventional torpedoes. The same homing torpedo also provided a potent antisubmarine warfare (ASW) weapon that could be used by surface ships, aircraft, and other submarines to counter the significant threat posed by the new nuclear-powered attack submarines. In fact, the torpedo is the only nonnuclear weapon available to effectively counter the nuclear submarine threat.

Everyone is aware that, in the postwar period, the Russians built large numbers of submarines to challenge the U.S. Navy and that, in turn, the U.S. Navy placed a heavy emphasis on ASW warfare to counter the Russian submarine threat. Yet, few people appreciate that the acoustic homing torpedo provided the stimulus for these massive national efforts or that the modern acoustic homing torpedo would play a key role in any future war at sea. In this era of nuclear deterrence, the ballistic missile submarine is considered a key factor in maintaining a stable balance, and the acoustic homing torpedo is the only conventional weapon available for use to defend the missile submarines. These torpedoes are also the only weapon available to counter the ballistic missile submarine threat.

It is impossible to dispute the fact that the torpedo has had a major impact on naval warfare because the tens of millions of tons of ships sunk by torpedoes and rotting on the ocean bottom are overwhelming evidence of the torpedo's effectiveness. Further, the torpedo's impact on ship design and tactics, the attack on Pearl Harbor, the SUBPAC campaign against Japanese shipping, the U-boat campaign in the Atlantic, and the torpedo's key role in numerous naval battles are conclusive evidence of the remarkable role that the torpedo has played in modern naval warfare. Although the torpedo is largely ignored by most historians, the evidence indicates that the torpedo played a very significant role in naval warfare in its first 100 years of existence. It is important to document this role, and, because the torpedo has been largely ignored and frequently maligned by naval historians, it is necessary to present a positive assessment of the weapon's many accomplishments to counter the abundant negative publicity that it has received. Since the torpedo has been a major, though seldom mentioned, participant in most of the significant events that have occurred, documenting the torpedo's role in naval warfare is itself a major task that can be accomplished only by reviewing a century of naval history.

Also, because the torpedo, a purely naval weapon, had a significant effect at the strategic level in both World Wars I and II, it is appropriate for an examination of the torpedo's role in naval warfare to trace the relationships between the total conflict and the war at sea in each of these wars in order to understand the significance of the role of sea control or sea denial in today's complex modern society. Thus, it will also be necessary to briefly examine the evolution of the role of sea transport in ancient and modern civilizations to understand how the torpedo, as a purely naval weapon, could play such a major role in two world wars.

Chapter 2

OVERVIEW

The torpedo has been demonstrated to be a major naval weapon in 20th-century warfare. However, the true historical significance of a weapon is ultimately related to the broader impact it has had on the total social structure of the nations that share the planet Earth. The torpedo, having sunk thousands of ships of all sizes and types, is clearly a major naval weapon. As deployed from submarines in World Wars I and II, it became a strategic weapon used to deprive island nations of the raw materials required to sustain their war efforts and even the basic food and fuel required to ensure survival. Since the torpedo is the most effective weapon ever conceived by man for destroying ships, its significance is directly related to the importance of sea transport in modern civilization.

As man entered the industrial age, the already flourishing trade between nations became even more vital as raw materials and finished products flowed in much greater quantities between the nations to support their economies. Civilization has reached a level of complexity that requires large-scale trade between nations, and ships provide a vital role in the transport of bulk materials such as oil, steel, and manufactured goods. The importance of sea transport may vary. For example, both the Soviet Union and the United States, as large continental nations, are less dependent on sea transport than island nations like Japan and Great Britain. However, no nation is an island unto itself, and the complex modern world society, with its huge demands for energy and high-technology goods, requires a massive seaborne exchange of raw and finished materials.

Ships conduct a major portion of this trade, and the sea lines of communication are vital links in holding together the fragile world community of nations and ensuring the exchange of wealth and raw materials between nations. During World Wars I and II, the torpedo demonstrated an awesome ability to destroy ships and to deny the use of sea routes to transport materials. It could be argued that the torpedo's destructive capability is exceeded only by nuclear weapons and that the torpedo is a uniquely significant weapon because it has the demonstrated capability to sever the vital sea lines of communications that are an essential part of our complex modern civilization.

Most of the earth's surface is covered with water, and much of the development of human civilization is closely related to the rivers, seas, and oceans that isolated people on landmasses surrounded by water. Early in the evolution of civilization, people learned that certain materials that floated on top of the water provided buoyancy and could support them when crossing bodies of water. From this very fundamental discovery, rafts and dugout canoes evolved. The invention of the sail extended the reach of these boats, and people started on their quest to master the sea. Basic navigation permitted sailors to venture beyond the sight of land. The wheel is often cited as the great invention that ushered in modern civilization. However, it could also be argued that acquiring the ability to cross bodies of water in crude boats was the key step in the evolution of modern civilization. When man conceived the boat, he was no longer isolated; he could undertake journeys to explore other areas and to acquire exotic new possessions.

The mobility that ships provided permitted travel over greater distances and the means for transporting significant volumes of goods and material for barter, trade, and war. The early civilizations in the eastern Mediterranean provide classic examples of the important role of ships as Egyptians, Phoenicians, Greeks, and, later, Romans vied for supremacy. The growth of these civilizations is integrally tied to the use of ships for trade, to colonize, and to expand their spheres of control. Ships also became important instruments of war since they could be used to project power. It was possible to transport an army and its supplies in ships, which made it feasible to attack an enemy a great distance away without conquering and controlling all the land between to ensure logistic support. The construction of ships of war became a specialized art, and fleets of warships became a measure of a nation's strength.

By the time of the Greek empire, man was acquiring scientific knowledge, and this was in turn reflected in ship designs. Archimedes' discoveries concerning the relationships of volume and weight in liquids, which became the law of physics known as Archimedes' principle that is fundamental to fluid mechanics, provided a scientific basis for the design of broad-beamed ships to carry larger cargoes. However, it also provided a fundamental clue about the basic vulnerability of ships. A ship would float as long as its weight (including cargo) per unit of volume did not exceed that of the seawater it displaced. To say it another way, if the weight of the ship increased to the point where it was greater than the weight of the seawater it was floating on, its specific gravity would be greater than the water, and it would sink.

This fundamental fact clearly explained why a ship holed above the waterline would not sink since only air would enter the ship. However, a hole below the waterline would allow the ship to fill with water, and the ship would, in all likelihood, sink. The early practitioners of naval warfare recognized this and added bow rams to warships to provide a means of holing an enemy ship below the waterline so that it would fill with water and sink. Early warships, such as the triremes, became highly specialized vessels designed for speed, for maneuverability, and for the protection of their crews. However, the ram became both a distinctive feature identifying warships and a major offensive weapon for sinking enemy ships. As ships and the sea lines of communication gained in importance as links holding together fragile empires, naval warfare became increasingly important as a means of controlling the seas and severing the links of enemy states with their distant colonies.

Starting with the Mediterranean basin, most of our modern civilization has sprung up along the banks of rivers and shores of seas and oceans, with ships providing the essential mobility required to explore new areas, conduct trade, colonize, and wage wars to conquer new lands. Major cities developed wherever good harbors existed or at the mouths of large rivers. Modern civilization penetrated the huge landmasses by using boats to follow the rivers to their headwaters. Most of the major inland cities, such as Rome, Paris, London, and Moscow, were built on rivers because they provided a waterborne path that greatly facilitated the transport of bulky goods and materials.

As ships became larger, more efficient sail riggings and more complex navigation evolved to allow extended voyages to explore other lands. The Romans ventured out into the Atlantic Ocean and along the coast of Europe and Africa. There are some who claim Roman ships even reached South America during some of their voyages. In northern Europe, the Norsemen were skilled sailors, and their voyages covered all of the north Atlantic as far east as Greenland and possibly the

northeastern part of the United States. Although the Vikings were known primarily as fierce raiders, they also colonized some remote areas, including Iceland and Greenland, and were recognized as superb seamen who extended the boundaries of the then known world.

By the middle of the 15th century, as Europe emerged from the Middle Ages, brave men in small ships were sailing both east and west to explore and chart the far-flung corners of the world. Prince Henry the Navigator, Diogo Cão, and Bartholomew Dias undertook voyages down the west coast of Africa, rounded Cape Horn, and ultimately established a sea route to the Far East. In 1492, Columbus sailed west to find the same lands and won fame as the discoverer of the new world. By 1522, with the completion of the voyage started by Ferdinand Magellan, the world had been circumnavigated. Man had defined the bounds of the planet he lived on, and ships had demonstrated the vital role they would play in linking together far-flung lands separated by oceans. In the 17th and 18th centuries, traders and colonists from various European countries, including France, Spain, England, Holland, Italy, and Portugal, vied for influence over, or control of, these far-flung new lands that lay across broad oceans. Larger ships evolved to carry cargoes to and from these distant lands, and the race was on to build great empires that spread over several continents.

The Portuguese concentrated on their route around the African continent to India and the Spice Islands. The Spanish were hard at work collecting the silver and gold in the new world, while the English displayed a keen talent for trading with and colonizing new lands. As domination of these new lands became national goals, the stage was set for an escalation in the role that the ship played in the evolution of modern society. Formerly, ships offered an attractive alternate means of transport, but they were not necessarily a vital element needed to achieve national goals. However, with colonies located thousands of miles across oceans, sea transport became the only link between the mother country and its distant possessions: ships were the only way to communicate with, trade, colonize, and control oversea territories. Consequently, control of the seas became a vital national interest because the wealth of overseas colonies had to be transported in ships.

The nation that controlled the seas could sever the link between another country and its colonies, thereby cutting off the flow of raw materials and wealth without conducting a major land war. The importance of sea control was quickly recognized, and navies became a major instrument for exercising national policy. All of the major powers built naval fleets and the English, Dutch, French, and Spanish fought great sea battles to gain control of the seas and to expand or acquire additional overseas possessions. Naval warfare became a major factor in achieving and maintaining status as a major world power

The Spanish built large numbers of warships to protect their sea lines of communication with the new world and to ensure the safe delivery of gold, silver, and precious jewels to the Spanish treasury. With the defeat of the Spanish Armada in 1588, Sir Francis Drake became an English national hero, and the significance of naval supremacy was demonstrated as a small island nation gained status as a major world power primarily due to its navy. For the next 250 years, the various European nations engaged in nearly continuous wars at sea as they strove to protect or expand their sea lines of communications. In addition to the Spanish and the English, the Dutch, Swedish, Portuguese, and French also engaged in major wars at sea to expand their spheres of control. Nations acquired vast wealth from overseas trade, and ships were the key means of acquiring status as a true world power.

Since ships were a vital requirement for acquiring overseas possessions and maintaining naval power and sea control, naval weapons, such as the cannon that were effective in destroying ships, came into widespread use.

The English, as an island nation, were acutely sensitive to the importance of sea power and demonstrated a tenacious single-mindedness in concentrating on naval supremacy as the best way to achieve their national objectives. By the middle of the 16th century, as the Elizabethan era began, daring English adventurers such as Sir Francis Drake, Sir Walter Raleigh, and John Hawkins demonstrated that English sea power was to play a dominant role in shaping the new world order. Starting with the defeat of the Spanish Armada in 1588 and for the next 300 years, English merchant marine trade and the Royal Navy combined to provide the foundation for one of the mightiest empires the world had ever known. The British Empire, held together by British sea power, spread throughout the world until it reached a point where the sun never set on the British flag.

By the beginning of the 19th century, as Napoleon strove to expand the French Empire in Europe, the relative roles of sea power and large land armies came into clear focus on a grand scale. While Napoleon demonstrated his military genius on land, the British fought long and hard to blockade him and constrain him to the European landmass. The British navy prevented the French from invading England, and British admirals such as Horatio Nelson prevailed at the battle of the Nile, at Copenhagen, and finally at Trafalgar to maintain British supremacy on the high seas. The near-term political consequences of the Napoleonic Wars are known to all. Napoleon was exiled to St. Helena, a remote island in the south Atlantic, and Europe's old national boundaries were reestablished. However, the historical significance of the major role that sea power played remained obscure for almost another century. It was not until Admiral Alfred Thayer Mahan, an early president of the U.S. Naval War College, wrote his classic book on the role of British sea power (*The Influence of Sea Power upon the French Revolution and Empire 1793–1812*, 1892), that a true comprehension of the fundamental importance of sea power in the modern world evolved. Indeed, civilization had reached a point where sea transport and sea control was vitally important.

During the 19th and 20th centuries, as the industrial age evolved, the importance of sea power continued to grow. Tens of thousands of Europeans migrated to colonize foreign lands, and, as many of these colonies became new independent nations, the volume and importance of seaborne trade continued to grow. The steady increase in seaborne trade between distant nations led to dependencies in which some nations provided raw materials while other nations specialized in the manufacture of finished goods. During the 19th century, as the industrial age began to flourish, this world trade continued to grow in importance as thousands of ships crisscrossed the oceans to provide the distribution system for an industrial system that would ultimately involve all of the earth's major nations. With the birth of the clipper ships, the time required to reach distant lands was substantially reduced, and the competition for world trade became more intense. Within a few decades, the more efficient tall ships replaced the clipper ships, and the final golden age of sail was in full bloom as the industrial age spread to the far corners of the earth.

By the middle of the 19th century, the industrial age was having an impact on ship designs. Iron started to replace wood in the construction of ships, and, with coal-fired steam power plants, ships were no longer totally dependent on the wind to get to their destinations. This meant ships were no

longer at the mercy of nature since they were no longer dependent on wind and tide. With steam power, they could leave port at any time and maintain regular schedules to distant ports. However, the coal-fired steam power plants required large amounts of coal, making it necessary to stockpile coal at intermediate locations because ships couldn't carry enough coal for extended voyages. Soon, there were coaling stations located at remote sites all over the world to provide the energy for the ever-growing fleets of steam ships.

The combination of iron ships and steam power also had a major impact on naval warfare. The first demonstration occurred during the U.S. Civil War in the famous battle of the *Monitor* and the *Merrimack*. Both were steam-powered ironclad warships, and their dramatic engagement off the Virginia coast left little doubt that a revolution in warship design was in the offing. The mighty sailing ships of the line were obsolete, and the future belonged to the steel warship because there was no way that a wooden sailing ship could survive against an armored steam-powered fighting vessel. The tradition-bound naval community was reluctant to accept change, and it took decades to strip all the sails off of fighting ships. However, new steel warships, with breech-loading rifled guns mounted in rotating turrets, left little doubt that a new era was at hand.

During this same period, as naval architects busily designed new steel warships, a retired Austrian Navy captain was working on a weapon concept involving a remotely controlled launch filled with explosives that could be used for harbor or coastal defense to sink enemy warships as they approached the coast. Fregattenkapitän Giovanni de Luppis had built a model of *Der Kustenbrander* (the coastal "fireship") and demonstrated it to the naval authorities in Vienna. They were impressed with the general concept but thought that the primitive steering mechanism and spring-wound propulsion system severely limited its effectiveness. They suggested that he consult with an engineer to further develop his concept. In 1864, De Luppis contacted an English engineer named Robert Whitehead working in Fiume, Austria, at Stabilimento Tecnico Fiumano (STF). Whitehead was well known in naval circles as the designer of the marine steam engine used in the new armor-plated, screw-driven warship SMS *Erzherzog Ferdinand Max*, the flagship of the Austrian Navy. In spite of their joint collaboration, the basic deficiencies in the design could not be overcome, and it was concluded that, given the available technology, the fireship would be too slow and cumbersome to be effective against ships with rapid fire guns.

However, Whitehead, fascinated with the basic idea, continued to work on various design concepts and concluded that the key to success would be to have the weapon run under water where it could not be seen. In 1866, Whitehead built and tested a revolutionary new underwater weapon that would forever change the course of naval warfare. The first so-called automobile torpedo, primitive though it was, represented a radical new weapon that would have a major impact on naval warfare. It would take another 50 years (until World War I) for the torpedo's destructive potential to be demonstrated on a grand scale. However, by 1870, Whitehead had demonstrated that his torpedo was a superbly effective weapon for making large holes in ships below the waterline to sink them by filling them with water.

So, in the closing years of the 19th century, as revolutionary advances were implemented in the shipbuilding industry to build bigger, faster, steel-hulled ships with screw-driven steam power plants,

the same technology spawned the torpedo, which would prove to be the most effective weapon ever conceived by mankind to destroy these modern new ships.

By the early 20th century, major advances were made both in the shipbuilding industry and in the expansion of seaborne international trade. As giant ocean liners such as the *Mauretania*, *Kaiser Wilhelm Der Grosse*, and *Titanic* competed for the coveted Blue Riband, the travel time between Europe and North America continued to shrink while shipboard accommodations became even more luxurious. Revolutionary changes also took place in the design of naval warships. Starting with the British battleship *Dreadnought*, a new concept in big-gun capital ships was born. This in turn led to a renewed naval armaments race as all the major powers initiated modernization programs to build new dreadnought-type battleships. By the eve of World War I, the giant improvements in ship design that had been implemented clearly demonstrated that man had conquered the oceans and was master of his own destiny. However, there had also been steady progress in perfecting torpedoes that were capable of sinking the biggest and the best of the mighty new ships. World War I was to dramatically demonstrate man's perverse nature as torpedoes sank millions of tons of ships.

The world has changed dramatically during the last 500 years as man learned to use ships and sea power to link together the far-flung lands that make up the planet Earth. One might question the changes. However, it has been a steady evolution, and modern civilization has become critically dependent on sea transport to keep our complex world society functioning. Huge quantities of food, industrial goods, and raw materials are shipped by sea among the nations to ensure basic survival and to stimulate economic growth. Our modern society is totally dependent on sea transport to maintain the flow of goods and materials needed to produce the standard of living to which we are accustomed. If this vital flow were cut off, the magnitude of the world disaster that would follow would approach that of a nuclear war. It is impossible to examine all of the shocks that would occur and to define their impacts. However, there would be precious few people on this planet who would not be affected in one way or another if all sea transport were abruptly terminated.

For example, Japan is totally dependent on imported energy to keep its home industrial machine running. If the flow of oil stopped, their industrial machine would grind to a halt, and the political, economic, military, and social consequences would be catastrophic. Although Russia is often touted as the classic example of a self-sufficient land power, not critically dependent on sea transport, it would be an extremely dangerous situation if all seaborne grain shipments were abruptly terminated and the Russian people were suddenly faced with the prospect of large-scale food shortages.

Our complex modern civilization is critically dependent on large-scale sea transport to maintain the flow of raw materials and finished products necessary to provide the quality of life that people have come to enjoy. Twice in the 20th century, in major world wars, nations have experienced the threat to national survival that results when unlimited torpedo warfare is conducted to sever seaborne lines of supply. The torpedo is not a glamorous weapon. In fact, there are few naval professionals that have anything good to say about torpedoes. There are a great many accounts in various languages that describe how torpedoes malfunctioned or failed to perform properly, but little has been said in a positive vein to document the impact that the torpedo has had on 20th-century naval warfare. The torpedo has had a major impact both at the tactical and strategic levels, and a need exists to examine and document the significant role that the torpedo played in two major world wars.

Chapter 3

GENESIS OF A WEAPON

The roots of the modern torpedo are difficult to trace because the word “torpedo” has been used in a generic sense to describe all types of underwater weapons and even some surface weapons. Consequently, there is a tendency to confuse the origins of the weapon with the origins of the word “torpedo.” This chapter examines early naval warfare techniques and technologies employed to sink ships and attempts to trace the origin of the modern torpedo and the various other weapons that, in earlier times, were also called torpedoes. As stated earlier, one of the first weapons of naval warfare was a ram attached to the front end of the vessel so that enemy ships could be holed below the waterline. Since a ship holed below the waterline filled with water and sank, the ram was an extremely effective weapon. However, it took both skill and daring to close with the enemy ship, successfully ram it, and to disengage the ram before the enemy ship sank and dragged the attacker down with it. The early practitioners of naval warfare clearly understood that sinking ships required filling them with water, and the ram was the weapon designed to sink ships.

When fire ships loaded with combustibles were maneuvered alongside enemy ships to set them on fire, the concept of using an unmanned ship as a remote destructive force was demonstrated. This was in the first century AD. Beginning in the seventh century, the Byzantine Empire ruled the seas for 400 years by using a secret weapon called Greek fire. Byzantine naval ships used pressurized nozzles to spray the incendiary liquid onto enemy ships through pressurized hoses, causing intense fires that were extremely difficult to extinguish. In its inert form, the liquid mixture, which would float on and burn on water, was probably based on naphtha, pitch, sulfur, and quicklime. (The Byzantine recipe was such a closely guarded state secret that the actual composition is unknown.) The Saracens used a version of Greek fire successfully against the Crusaders. The liquid could also be placed in bottles or jugs with lighted wicks, which were hurled into enemy ships; the liquid ignited when the container broke. Here we see the first indications of chemical warfare and the birth of the incendiary bomb. Fire was then, as it still is, one of the most feared shipboard hazards.

The introduction of gunpowder from China opened the way for an escalation in the fireboat concepts of earlier years. At the siege of Antwerp in 1585, an Italian engineer named Lambellie set adrift four flatboats, each loaded with 7,000 pounds of black powder and fused with a length of sulphuretted match-rope. In Shakespearean times, these weapons were called petards, but they were actually the first floating mines. Only one of the flatboats exploded, but the attempt was classified a success because the bridge over the river Scheldt was demolished. During the 17th century, navies used several different types of floating petards, or mines. In 1628, the English used them at the siege of Rochelle. The “granddaddy” of floating mines is known as the St. Malo mine. In 1695, a bark of 300 tons was filled with 20,000 pounds of gunpowder covered with masonry, old cannons, and rocks. The vessel was sailed into the fortified French seaport of St. Malo, and a long match was ignited to give the crew time to escape. The resultant explosion destroyed much of the seaport. In 1770, the Russians demonstrated their fondness for bombs and explosives by sending two large floating mines against the Ottoman fleet in the port of Tehesma. The Ottoman fleet and a substantial portion of the

port's fortifications were destroyed by the explosion. Since the explosive was carried in a vessel that floated on the surface of the water, the gunpowder or explosive weapons used up to the 18th century were all surface weapons.

The next advance in naval weapons is attributed to the American engineer David Bushnell, who was born in Saybrook, Connecticut, in 1742, entered Yale College at New Haven in 1771, and graduated in 1775. Bushnell was a fine scholar, and he showed a keen interest in underwater vehicles, navigation, and underwater warfare during his collegiate career. In the area of weapons, he conducted experiments to demonstrate that, contrary to accepted theory, gunpowder could be exploded under water. His first experiment was with 2 ounces of powder that he exploded under water to demonstrate that powder would burn when submerged. In additional experiments, he used larger charges set off under rafts to demonstrate that, in underwater explosions in shallow water, the energy was focused upward toward the surface (a type of shaped charge). From these experiments, he concluded that the most efficient way to sink a ship would be to set the charge off under the keel so that the concentrated energy from the explosion would be vented into the ship and destroy it. When the American colonies revolted against Great Britain, Bushnell proposed building a secret weapon to sink the British fleet anchored in New York Harbor. Although he didn't use the word, he proposed building a submarine.

When completed, the strange vessel was called the *Turtle*, named for its shape because it looked like two turtle shells that had been placed together and had somewhat of an egg shape. There was a brass conning tower with viewing ports on top, and steering was by a rudder. A hand-operated screw propelled it through the water, and a similar vertical screw enabled it to climb or descend when submerged. In addition, there were navigational aids, including a compass and a depth gauge. It was submerged by letting water into a tank on the bottom and brought to the surface by pumping the water out. For emergencies, there was a 200-pound lead ballast that could be jettisoned to provide positive buoyancy. The *Turtle* carried an external charge of approximately 150 pounds of explosives. The explosives were to be attached to the bottom of the enemy warship with a vertical screw (rather like a drill). A clockwork timer would then be activated to give *Turtle* time to clear the area. Ideally the one-man crew of the *Turtle* should have had at least four arms: one to operate the vertical propeller, one to operate the horizontal propeller, one to control the rudder, and at least one other to attach the explosives, operate the pumps, release the ballast, etc. In 1776, the *Turtle* conducted an attack against the 64-gun flagship of the British fleet in New York, HMS *Eagle*. The operator, Sergeant Ezra Lee, succeeded in making a submerged undetected approach and getting under the ship. However, the bottom was sheathed with copper and, unfortunately, the screw could not penetrate it. Consequently, the explosives could not be attached; with daylight approaching, the attack had to be terminated. Although the *Eagle* escaped, the *Turtle* demonstrated the feasibility of using a subsurface vessel to attack major combatants. Without its copper sheathing, the *Eagle* might have sustained substantial damage.

There were no further attempts to use the *Turtle*. However, Bushnell continued to concentrate on using underwater explosives to destroy British ships. In the summer of 1777, he conducted an attack against the British frigate *Cerberus* anchored near New London, Connecticut. Underwater explosive charges (later called torpedoes) were attached to each end of a line 200 to 300 fathoms long with floats on it. The line was taken upstream and allowed to drift toward the target ship so that the line

would get caught by the bow of the ship and the torpedoes would be streamed astern. The explosive charges, or torpedoes, had a spiked wheel that would detonate the charge when the wheel rotated against the side of the ship. Fortunately for the *Cerberus*, she had a captured schooner alongside, and the prize crew on the schooner detected the line in the water first. The crew hauled in the line, and, when the torpedo reached the stern, it exploded, killing three men and destroying the schooner. The frigate escaped, but Bushnell had demonstrated that a ship could be sunk using underwater explosive charges.

In December 1777, Bushnell undertook another attempt against the British fleet anchored at Philadelphia. He constructed several floating torpedoes consisting of submerged kegs filled with gunpowder that were supported at the desired depth by buoys floating on the surface. The kegs were designed to explode when the buoy collided with any object. The plan was to take the torpedoes up the Delaware River just above Philadelphia and release them on the ebb tide so that the current would take them down against the ships anchored in the river. Although the torpedoes were released at night, it was daylight before the torpedoes reached the British ships, and the buoys were discovered. The British dispatched a small boat to examine the floating objects, and the boat and crew were blown to bits when they tried to retrieve one. This brought the British fleet to General Quarters, and the awesome firepower of the British fleet was brought to bear on some kegs floating in the Delaware River. This led to a humorous political essay known as “The Battle of the Kegs.” The action also panicked the British into moving to a new anchorage.

David Bushnell was a pioneering genius in the field of undersea warfare. He is generally acknowledged as the father of the submarine, and he is also frequently referred to as “the father of the torpedo” in 19th-century literature. It must be recognized that, in the 19th century, the word “torpedo” was used to describe all explosive devices that were set off under water, and Bushnell is definitely the father of this class of underwater weapons. In modern terminology, these weapons would be classified as mines, and this change in terminology can lead to some confusion if the casual reader is not sensitive to such ambiguities.

Some 20 years later, another distinguished American inventor became active in the field of submarine warfare. Robert Fulton, born in Little Britain, Lancaster County, Pennsylvania, in 1765, started his early career as an artist but, while studying in England, gave up painting to enter the engineering profession. For several years Fulton was engaged in engineering in Birmingham, England. He took out several patents and published some works on navigation. About 1796, Fulton became very interested in submarine warfare and went to France to offer his services to the French Directory. In 1800, Fulton built his first submarine boat in France. In 1801, he built a second, much improved, submarine named *Nautilus*. The *Nautilus* was tested successfully in the Seine near Paris; later, at Brest, it was used to attach a clockwork torpedo to the bottom of a vessel and destroy it. This is the first recorded case of a submarine vessel being used to sink a surface vessel. In spite of his success, Fulton and the French officials could not come to an agreement on how his weapon was to be utilized, so he returned to England.

William Pitt, the Prime Minister of England, became very interested in Fulton’s work and provided support to build some floating torpedoes. These “catamaran” torpedoes were oblong wooden vessels 21 feet long by 3½ feet wide that floated just awash. They contained a 400-pound

charge of gunpowder and had a clockwork firing mechanism. The British Admiral Lord Keith conducted a catamaran attack against the French fleet at Boulogne on October 2, 1804. The attack caused great excitement, and the French ships had to slip their cables to avoid the exploding torpedoes. However, although 10 mines exploded, none of them came in contact with a French warship, and the attack was a very limited success. After several other experiments in England, Fulton came back to his own country to work on his weapons. Although Fulton had Pitt's support in developing submarines and torpedoes, the Royal Navy disliked him intensely. The First Sea Lord, Earl St. Vincent (Admiral Sir John Jarvis) called Pitt "the greatest fool that ever lived, to encourage these inventions, which if successful, would deprive England of her power."

The English word "torpedo" first appears in Fulton's writings after he returned from France, and he is generally acknowledged as the originator of the word "torpedo." In Fulton's time, the French word "torpille" was being used in connection with submarine explosive charges. Some early works claim the derivation of the word is related to electric eels (family torpedinidae) and the way they used electrical shocks to attack their enemies; other references suggest the word "torpedo" was derived from the word "torpid" since the weapon rendered the target inactive. In either case, the word "torpedo" was used by Fulton in a book published in 1810 (*Torpedo War and Submarine Explosions* by Robert Fulton) that described all types of underwater weapons under the generic title "torpedoes."

In 1806, Fulton presented his plans to U.S. Government officials, including the President, and he received some vocal encouragement to continue his experiments. In July 1807, after two previous failures, Fulton succeeded in destroying a vessel in New York Harbor. His next major invention was a harpoon torpedo consisting of a harpoon fired from a special musket alleged to be capable of penetrating any ship afloat. The harpoon had a line attached to a float supporting a torpedo filled with explosives and a contact fuse. When the torpedo was swept into contact with the ship's bottom, the contact fuse was activated and the charge exploded. In 1810, a committee of naval officers convened to evaluate the harpoon torpedo. Commodore Rodgers was in charge of defending the frigate *Argus*, designated as the target. The Commodore demonstrated zeal and ingenuity by surrounding the *Argus* with nets, booms, spars, and grapnel. This extensive defensive system frustrated Fulton, and he admitted that his harpoon torpedo would not be effective against a ship so equipped. Shortly thereafter, Fulton terminated his work on torpedoes and turned to marine steam propulsion, a field in which he later gained much fame.

In 1829, a 15-year-old young man named Samuel Colt began to experiment with underwater explosives by blowing up a raft on a small lake with a submerged charge of gunpowder. For the next dozen years, he continued, at his own expense, to conduct private experiments to develop a weapon called a submarine battery. In 1841, he wrote a letter to President Tyler that offered the invention to the government as a means of defending American seaports from an attack by all the combined fleets of Europe. In March of 1842, Colt used electricity to explode a keg of gunpowder in New York Harbor, and, in July of that same year, he destroyed the old gunboat *Boxer* with an underwater charge. The government was impressed with Colt's torpedo and requested additional demonstrations. On August 20, 1842, in the presence of the President and the Cabinet, Colt destroyed a schooner on the Potomac River with a torpedo exploded by electrical energy. The operator that set it off was 5 miles from the vessel when the charge was fired. Congress appropriated \$17,000 for Colt to use in

further demonstrating his weapon. On October 18, 1842, the 300-ton brig *Volta* was destroyed by Colt in New York Harbor.

All the vessels destroyed by Colt up to this time had been at anchor. However, on April 13, 1844, he used an “electric torpedo” to destroy a 500-ton vessel while it was underway at 5 knots on the Anacostia River. Mr. Colt was on land at a considerable distance from the ship when he exploded the torpedo by sending an electrical signal down a wire attached to the weapon. This experiment, witnessed by Congress, was the last experiment that Colt conducted. It is important to keep in mind that Colt’s electric torpedo bore no resemblance to a modern torpedo; rather, it was a stationary moored mine that was remotely activated, over a wire, from a shore-based observation site. From the frustrations of his torpedoes, Colonel Colt went on to fame and fortune as a world-renowned designer and manufacturer of firearms. Colonel Colt’s torpedoes were dramatically effective, but there seemed to be a moral issue suggesting that use of such a weapon would be cowardly and ungentlemanly. This view, shared by high government officials, including the President and senior Navy officials, led to a termination of all work on devious underwater weapons.

There are also accounts of work done by numerous other engineers and scientists (Warner, Himly, Hennebert, etc.) to build underwater weapons, called torpedoes, in France, Germany, and other European countries. These weapons saw limited use in various wars and rebellions. However, all of these appear to be stationary weapons that would now be classified as mines. During the Crimean War (1854–1856), the Russian Government made extensive use of torpedoes to defend their harbors, including Sevastopol, Kronstadt, Sveaborg, and the entrance to the Sea of Azov. Two kinds were employed. One was an electrical bottom mine activated from shore that was similar to those built by Colt in the United States. The second type was a floating mine with a contact fuse. General Delafield, a U.S. Army observer in the Crimea, was greatly impressed with the effectiveness of the Russian torpedoes and recommended the use of torpedoes for harbor defense in the United States.

During the U.S. Civil War (1861–1865), torpedoes came into such widespread use as to attract worldwide attention. The Confederates, with essentially no navy, had an immense coastline full of rivers, bays, and inlets to defend, and these areas were swarming with Union men-of-war. The Confederates were quick to recognize a rare opportunity to conduct torpedo warfare against the Union Navy. In early 1862, a Torpedo Bureau was established at Richmond, Virginia, under the command of Brigadier General Rains. Shortly thereafter, a Confederate Naval Submarine Battery Service was formed and commanded, during most of the war, by Hunter Davidson, a former U.S. Navy officer. Although two different torpedo organizations were formed, it does not appear that their duties were significantly different since both conducted offensive and defensive operations. Rather, it seems that the split was geographical. For example, the Confederate navy was responsible for all activities in the James River while the Confederate army was responsible for all torpedo activities in the Charleston area. Considering the severe raw material shortages that they faced, the Confederates displayed much ingenuity in their torpedo work and developed an impressive array of weapons during the Civil War.

The first torpedoes of the war were discovered in the Potomac River near Aquia Creek on July 7, 1861. The first sinking occurred on December 12, 1862, when the Union gunboat *Cario* was totally destroyed by a torpedo as it was going up the Yazoo River. The *Cario* has the dubious honor of

being referred to as the first warship destroyed by a torpedo while engaged in actual warfare. This torpedo was actually (by modern definition) a bottom-moored mine exploded by a friction fuse activated by a trigger line located in a rifle pit on the shore.

As might be anticipated, the Union navy, because it had a lot of ships to lose, was violently opposed to torpedo warfare and claimed it was cruel, inhuman, and criminal. The Confederates, because they lacked a strong navy, looked upon the torpedo as an ideal weapon for the defense of harbors and rivers. They were also interested in developing offensive and mobile torpedoes for use against Union warships. The statistics seem to reflect these views: Confederate torpedoes sank 22 Union vessels and damaged 12 others. Union torpedoes accounted for six Confederate ships, and these events were all near the end of the war because the Union forces were reluctant to employ torpedoes during the early part of the conflict.

On August 5, 1864, Union naval forces under Admiral Farragut conducted an attack against the fortifications at Mobile, Alabama. For the attack, the 1,034-ton monitor *Tecumseh* was placed at the head of the column, and, shortly after entering the danger area, it sank when it hit a torpedo. The monitor sank by the bow and took Captain Craven and 70 of his officers and men to the bottom. The flagship *Hartford* was signaled to advise that there were more torpedoes ahead. In replying, Admiral Farragut coined one of the great naval quotations of all time when he replied, “Damn the torpedoes. Four bells, Captain Drayton, go ahead. Jouett, full speed.” With the passage of time, this has been shortened to “Damn the torpedoes, full speed ahead,” and it is one of the most famous naval quotations. Unfortunately, the admiral’s brave action was taken against stationary moored torpedoes—mines by modern definition. Somehow “Damn the mines, full speed ahead” just doesn’t have the same ring to it; this appears to be a case where it is better to be eloquent rather than technically accurate.

The “infernal machine,” or coal torpedo, is an example of how the word “torpedo” was applied to all manner of explosive devices. The Confederates are credited with creating this “terrible” weapon to destroy Union vessels by blowing up their boilers. In outward appearance, it resembled a lump of coal; it consisted of a cast hollow steel or iron container that held 7 to 10 pounds of explosive. It was then dipped in a hot mixture of coal tar, wax, and coal dust. The finished products had the look, feel, and weight of coal, which made them extremely difficult to detect. It is claimed that the Confederates had a trained body of men whose duty it was to place coal torpedoes in Union coal piles, barges, and even in the bunkers of vessels. A number of ships, including the large Union army transport *Greyhound*, were mysteriously destroyed when their boilers blew up, and a great number of unaccountable explosions were attributed to the coal torpedo when it was finally detected.

The coal torpedo is a classic example of a “terror” weapon. Its covert use caused a major deception because the explosions were attributed to faulty boilers. This caused the expenditure of extensive resources to resolve a nonexistent problem and created confusion and delays because ships were disabled and the reliability of the remaining ships was subject to question. Even when the coal torpedo was finally detected, it took a massive effort to control it because it was like looking for a needle in a haystack. There were huge stockpiles of coal everywhere, and it was next to impossible to closely examine and guard every lump of coal to keep the supply from becoming contaminated with coal torpedoes.

The Civil War also saw the advent of the movable or offensive torpedo. Both the Confederate and Union navies initiated development of offensive spar torpedoes. A spar torpedo consisted of a metal case containing 40 to 100 pounds of explosive that was mounted at the end of a spar or outrigger that projected from the front end of the firing vessel. The firing mechanism consisted of either a gun lock with a percussion cap, fired by the pull of a line, or a chemical fuse that shattered when the charge hit the target ship. Small steam launches, with the spar torpedoes mounted so that they could be lowered well below the waterline of the enemy, were the favored vessels for spar torpedo attacks. The spar torpedo was nothing more than an explosive ram that provided the means for a small launch to make a big hole in an enemy vessel below the waterline. Delivering spar torpedoes was a high-risk business, and quite a few torpedo boats were lost during attacks. However, it was an effective offensive weapon, and several vessels on both sides were sunk or damaged by spar torpedoes.

In 1864, the Confederate navy launched a major ironclad warship, the *Albemarle*, that threatened to break the Union blockade in the Virginia area. The Union navy equipped a new steam launch with a spar torpedo designed by Assistant Naval Engineer John J. Lay and used this new weapon system to attack the ironclad *Albemarle* in its home anchorage. The attack, conducted by Lieutenant William Cushing, successfully sank the *Albemarle*, but the torpedo launch also sank. Only Cushing and one other crewman survived the attack. The Lay spar torpedo had a complicated firing device that required Cushing to stand in the bow of the launch and manually set and fire the charge while under direct fire from the Confederate ram. Cushing was awarded \$56,000 for the *Albemarle* sinking, and the U.S. Navy's first torpedo boats were designated the *Cushing* class three decades later in honor of this Civil War hero.

The Confederate torpedo boat was frequently called a "David," and in battle it was truly a "David and Goliath" scenario when a small steam launch attacked a major combatant. It is interesting to note that, with the appearance of offensive torpedoes such as the spar, a change in terminology was initiated to reduce the confusion caused by the broad general use of the word "torpedo." The stationary, or defensive, torpedoes that were used to protect harbors and rivers generally came under the control of the army engineers of the various nations, and, sometime shortly after the Civil War, the name "submarine mines" came into general use by military engineers to describe all of the stationary harbor and coast defense underwater weapons. From about 1870 on, the word "torpedo" was generally used to describe movable offensive underwater weapons such as the spar or towed torpedoes, and the army word "mines" was used for stationary underwater weapons.

Another Civil War incident with historical significance involved the first sinking of a warship by a submarine. A New Orleans lawyer, Horace L. Hunley, serving as a captain in the Confederate army, designed a vessel that could operate on the surface or below it. In 1863, a 35-foot iron-hulled submersible was built at Mobile and named *H. L. Hunley*. It was powered by an eight-man crew turning a crankshaft that ran the length of the boat and connected to a propeller at the rear. A helmsman standing in a conning tower at the front end steered it and controlled the trim\ballast; a spar torpedo was mounted on the bow. The *H. L. Hunley* was truly a disaster-prone vessel. During the vessel's brief existence, some 35 men, including the designer, H. L. Hunley, lost their lives trying to get this temperamental vessel to function properly. On February 17, 1864, the *H. L. Hunley*,

utilizing a spar torpedo, successfully attacked and sank the *Housatonic*, one of the latest steam-driven Union warships. However the *Housatonic* did not die alone; somehow the *Hunley* managed to also sink itself in the attack. After the war, divers examined the wrecks and concluded that the *Hunley* was operating with its conning tower hatch open and was swamped when the torpedo exploded against the *Housatonic*. Although the *Hunley* paid the supreme price to achieve its goal, it was the first submersible to sink a warship in time of war.

The spar torpedo provided ships with an offensive torpedo, but its short-range effectiveness left much to be desired. After the Civil war, inventors in the United States and abroad were working on other types of movable torpedoes. One type that came into widespread use during the 1870s was the “otter,” or towing torpedo. The one most commonly used was the Harvey towing torpedo developed jointly by two Royal Navy officers, Captain John Harvey and Commander Frederick Harvey. It consisted of two explosive-filled copper cases that were towed some 150 yards behind the ship at a 45° angle, somewhat like modern minesweeping paravanes. The towed torpedoes could be electrically fired or set off by contact fuses. The Harvey, or otter, torpedoes were widely adopted by most of the world’s navies. However they saw very limited use in actual combat because they were soon replaced by the Whitehead automobile torpedoes that started to appear in large numbers during the 1870s.

Chapter 4

THE FATHER OF THE TORPEDO

Considering the awesome destruction that the torpedo has wrought, one would expect the creator of such a deadly weapon to be a world-renowned inventor like Thomas Edison, Samuel Colt, or Alexander Graham Bell. Very few people can even identify Robert Whitehead as the creator of the most deadly naval weapon ever conceived, and there has been surprisingly little written about him or the automobile torpedo that he invented. Although the torpedo has become a much feared weapon, the father of the torpedo has remained a relatively obscure English engineer. Few people recognize or appreciate the mechanical genius that Whitehead demonstrated when he conceived and built the automobile torpedo. Some might consider it an evil genius. However Whitehead was not a violent man by nature, and he honestly believed that the torpedo would reduce the risk of war because its great destructive potential would act as a deterrent. He made a fortune building torpedoes and selling them to all nations, and, strangely enough, the torpedo remained primarily a deterrent weapon during his lifetime; its awesome destructive potential was not demonstrated until a decade after his death during World War I.

Robert Whitehead was born in Bolton in England on January 3, 1823. The Whitehead family was very much involved in the industrial revolution that was sweeping England at the time. His grandfather, also named Robert Whitehead, reputedly opened the first bleach works in England at Elton in 1771 and later founded a calendering works—a cloth finishing process—in Bolton. Robert senior had two sons. James, the eldest son, inherited the calendering business, and his other son, John, became the sole proprietor of the cotton bleachery at Elton. James Whitehead lived on Bury Street in Bolton in a modest house next to the calendering works. In 1814, James married Ellen Swift at Bolton-le-Moors. Ellen Swift also came from good engineering stock. The family firm of Thompson Swift & Cole operated a brass and iron foundry on St. Georges Street in Bolton and built a host of mechanical machinery, including steam engines, sugar mills, mill equipment, and hydraulic presses. Robert Whitehead's inventive genius can in part be traced to the strong active engineering interests inherited from both sides of his family tree.

James and Ellen Whitehead had eight children—four boys and four girls. William, the eldest son was born in 1821. Robert, the father of the torpedo, was born on January 3, 1823. Another son, James, was born in 1825, and the fourth son, John, was born 2 years later. The four daughters—Elizabeth, Alice, Ellen, and Mary—completed the family. At the time of Robert's birth there were 28 cotton mills in Bolton employing over 4,000 people, plus other factories and foundries. For a young technically oriented boy, there was much to see and do. Steam power was in its infancy, and there were new steam locomotives that hauled wagons on steel rails. There were also strange new craft on the rivers and canals with long spindly funnels and paddle wheels that could tow strings of barges up and down the waterways, much to the delight of the young people that watched along the banks. Steam was also replacing water power as the power source to drive the machinery in the mills and factories. In 1823, when Robert Whitehead was born, Bolton had 39 steam engines with a total energy output of 913 horsepower (hp) to operate the local mills and factories. Thirty years later,

Robert Whitehead would design and build a single marine steam engine for the Austrian Navy that had almost as much power as all the steam engines in Bolton at the time of his birth.

As a toddler, Robert Whitehead thoroughly enjoyed the brief visits to his father's calendering works and to Grandfather Swift's foundry to see the strange and wondrous new steam engines that were being built. He also enjoyed visiting his favorite uncle, William Swift, who had an engineering background and did much to stimulate Robert's inborn interest in mechanical devices.

In 1829, his formal education began at the Bolton Grammar School, where he joined his older brother, William, who was already in his second year of study. The other two younger Whitehead brothers, James and John, also entered the school when they were old enough. Nothing is known of Robert's accomplishments at the school since no records exist prior to 1837; however, his younger brother John distinguished himself by winning the Popplewell Foundation Exhibition to St. John's College, Cambridge. In 1837, Robert entered a private school at Fairfield House that was operated by the Reverend Franklin Baker. This establishment, only a 2-minute walk from the Whitehead home on Bury Street, offered courses in Greek, Latin, bookkeeping, arithmetic, drawing, geography, and history, with special attention devoted to moral, cultural, and physical development.

In 1839, having completed 2 years at Parson Baker's educational establishment, Robert Whitehead entered an engineering apprenticeship with the firm of Richard Ormerod & Son of Aytoun Street in Manchester. Undoubtedly, a major factor in the apprenticeship selection was the fact that Robert's favorite uncle, William Swift, was the manager at Ormerod. It was an abrupt transition for a 16-year old boy, but Robert was at last in close contact with his beloved machinery and gaining valuable hands-on experience working on engines and machinery. This practical experience remained a valuable asset throughout the rest of his long and productive working life. In addition, his uncle made sure that he also acquired sound theoretical knowledge to back up his practical skills. One of his first apprenticeship jobs was the great span on the roof of Manchester's railway station, where he worked on narrow girders, high above the ground, by helping to bolt the various sections together. He moved next to the workshops to gain practical experience in operating the various machines and then proceeded to the drawing office where he demonstrated outstanding ability as a draftsman. His superior drafting ability earned him a reputation for "exquisite draughtsmanship," a skill he was to retain and use constantly until he was nearly 80 years old.

While working full time as an apprentice, he also attended evening classes at the Mechanics Institute located on Cooper Street in Bolton. For the sum of five shillings per quarter, he studied mechanical drawing, pattern making, and other theoretical engineering and mechanical courses. The technical courses complemented the practical training he was receiving as an apprentice and provided the necessary counterbalance to ensure that he would develop into a highly competent engineer.

The precise duration of his apprenticeship is difficult to establish; available sources do not agree on the date when the apprenticeship ended or on the date when he left England. However, the period between 1844 and 1847 was a very busy time in the life of Robert Whitehead. In these years, he completed his training, became an engineer, and fell in love with the daughter of James and Anne Johnson from Doncaster. Frances Maria Johnson became Mrs. Robert Whitehead. He also made a major decision about his career by deciding that his chances for fame and fortune as an engineer

would be enhanced if he accepted a job on the European continent. The industrial revolution was rapidly spreading throughout Europe, and there was a great demand for English engineers trained in the design and construction of textile machinery and steam-powered prime movers.

Sometime during this period (1844–1847), Robert Whitehead emigrated to Marseilles, France, where a relative obtained employment for him at the La Seyne shipyard; shortly thereafter, he was on the move again, crossing the tiny Kingdom of Piedmont to the city of Milan in northern Italy. Northern Italy, under the control of the Austrian Empire in 1847, was being swept by the industrial revolution that was changing the face of Europe. The abundance of cheap labor and the traditional silk-spinning industry of northern Italy made Milan a natural hub of the emerging textile industry being fostered by the new machine age. Robert Whitehead set up a consulting engineering business in this new center of the cotton trade, and, because of the high esteem that British engineering expertise enjoyed, he had no shortage of customers.

He concentrated on the new textile industry, and in a short time he was doing a thriving business designing and inventing new textile machinery. Whitehead prudently protected his inventions by registering them with the patent office in Vienna (Milan was within the borders of the Austrian Empire). The patents covered machines designed for the Milan weaving industry and would, in time, yield a comfortable royalty income. Although Whitehead's future looked decidedly encouraging, there were dark clouds on the political horizon that would ultimately destroy Robert Whitehead's consulting engineering business.

By 1848, a rising tide of nationalism was feeding the fires of revolution throughout Europe, and there were ominous rumblings throughout the Hapsburg Empire. Rumors of riots and rebellions trickled throughout northern Italy. On March 17, 1848, Metternich (Austrian Minister of Foreign Affairs) fled from Vienna in the face of a threatened revolution. The following day, the people of Milan rose against their Austrian oppressors, and, to the surprise of all concerned, the citizens of Milan defeated General Radetzky (Austrian Field Marshal) and his 20,000 troops. All of Italy was caught up in revolution; for Whitehead, this popular surge of Italian nationalism meant disaster.

The newly formed provisional government promptly decreed that all patents issued by the previous Austrian regime were invalid. Since Whitehead's patents were his major asset and source of income, this decision essentially put him out of business. In addition, the fierce street fighting in Milan placed him and his young wife Frances in personal danger. With the birth of their first son, James (who died in infancy), and Frances pregnant with a second child, it became essential for them to find a more secure area in which to settle. Even though Austria temporarily regained control of Milan, it was apparent that northern Italy would continue to be a battlefield as the struggle for unification continued.

A return to England was considered, but his older brother William, engaged in a series of civil engineering projects along the Adriatic coast, encouraged Robert to explore employment opportunities at the various shipyards and engineering companies that were springing up along the coast. Before leaving northern Italy, Robert had one final opportunity to demonstrate his engineering skills when he undertook the task of designing and supervising the building and installation of the pumping

machinery to drain the vast Lombardy marshes. Whitehead's pumps proved to be ideally suited for the task, and the success of this task further increased his stature and reputation as an engineer.

On completion of the drainage project, Whitehead moved his family to Trieste on the Adriatic coast, where he had obtained an appointment, as a Constructor, with the well-known shipbuilding company of Austria Lloyd. His reputation as an engineer continued to grow; within a short time, he was approached by Stabilimento Strudthoff, the leading marine engineering firm on the Adriatic coast, and offered the position of Technical Director. This was a major accomplishment for a young man only 26 years old, and he accepted without hesitation. The next few years were happy and productive as Robert Whitehead's stature as an engineer continued to grow. In 1849, the Whiteheads were blessed with their first daughter; their second daughter, Alice, was born in 1851; and their second son, John, was born in 1854. Strudthoff continued to offer Whitehead the challenge that his restless genius needed, and his professional reputation continued to grow.

In the early 1850s, he designed and built a number of units for the Austrian Navy, and his reputation received a further boost in 1854 when he designed his first screw propulsion system. Two years later, in 1856, Whitehead designed and built the first cylindrical marine boiler to be produced in the Austrian Empire, which clearly demonstrated that his theoretical expertise was fully equal to his demonstrated practical expertise. The design and stress calculations were difficult theoretical tasks that Robert Whitehead had to master to build a cylindrical boiler.

Although only a little over 30 years of age, Whitehead was attracting considerable attention in marine engineering circles. He was held in high esteem as a design engineer and enjoyed the reputation of being scrupulously fair and honest. He was receiving an ample salary from Strudthoff, but he yearned for more responsibility and independent authority to select his own tasks. In 1856, a new engineering firm, Stabilimento Tecnico Fiumano (STF), located a few miles up the coast at Fiume, offered him the position of manager at their new facility. Since this position involved independent management of the engineering works, it strongly appealed to Whitehead, and he accepted with very little hesitation.

The men financing STF were both influential and well connected, and they were instrumental in obtaining attractive contracts from the Imperial Navy Office in Vienna. The initial contracts were for minor engineering projects such as winches and donkey engines. Whitehead's outstanding engineering ability was quickly recognized, and STF started getting major contracts for marine steam propulsion systems. Whitehead established a solid reputation as the designer and builder of functional, well-engineered marine power plants that were extremely reliable and trouble-free in operation.

As manager, he had unquestioned control of all engineering work at STF, and he thrived on the responsibilities that he was charged with. The Whiteheads moved into a residence named "Casa Rossa" that was located right on the grounds of STF and overlooked the front gate. This allowed Whitehead to dedicate himself totally to the job; it was not uncommon to see him out in the factory in his shirt sleeves showing a machinist how a job should be done or to find him working into the wee hours of the morning to revise drawings or prepare new designs. On July 21, 1858, another son, James Beethom, was born, and 4-year old John was showing signs of inheriting his father's

engineering ability. Known to the family as Jack, young John was drawn to the factory like a magnet, and he could usually be found in the machine shop where he was trying to assist the machinists with their work. Robert Whitehead had achieved success in his career and in his family; the future beckoned brightly for him.

Although he was unaware of them, storm clouds were again gathering in Europe as Italy, and Germany moved relentlessly toward national unification. In 1859, Italy, allied with Napoleon III, had recovered the province of Lombardy, and it appeared highly likely that further conflict would follow as Italy tried to take Venetia, with its major seaport, Venice, away from the Austrians.

Faced with the prospects of a naval war in the Adriatic, Austria had an urgent need for a strong fleet to defend its short but vulnerable coastline. The Italian Navy was the second most powerful navy (the French had the largest fleet) in the Mediterranean. Austria's only hope of retaining the important port of Venice was to build a strong navy to counter the Italian threat. The key question was Austria's ability to match Italy's naval strength before war broke out. The resulting naval race brought Whitehead and STF an important project that would have major impact on his future. The Austrian Government approved the construction of a revolutionary new armor-plated screw-driven warship, SMS *Erzherzog Ferdinand Max*, named for the *Archduke Ferdinand Maximilian*. More commonly known as the *Ferdinand Max*, she was to be the flagship of the new Austrian fleet, and the contract for the design and construction of her steam propulsion system was awarded to Robert Whitehead and Stabilimento Tecnico Fiumano.

Warship designs underwent revolutionary changes during the middle decades of the 19th century. The classic three-decker ships of the line had become extremely vulnerable as solid shot gave way to new shells filled with explosives. The wooden ships offered little protection against the explosive shells, and the adaptation of armor and ironclad hulls was a direct reaction to the threat posed by the new shells. There were also struggles taking place between supporters of wooden ships and proponents of iron ships, between sail power and steam power, between paddle wheel advocates and screw propeller enthusiasts, and those who favored massive broadsides with the old smooth-bore guns and those who favored the use of one or two large-caliber breech-loading rifled guns located in rotating armored turrets.

Although it was a revolutionary period, the changes were actually painfully slow evolutions because of the traditionally conservative nature of senior naval officers. A benchmark in this change was the battle of Sinope in November 1853, when the Russian fleet, using new explosive shells, completely wiped out the Turkish wooden-walled ships. This battle convinced even the ultra-traditional British that a revolution in naval armaments was underway, and the rest of the European powers were quick to start building new steam-powered armored warships.

Robert Whitehead, with his contract for the *Ferdinand Max*'s power plant, was in the mainstream of this revolutionary period, and his well-engineered conservative designs were to win him a well-deserved reputation as a leading designer of marine power plants. The Whitehead-designed 800-hp power plant gave the 5000-ton *Ferdinand Max* a credible 11-knot speed and proved to be reliable and trouble-free. The simple, proven power plants he designed for the Austrian Navy did much to enhance his reputation and that of STF.

Sometime prior to 1860, an officer of the Austrian Marine Artillery had designed a small boat that, when loaded with explosives, could be used to attack warships engaged in close-in blockades. The concept was never developed beyond the drawing board stage, but, when the officer died, his papers came into the possession of a retired Austrian Navy officer—Fregattenkapitän Giovanni de Luppis. Being retired, De Luppis devoted his leisure time to improving this fascinating concept. He spent many months improving the original drawings, and finally he built a scale model. The wooden scale model was powered by a clockwork motor that drove a screw-type propeller in the stern. A large rudder, located behind the propeller, was controlled by an observer on shore by manipulating tiller ropes to steer the model toward the intended target. The gunpowder charge stored in the hull was detonated by means of a percussion cap in the bow that was activated upon collision with the target ship.

De Luppis experimented with and modified *Der Kustenbrander* (the coastal fireship) until he was satisfied with its operation and then presented himself and the model to the naval authorities in Vienna. The experts were not overly impressed with *Der Kustenbrander* and advised De Luppis that they considered it unworkable because of the slow speed, awkward steering system, and ineffective propulsion system. However, they did agree that the basic concept had potential and recommended that De Luppis work with a consulting engineer to further develop the concept. The retired Fregattenkapitän was living in a villa on the Adriatic coast; with his lively interest in naval affairs, he was well acquainted with the reputation of the English engineer Robert Whitehead who managed the Stabilimento Tecnico Fiumano facilities. He lost no time in seeking a meeting with Whitehead to explore the possibility of a cooperative effort to further develop the concept.

Robert Whitehead met Giovanni de Luppis sometime in 1864 and was immediately intrigued by the possibilities of the device. However, he could also see that the concept had serious shortcomings. It would be a challenge to his ingenuity, and he felt compelled to take up the invitation. With De Luppis's help, Whitehead built a full-scale working model, and they proceeded to test it in the bay facing the STF factory. The engine proved to be unreliable, and the maze of tiller lines, usually operated with great enthusiasm by De Luppis, was not suitable for accurate navigation. The experiments confirmed the fears expressed by the naval experts: the craft was ridiculously slow, and the range, on the rare occasions the tiller lines worked, was woefully short.

However, Whitehead continued to think that the device contained the basis of a workable concept and undertook redesigns of the motor power and the steering gear to improve its performance. Every modification brought fresh frustrations; finally, after months of work, Whitehead was forced to admit that the basic concept was flawed. Running on the surface at slow speeds made *Der Kustenbrander* hopelessly vulnerable since it could be sunk easily by the rapid fire guns installed on the new warships. Whitehead reluctantly informed De Luppis that he considered the concept unworkable, and the short-lived partnership was terminated.

Even after he stopped working on the project, the concept continued to intrigue Whitehead, and he found himself working on the problem subconsciously, always looking for the key idea that could transform it into a successful weapon concept. It was fast becoming Robert Whitehead's magnificent obsession.

Chapter 5

BIRTH OF THE TORPEDO

Still intrigued by the idea of an unmanned weapon that could sink a ship, Robert Whitehead found it difficult to concentrate on his main tasks, and his subconscious mind continued to address the problem of how such a weapon might be built. He continued to sketch various configurations and to examine new concepts in an effort to find the ingredients for a successful weapon. While working on the steam propulsion system for the *Ferdinand Max*, Whitehead had become aware that it was fitted out with a bow ram designed to hole enemy vessels below the waterline. The ancient ram, when added to the new armored steam-powered screw-driven warships provided a potent weapon system. Being an engineer, Whitehead was quick to appreciate that the most efficient way to destroy a ship was to hole it below the waterline so that it would fill with water and sink: clearly, any new weapon would be more effective if the explosive charge detonated below the waterline.

Once the concept of an underwater detonation was in place, it logically followed that, if the weapon traveled under water during the attack, it would be essentially invisible and extremely difficult to counter. The main drawback of *Der Kustenbrander* had been its vulnerability due to its slow speed and exposure to crippling fire from rapid-firing guns during its surface approach to the target vessel. Robert Whitehead conceived a self-propelled (automobile) torpedo that would travel under water to the target and impact the target below the waterline to inflict maximum damage. Such a weapon would be invisible, and, with its underwater explosive charge, it would also pose a major threat to surface vessels. The concept was brilliant, but the theory, technology, and engineering knowledge to build such a weapon were nonexistent. The magnitude of the engineering challenges involved made the problems encountered with *Der Kustenbrander* seem trivial by comparison.

Once Whitehead made the decision to undertake the torpedo project, his energy was totally devoted to the effort. He selected a small but secure corner of the factory and locked himself away to work on his new weapon. His son John, then 12 years of age, and a single trusted mechanic represented the total workforce for the secret undertaking. The design of a sophisticated weapon such as the torpedo, with its numerous and complicated subsystems, requires extensive theoretical and practical knowledge in a number of very diverse technical areas. Normally, it would require a team of engineers and scientists with expertise in propulsion, hydrodynamics, warheads and exploders, guidance and control systems, and structural hull design to design a torpedo.

For one man to undertake such a task by himself would require genius of a high order. Robert Whitehead's undertaking is all the more awesome when one considers that much of the theory required to support the design evolution (hydrodynamic coefficients, drag calculations, control system stability, servomechanisms, etc.) did not exist and would not reach maturity until almost a 100 years later. He was a pioneering genius who entered into uncharted and unexplored regions of engineering science, overcame all manner of technical problems, and created a new weapon that revolutionized naval warfare. Robert Whitehead's long and difficult quest to develop an automobile torpedo was truly a masterful demonstration of artisan genius; the theory didn't exist, but he experimented, tested, and modified each component until he achieved success.

The difficulties were manifold, but, one by one, Whitehead tackled the design of the exploder, the power plant, and the high-pressure air tank; slowly, but surely, the strange new weapon began to take shape. The resulting weapon was given the generic name of all underwater devices and called a torpedo. During its early years, it was generally referred to as an “automobile torpedo” to denote that it was a self-propelled weapon or a “fish torpedo” since it looked somewhat like a fish and traveled under water.

Although Whitehead had the concept clearly in mind, the translation from concept to physical reality took 2 long years of dedicated effort in an isolated workshop as he struggled to perfect his torpedo. He was totally devoted to the task and pursued it with dedication and relentless effort. As if to confirm Whitehead’s title as the father of the torpedo, the original handmade torpedo was always affectionately referred to in the Whitehead family as “the baby.”

But while he was isolated in his workshop laboring to build his infant torpedo, the clouds of war were again gathering over Austria as Prussia’s Chancellor, Bismarck, pursued his plan to crush the Hapsburg Empire in order to make Prussia the undisputed head of the new German Empire. The war between Prussia and Austria erupted on June 14, 1866, and Italy, seeing an opportunity to claim Venice, joined the Prussians and declared war against Austria a few days later. The climax of the Austro-Italian conflict was the battle of Lissa on July 20, 1866; it was the first large-scale sea battle between ironclads. On paper, the Austrian fleet was vastly outclassed by the larger, better-equipped Italian fleet. Austria’s two new warships, *Ferdinand Max* and *Hapsburg*, did not have their rifled guns because Krupp had intentionally defaulted on their delivery just before hostilities started. Consequently, the Austrians had to use old smooth-bore cannons to equip their new armored warships. The Austrians, with their seven ironclads, could deliver a total broadside of 1,776 pounds, while the Italians, with their twelve ironclads mounting 208 rifled guns, could deliver a total broadside of 20,392 pounds. With a 10 to 1 advantage in broadside weight, it was assumed that the Italians would utterly destroy the Austrian fleet.

However, the Austrians had one major advantage in that their commander-in-chief, Konteradmiral Wilhelm von Tegetthoff, was a highly experienced and successful combat officer. This was somewhat of a rarity in a period in which most naval officers had never heard a gun fired in anger. He had served in the force that had blockaded Venice in 1848, in several Black Sea battles during the Crimean War, and, as a kommodore, he had commanded a steam frigate in spirited action against the Danish fleet in 1864 during the Schleswig-Holstein affair. Konteradmiral Tegetthoff recognized that he was at a decided disadvantage in terms of firepower and made the decision that ramming would be his primary tactic. The use of rams on armored steam-powered warships was a relatively untried tactical maneuver, but it was a potentially powerful one if the armor effectively protected the ships as they closed to ram the enemy. The larger Italian fleet, commanded by Admiral Count Persano, a mediocre leader with a preference for shore duty, had to be ordered to sail against the enemy, and, even then, Admiral Persano balked at a direct attack on Venice. The two fleets met near the Island of Lissa off the Dalmatian coast as the Italians finally moved against the Austrians.

Tegetthoff, in the spirit of Nelson at Trafalgar, aggressively attacked the Italian line when he saw a gap forming between the Italian 1st and 2nd Divisions. From the *Ferdinand Max*’s halyards, the signal flags directed the Austrian fleet: “Ironclads will ram and sink the enemy.” As the Austrian

fleet approached the Italian line, the Austrian ships took enormous punishment because the Italian fleet was passing directly across the bow of the Austrian fleet. Essentially, the Italians were crossing the “T” and enjoyed the advantage of concentrated firepower during the approach. However, once the Austrians broke the Italian line, the battle turned into a melee as the Austrians executed their ramming tactic.

Tegetthoff’s flagship, the *Ferdinand Max*, rammed and damaged two Italian ships, the *Re d’Italia* and the *Palestro*, during the initial attack, causing considerable damage. Tegetthoff initiated a second attack against the damaged *Re d’Italia*, and Whitehead’s steam engines were called on to demonstrate their maximum capabilities as full power was applied for a second ramming. Whitehead’s engines never faltered as the *Ferdinand Max* leapt forward and sunk her ram deep into the bowels of the *Re d’Italia*. With full power applied by the *Ferdinand Max*, the Italian ironclad heeled over under the force of the ram; as the engines were reversed, the *Ferdinand Max* slid smoothly clear, and the *Re d’Italia* sank like a stone.

The Italians were utterly demoralized by the aggressive Austrian onslaught; when the two fleets drew apart, Admiral Tegetthoff reformed his battle line so that his ships separated the enemy ships from the island of Lissa. Admiral Persano re-formed his original line-ahead formation, turned tail, and sailed back to harbor without trying to reengage the weaker Austrian fleet.

The Austrians had won a tremendous victory, with three Italian ironclads sunk and three more severely damaged. Persano was disgraced and dismissed from the Italian Navy while Tegetthoff received a hero’s welcome, was promoted to Vizadmiral, and was showered with medals and honors. Since the Austrian army was defeated by the Prussians and Austria had to sue for peace, the battle of Lissa was the only bright spot for the Austrians in the Austro-Prussian War: Admiral Tegetthoff was a national hero.

Shortly after the battle, Admiral Tegetthoff sent a telegram to Robert Whitehead at STF that thanked him for his first-class engines and stated that they were the key to his successful battle. When the newspapers got hold of the story, Whitehead suddenly became famous, and, a few weeks later, Emperor Franz Josef personally thanked Whitehead and presented him with a diamond ring. The battle of Lissa, being the first battle between ironclad fleets, attracted considerable attention, and it was generally held that the ram, when attached to an armored steam-powered vessel, was the ultimate weapon. However, Whitehead’s long hours of effort in his secret workshop were paying off, and a major new naval weapon was about to see the light of day.

Exact details of the first Whitehead torpedo have never been revealed. The original prototype torpedo was lost during sea trials in 1866, and Whitehead, who believed strongly in the value of design secrecy, chose never to release any information about his first torpedo. Additionally, Whitehead, as a result of his bitter experience in Milan, had lost faith in patents and refused to disclose details of his weapons to anyone unless they were willing to pay for them. However, some details can be deduced from information published concerning the Austrian Navy trials conducted in December of 1866.

The torpedo, shaped somewhat like a fish, was about 12 feet long with a maximum diameter of 14 inches. The nose section contained a contact detonator and 18 pounds of explosives. The shell

was fitted with two vertical fins that ran the length of the body. These fins provided stability and kept the torpedo from rolling or spinning. Small adjustable trim tabs located behind the propeller served as rudders to provide reproducible azimuth control. A simple hydrostatic valve was used to sample depth pressure, and the valve activated an elevator linkage to hold the torpedo at a preset depth. The main body of the torpedo was made from wrought iron boiler plate and weighed approximately 300 pounds.

Immediately behind the warhead was the air flask that held air compressed to 370 pounds per square inch (psi) to provide the propulsive energy to power the unique rotary engine that Whitehead had designed for his torpedo. Whitehead also designed an ingenious air regulator valve that supplied the rotary engine with reduced-pressure air to ensure a constant and reproducible torpedo speed. Both the regulator and the compressed-air motor represented superb mechanical design solutions to some of the difficult problems that had to be mastered to build a practical automobile torpedo. The torpedo was fitted with a single twin-bladed propeller running at approximately 100 revolutions per minute (rpm). The propeller was located inside a stationary shroud, with the rudder tabs located behind the shrouded propeller. All controls were set by trial and error. The complete weapon had a 200-yard range at a speed of 6 knots, or, by reducing the speed, the range could be extended to over 300 yards.

Although it was a major engineering accomplishment, Whitehead's first torpedo was by no means perfect, and it frequently failed to maintain its preset depth when tested in the harbor in front of the plant. Sometimes it would skim along on the surface, and other times it would dive right to the bottom and get stuck in the mud. Had it not been for his sudden fame as the designer of the *Ferdinand Max's* power plant, Whitehead would have, in all probability, continued to work on and perfect his beloved torpedo.

However, when the Austrian Government decided to give Whitehead an award for the design of the *Ferdinand Max's* power plant, he suddenly had a once-in-a-lifetime opportunity to meet key Austrian Government and naval leaders, and he could not pass up the golden opportunity to tell them about the new weapon that he was developing. The Austrian Navy was quick to realize the potential of such a weapon, and, in December 1866, Whitehead was asked to submit his torpedo for official trials. The trials were impressive, but the erratic depth-keeping made it apparent that the weapon was not yet ready to be issued to the Imperial Navy. The Austrians thought the weapon had great potential but needed further improvements in the depth control. Whitehead, well aware of the depth control problem, was neither surprised nor disappointed by the decision, and he returned to Fiume to work on the depth-keeping problem.

Some of the decisions Whitehead made in designing the original torpedo attest to the natural genius he had for intuitively selecting the best design solution for his torpedo problems. It took another 100 years and untold millions of dollars for theory to mature to the point where it was possible to design torpedoes analytically and predict their performance. With this modern technology, it is possible to define analytically the contribution of a stationary shroud and to show the significant benefits of placing the control surfaces behind the propellers.

Yet Whitehead seemed to intuitively sense the optimum solution and execute it without the benefit of computers and a large staff of specialists. The torpedo itself provides an elegant testimonial to Whitehead's genius; a modern torpedo still bears an amazing resemblance to the primitive weapon he conceived over 100 years ago. In spite of 100 years of development, it is still basically the same. When one examines the massive evolutionary design changes that have occurred in ships, automobiles, and airplanes as they were steadily improved and compares this trend with the minor changes that have occurred in torpedo designs, the comparison clearly indicates that Robert Whitehead's original torpedo was the work of an artisan genius.

However, even geniuses have occasional problems, and, in spite of additional modifications, and further testing in the Adriatic, the torpedo depth performance continued to be erratic. Even so, the Austrian Navy remained very much interested in the torpedo and again the following year requested further trials. It was obvious that the admirals had an unusual interest in the new weapon, but again the erratic depth keeping tempered their enthusiasm. Once again, Whitehead returned to his secret workshop at STF to wrestle with the depth problem.

As 1867 passed into 1868, the solution to the erratic depth control continued to elude Whitehead, and, since there was no theory or technical information in existence to support his work, he had to struggle on alone, trying to find a solution. By this time, he had been working on his torpedo for almost 4 years, and at times he became frustrated and despondent because the solution to the depth problem continued to elude him. In fact, at one point he seriously considered giving up any further work on the torpedo and concentrating his energies on marine power plants again. However, two events occurred in the spring of 1869 that gave him new energy. First, the Emperor, in recognition of his contribution to Austrian engineering, made him a baron, and he was also awarded the Order of Franz Josef for a prize winning exhibit at the Paris Exhibition. Second, the Austrian Navy was again pressing for another series of torpedo trials.

Whitehead's close professional relationship with the Austrian Navy during this period led to a personal relationship that was to have a major impact on his life. His daughter Alice fell in love with a handsome young Austrian naval officer, Kapitänleutnant Count Georg Hoyos. He was a veteran of the Battle of Lissa and also a skilled engineer with a patented design for a pneumatically operated life saving device. Kapitänleutnant Hoyos was in love with Alice, and he also, with his naval engineering background, got along famously with his future father-in-law. In fact, he later resigned from the Austrian Navy and became Whitehead's trusted chief assistant in the torpedo business. In later years, when Robert Whitehead returned to England and went into semiretirement as a country gentleman at Paddockhurst, Count Georg Hoyos took over the day-to-day operation of Whitehead's lucrative torpedo business. He was an extremely competent engineer and businessman.

Frustrated in his effort to perfect the depth control system, Whitehead turned his attention to the design of a launcher for his torpedo. He felt strongly, for reasons of coyness, that the torpedo should be launched under water. In a short period of time, he designed an underwater launcher consisting of a tube, mounted below the waterline, with doors at each end. By closing the outer door, water was kept out of the tube, and a torpedo could be loaded into the dry tube through the inner, or breech, door. With the torpedo loaded, the breech door was closed, and the outer door was opened to

flood the tube with seawater. A charge of compressed air impulsed the torpedo out of the tube, and a guide stud kept the torpedo straight and level as it exited.

Finally, the tube had a special air valve to blow out the water in the tube before opening the inner door to load the next torpedo. Again, it is a tribute to Whitehead's engineering that the tube he designed has stood the test of time with essentially no major changes in form or function. It was a remarkable piece of original engineering design that became the accepted standard for reloadable submerged torpedo tubes and is still in common use today.

Unfortunately, the brilliant engineering applied to the launcher design failed to solve the persistent depth-keeping problem. Whitehead had incorporated various improvements to his torpedoes since the last trials, including a new one-piece air flask that could be charged to 1200 psi. Also, the speed had been increased to 11 knots. The design of the launcher and modifications to the torpedoes took considerable time, and the trials did not start until October of 1868. Whitehead produced two different models of the weapon for evaluation—one with a 14-inch diameter and one with a 16-inch diameter. Again, poor depth performance was the major problem. About 50% of the torpedoes fired passed beneath the target vessel anchored 700 yards downrange, but only 16% of the torpedoes were at the correct depth to hit the target. So, Whitehead was again facing failure because of erratic depth-keeping. It seemed hopeless, but Whitehead asked for a 3-week delay to carry out further adjustments.

The depth problem was a source of great frustration, and Whitehead labored day and night, hoping for a miracle. Whitehead's miracle is reported to have come in the form of an inspiration one night while he was tossing and turning in his bed. Whitehead immediately named his new depth-keeping system "The Secret," and it remained a closely guarded secret for many years. In fact, The Secret became the main bargaining point in his contractual negotiations with foreign navies. Only a very limited number of selected torpedo specialists were told how The Secret functioned, and they were sworn to secrecy.

The Secret was in reality a simple modification made to the existing hydrostatic valve used for depth control. In the original torpedo, a spring-loaded hydrostatic valve was supposed to control depth. The spring was preset for the desired operating depth. If the torpedo exceeded the preset depth, the increased pressure on the hydrostatic valve compressed the spring and, through the attached control linkages, gave an up-elevator signal that would cause the torpedo to rise to a shallower depth. If the torpedo were shallower than the preset depth, the spring would overcome the hydrostatic valve, causing the linkage to reverse direction and give a down-elevator signal so that the torpedo would go deeper. This was a simple undamped "bang-bang" (on-off) control system, which was both unstable and temperamental, as the torpedo's erratic depth performance had demonstrated.

Whitehead's inspiration was to incorporate a pendulum into the depth mechanism to sense and control the attitude of the torpedo and to provide much-needed damping for the existing unstable system. The pendulum was connected to the elevator control linkages; when it detected a change in torpedo attitude, it would apply an opposite elevator signal to correct it. Thus, if the pendulum sensed that the torpedo had an up or positive angle (torpedo heading for the surface), it would send a

down elevator signal to correct the angle. This simple modification provided much-needed damping, and the depth trajectory became extremely stable, with the depth error reduced to ± 6 inches.

The modified depth control system known as The Secret is another remarkable tribute to Whitehead's engineering skill and genius. Control system design is a 20th-century technology. Whitehead did not know about body coefficients, stability, servo-mechanisms, or system response time, yet he managed to understand the problem and come up with a workable solution even though the theory to support his design solution would not be available for another 70 years. The fact that his primitive torpedo depth control concept remained in use right up through World War II and was good enough to sink thousands of ships demonstrates Whitehead's rare engineering talent.

When the trials were resumed, the Austrians gave the modified torpedo high praise. They were much impressed with the torpedo's improved performance, and the naval committee recommended the purchase of Whitehead torpedoes. In fact, if the Austrian treasury had not been drained dry by the Seven Weeks' War (the Austro-Prussian War), the Austrian Government would have purchased the exclusive rights to the Whitehead torpedo. However, bowing to fiscal reality, they signed a nonexclusive contract with Robert Whitehead, which left him free to sell his torpedo to any other nation prepared to pay the asking price. At the time, it was rumored that the Austrians paid Whitehead approximately £20,000 for nonexclusive rights to the torpedo.

Whitehead immediately began to solicit other governments; he wrote personal letters to all the leading European naval powers, the United States, and various other foreign powers in a quest for new orders. Unfortunately, since the word "torpedo" was a generic term used to describe many different explosive weapons, Mr. Whitehead's announcement of a "new" torpedo did not generate much interest in the international marketplace, particularly given the £20,000 price tag. Although his initial attempt to solicit foreign buyers yielded no immediate results, news of the first successful automobile torpedo was soon widespread in naval circles, and curiosity about the weapon was building.

In 1868, the Commander of the British Mediterranean Fleet, Vice Admiral Lord Clarence Paget, and the British Ambassador, Lord Bloomfield, visited Fiume and witnessed a series of torpedo trials that Whitehead conducted for the benefit of foreign visitors. Admiral Paget was impressed with the new weapon and recommended that the British Government send an official to negotiate with Whitehead. In September 1869, the U.S. frigate *Franklin*, flying the flag of Rear Admiral Radford, visited Trieste, and the Admiral took a special side trip to Fiume to learn about torpedoes. The Americans learned all they could about the automobile torpedo but balked at Whitehead's £20,000 price tag.

Also in 1869, at the British Admiralty's request, a team of gunnery experts from the British Mediterranean Fleet evaluated the torpedo and enthusiastically endorsed the new weapon. Based on this enthusiastic report, the British Admiralty decided to invite Whitehead to England to participate in a series of trials. The increased interest shown by the Royal Navy was a positive sign for Whitehead. If the world's greatest navy was interested, there was little doubt that other navies, large and small, would develop a sudden interest in Whitehead's torpedoes, and that would be good for business.

The highly successful British trials were completed in October 1870, and, in April 1871, Whitehead signed a contract with the Royal Navy under which he received £15,000 plus trial expenses of £2,500 in exchange for a nonexclusive right to build the fish torpedo in England and the right to purchase models directly from the factory in Fiume. The British took immediate steps to build their own version of the fish torpedo in the Royal Laboratory at Woolwich Arsenal. The first British torpedo, the 16-inch Mark 1 RL, broke fresh ground since it included some impressive innovations, such as the first counter-rotating propeller.

Under the mutual exchange agreement between Whitehead and the Royal Navy, Whitehead was informed of all British improvements, and some of them were incorporated into the torpedoes being produced at Fiume. Also during this period, both Whitehead and the British designed new torpedo engines. After evaluating both engines the British three-cylinder radial engine, designed and built by the firm of Peter Brotherhood, became the standard torpedo engine; Brotherhood radial engines were powering torpedoes right up through World War II.

Once Whitehead had secured the British torpedo contract, he was reasonably sure that other nations would fall in line. Thus, when STF went bankrupt because of the lack of Austrian Navy contracts, Whitehead took a gamble and sought financing to purchase the factory at Fiume. Whitehead purchased the premises from STF and set up his own torpedo business *Silurificio Whitehead*. Within a short period of time, the French had signed a contract similar to the British. In 1873, Germany and Italy signed major contracts for Whitehead torpedoes, and a host of other countries (Russia, Holland, Spain, Norway, etc.) began queuing up to purchase Whitehead torpedoes. By the mid-1870s, Robert Whitehead's gamble in setting up *Silurificio Whitehead* had paid off handsomely, and he had become a wealthy man from selling torpedoes to all the major naval powers.

By the late 1870s, Whitehead was financially independent, and his lifestyle changed accordingly. He began to purchase investment properties to diversify his wealth and began spending more and more time back in England. He had two private Pullman railroad cars that he used to transport the family when he went on holiday, and he began shopping for a suitable British estate. He first purchased Springfield House at Midhurst; shortly thereafter, he purchased a huge 3,000-acre estate at Worth called Paddockhurst.

Paddockhurst was a magnificent estate with a huge Tudor house, and Whitehead thoroughly enjoyed the life of a country gentleman. With the passing of time, his son-in-law Georg Hoyos took over the operation of the torpedo business, and his son John became the Technical Director of the Austrian plant. Paddockhurst became the elder Whitehead's obsession, and he proceeded to spend a fortune to improve and maintain the huge estate. The years spent at Paddockhurst were happy ones, but the estate cost a fortune to operate. Whitehead grew concerned about these costs, particularly since there was no return on the investment, and he finally decided to sell and move to a smaller place at Beckett Park. Although Whitehead enjoyed the life of a country gentleman, he still had a strong interest in his torpedo business and continued to actively participate in the design of the new models that were periodically introduced. In fact, at 80 years of age, he was still producing design layouts for new torpedoes that were produced by his company.

In spite of his wealth and success, Whitehead's accomplishments were never formally recognized by the British Government. Early in his career, he had been made a Baron of the Austrian Empire, and he received the Legion of Honor from the French and numerous other prestigious decorations from the Prussian, Danish, Italian, Greek, Portuguese, and Turkish Governments. Yet, his mother country continued to withhold recognition for his contributions to the Royal Navy. It is reported that Whitehead was very sensitive about the fact that he was ignored by his own government and that he very much wanted formal British recognition for his accomplishments.

Whitehead, being an engineer who was not schooled in the rules of diplomacy, had committed a major error in protocol when, as an English citizen, he failed to obtain Queen Victoria's permission before accepting the Austrian title of baron. This reportedly angered the Queen, and, although Robert Whitehead lived a long life, so did Queen Victoria: he never received an English title from his Queen. It is also suggested that, deep down, the Royal Navy resented Whitehead's torpedo; there was little enthusiasm for recognizing his accomplishment by awarding him any official recognition for inventing a weapon that threatened the very existence of the Royal Navy. Whitehead acquired great wealth and was decorated by most of the great powers, but the British Government steadfastly ignored him, never giving him any formal honors for his accomplishments.

Chapter 6

THE COMPETITORS AND THEIR PRODUCTS

By 1870, when the British trials were conducted, the Whitehead automobile torpedo had become common knowledge in international naval circles, and there was widespread interest in this new weapon. Within a very short period of time, most of the major world powers had journeyed to Fiume to place their orders for torpedoes, and Silurificio Whitehead was doing a lucrative business. Whitehead, still bitter about the earlier loss of patents in Milan, refused to patent his new torpedo design. This meant information was available only to those who paid hard cash and took an oath not to reveal the secret.

Consequently, there was worldwide interest in the new weapon but very little detailed information available about how it was built. Whitehead had a monopoly on the torpedo business, and he was doing extremely well financially. Foreign governments and private entrepreneurs were interested in getting into the business, and, in the last three decades of the 19th century, all manner and types of torpedoes were built and evaluated.

The Biblical phrase that “many are called but few are chosen” could be aptly applied to torpedoes. It would take a complete book just to describe in any detail all of the torpedoes that were designed and/or built during this colorful era. These torpedoes, incorporating all types of fascinating technological innovations, provided a number of weapons that were truly ingenious and innovative, some of which included advanced design concepts. However, of the score or more torpedoes that were built and tested, only three or four were ever produced in quantity, and none of them ever seriously challenged Whitehead’s leadership role.

The self-propelled torpedo was a new weapon concept, and there were many different opinions about how it should be designed and used. This led to some unusual, even wild, torpedo concepts and confusing, sometimes contradictory, terminology to describe the various types of torpedoes. A torpedo that could not be steered by the firing vessel was called an uncontrolled torpedo, and, if the firing platform could give steering commands to the torpedo during its run, it was called a controlled torpedo. If the torpedo ran completely beneath the surface of the water with its own depth control, it was generally called a fish torpedo. A torpedo suspended from a buoy that ran on the surface was generally called a semi-submerged type, and torpedoes that ran at or near the surface but dove underneath the target to explode were called dirigible torpedoes.

If the prime mover and energy source were both in the torpedo, it was called an automobile type, and, if the propulsion energy were external to the torpedo (an electric torpedo powered over a wire link from a generator), it was called a locomotive torpedo. To confuse matters even further, not all authors used the same definitions, and one author’s semi-submerged torpedo might be another author’s dirigible torpedo. If the definitions were applied to Mr. Whitehead’s weapon, it could be called an uncontrolled automobile torpedo.

The Whitehead concept of an uncontrolled fish-type automobile torpedo seemed to attract the greatest interest, and most of the other torpedoes that were produced in quantities fell into this

general class. Perhaps the greatest challenge to the Whitehead torpedo was the Schwartzkopff torpedo (or Blackhead torpedo) manufactured by the Berlin machine works Berliner Maschinenbau. There is a story that, while the German engineer Louis Schwartzkopff, the owner of Berliner Maschinenbau, was a houseguest of the Whiteheads at Casa Rossa for discussion of business ventures, someone broke into Whitehead's office and stole a complete set of plans for his torpedo.

It was unthinkable to suspect a respected business associate like Schwartzkopff of such an act, so Whitehead and his son-in-law Georg Hoyos strongly suspected that the Russians or the U.S. Navy had stolen the plans. However, within a year of the theft, Schwartzkopff was offering his own automobile torpedo for sale. The torpedo was an almost identical copy of the Whitehead weapon except that it was made of phosphor bronze, a secret material developed by Schwartzkopff. Phosphor bronze did not rust: for a weapon that was frequently immersed in saltwater, this was a very appealing advantage, particularly for smaller nations that did not have highly trained personnel to continuously maintain their torpedoes. It appears that, in this instance, Whitehead's lack of faith in patents cost him dearly; he had no patent for his torpedo and therefore no legal recourse.

The phosphor-bronze Schwartzkopff torpedo cost almost 50% more than the iron Whitehead torpedoes, but a number of countries, including China, Russia, Japan, and Spain, purchased them. They were sold in substantial numbers, and they were the only other early torpedo to be used in actual combat to sink an enemy ship. Strangely enough, the German Navy continued to purchase Whitehead torpedoes for another 5 years; it was not until 1879 that the Schwartzkopff torpedo saw service in the Imperial German Navy. During the Spanish-American War, the U.S. Navy captured a number of Spanish Schwartzkopff torpedoes. After the war, the phosphor-bronze torpedo shells were used as decorative light poles at the fleet landing in Newport, Rhode Island, and, for the next 40 years, the U.S. Navy had maintenance-free light poles that neither rusted nor corroded, thanks to Louis Schwartzkopff.

The U.S. Navy became interested in the Whitehead torpedo shortly after Admiral Radford's 1869 visit to the STF factory in Fiume. Admiral Radford was very impressed with the Whitehead torpedo and strongly recommended that the U.S. Navy acquire such a weapon. A detailed report of the visit, which described the torpedo in considerable detail, was prepared by LCDR Marvin who had accompanied Admiral Radford on the visit, and this report was sent to Admiral Porter at naval headquarters in Washington. Admiral Porter in turn forwarded the report to the new U.S. Naval Torpedo Station, which had been founded in the summer of 1869 in Newport, Rhode Island, and requested that they "examine carefully into this subject and ascertain if torpedoes of this plan cannot be gotten us."

In 1871, the Naval Torpedo Station began working on a torpedo that bore a striking physical resemblance to Whitehead's weapon. Since the U.S. Navy did not have access to specific engineering details, particularly how the secret depth control system operated, Lieutenant Commander Matthews, Commanding Officer of the Naval Torpedo Station and the designer of the U.S. Navy's first self-propelled torpedo, had to start from scratch to build the Navy's first automobile torpedo. A number of experimental runs were made with the Torpedo Station's first torpedo during the period from 1871 to 1873, and at least one major redesign was undertaken to improve the depth and propulsion performance. The Torpedo Station's fish torpedo had depth control problems and, at

best, merely represented an attempt to duplicate Whitehead's concept. When Commander Matthews was transferred to a new duty station in 1874, further development effort was terminated, and the fish torpedo became a museum showpiece as the U.S. became involved in evaluating the new torpedo concepts that were being generated by U.S. inventors.

During this same timeframe (1869–1871), Lieutenant John Adams Howell conceived a unique torpedo that was powered by a large flywheel that was spun up to a high speed by an external power source prior to launching the torpedo. The kinetic energy, or inertia, stored in the rotating flywheel was then used to drive the torpedo through the water. In 1871, he was awarded U.S. Patent Number 121,052 for his flywheel propulsion system. The same patent application also claimed invention of the use of the flywheel as a gyroscope to control the torpedo's directional accuracy, but this significant claim was disallowed by the patent examiner.

For the next 20 years, Lieutenant Howell successfully pursued two separate, but related, careers—as a full-time career naval officer and as the engineer who designed and developed the Howell torpedo. He was eminently successful in both careers. As a naval officer, he had a distinguished career that included combat duty during the Civil War, head of the navigation department at the Naval Academy, Commanding Officer of USS *Adams*, and, finally, as Rear Admiral Howell, Commander in Chief of the North Atlantic Fleet. As a military inventor, in the early 1870s, he built a series of experimental flywheel-powered torpedoes and conducted extensive trials to develop his concept. His early models included one that incorporated a centrifugal pump as the propulsor. The pump sucked water in through holes in the torpedo shell, and, as it pumped the water out through a hole in the rear, thrust was produced. This was surely the first jet-propelled torpedo.

Howell experienced a host of problems in developing such a radical new concept, and he devoted whatever time he could spare to conducting tests and incorporating refinements into the design. By 1883, Howell had firmed up a design that incorporated a 112-pound flywheel operating at 10,000 rpm that drove the torpedo, through two variable-pitch propellers mounted side by side in the afterbody, approximately 400 yards. The torpedo also included an ingenious arrangement that used the flywheel inertia to steer the torpedo and keep it on a straight course during its run to the target.

In 1887, Congress appropriated funds for torpedoes and directed the Secretary of the Navy to solicit proposals for torpedoes and to conduct trials to evaluate any promising torpedo concepts. In early 1883, the Navy's Bureau of Ordnance prepared a qualified bidders list and solicited proposals for torpedoes that were to be evaluated at the Navy Yard in Norfolk, Virginia. The two most qualified bidders (Whitehead and Schwartzkopff) did not submit bids because they did not want to bring their torpedoes to the United States for evaluation. Captain Howell and two other concerns submitted proposals for torpedoes.

The three inventors then had to appear before the Navy Torpedo Board and undergo a self-financed demonstration and evaluation of their torpedoes. Asa Weeks and The American Torpedo Company, the other two competitors, both presented rocket-powered surface torpedoes while Howell presented his flywheel-powered fish torpedo for evaluation. In the spring of 1884, the Torpedo Board rejected the two rocket torpedoes and recommended that three of the new Howell torpedoes be

built by the Washington Navy Yard for additional evaluations. Two of the three new model torpedoes sank on their first run because of leaks, and, since the flywheel torpedo was wakeless, it was extremely difficult to tell exactly where they had gone down. Fortunately, they were finally recovered, the leaks were repaired, and a very successful test program was conducted.

The Howell torpedo was subsequently selected for service use by the U.S. Navy and ultimately became the U.S. Navy's first operational automobile torpedo when it was installed on battleships in the early 1890s. In 1888, Captain Howell sold his patent rights to the Hotchkiss Ordnance Company, and production of the Howell Mark 1 torpedo was started in their Providence, Rhode Island, plant. The Howell Mark 1 was 14.2 inches in diameter, slightly over 11 feet long, and carried a 100-pound warhead. It was powered by a 132-pound flywheel spun up to 10,000 rpm, which drove the torpedo 400 yards at 25 knots with a maximum range of 700 yards at reduced speed. The Howell was used on both battleships and torpedo boats and remained in use until the turn of the century when it was replaced by new higher-performance Whitehead torpedoes. The Howell torpedo with its wakeless propulsion system and directional stability was a formidable weapon in its day. There are still a few of the Hotchkiss-manufactured brass Howell torpedoes on display in naval museums, and they are outstanding examples of the superb craftsmanship of American artisans in the late 19th century.

Two other interesting uncontrolled fish torpedoes were the Hall and the Peck models. Both used superheated steam stored in an insulated flask to provide propulsion energy. Because the steam contained more energy than cold compressed air, these torpedoes tended to have better performance than a similar air-powered Whitehead. However, there had to be a ready source of high-pressure steam available to fill the flask, and the torpedo had to be fired before the steam cooled down. The design of hot gas versions of the basic Whitehead torpedo provided similar dramatic increases in performance, and, because the Whitehead variants did not require an external steam source, they quickly became the accepted concept.

Finally, the Paulson fish torpedo is of interest because of its unique propulsion and navigation subsystems. The torpedo used compressed carbonic acid as an energy source. The hot gases were discharged into an ejector where they reacted with seawater, and the ejector then functioned as a jet propulsor to move the torpedo through the water. To keep the torpedo on course, a magnetic compass was hooked up to the steering system. If the torpedo strayed off its preset course, the compass needle would come in contact with a stud and activate a steer command to bring the torpedo back on course.

Rockets seemed to fascinate early torpedo designers, and there were rocket torpedoes of all sizes and types. None of them ever reached operational status, and they all seemed to share some common traits in that they tended to be very erratic, sometimes spectacular, and on occasion downright dangerous to all involved. During the Civil War, Major Hunter, of the U.S. Army Engineers Corps, designed an underwater rocket gun and rocket torpedo. The gun, located several feet below the surface of the water, fired a three-foot-long projectile containing a warhead and a pyrotechnic rocket charge to propel it. Major Hunter conducted a number of successful tests in New York Harbor, but, unfortunately, he became the victim of his own torpedo when one of them malfunctioned and blew him up instead of the target.

A decade later, Lieutenant F. M. Barber, stationed at the U.S. Naval Torpedo Station, designed another rocket torpedo to be fired from a submerged tube. The Barber torpedo was 7 feet long and 1 foot in diameter, and it contained a 48-pound warhead and 51 pounds of rocket propellant. It incorporated some innovative concepts, including a spiraled outer casing so that the torpedo would be spin stabilized as it went through the water as well as a trim tank that filled with water during the run to compensate for the loss of weight as the propellant burned. In spite of these features, the Barber torpedo demonstrated a totally uncontrolled trajectory; further work was discontinued because of its unpredictable and erratic behavior.

There were also numerous surface or semi-submerged rocket torpedoes, including the Ericsson rocket torpedo, the Weeks rocket torpedo designed by Asa Weeks, and The American Torpedo Company's rocket torpedo. The latter two rocket torpedoes both competed against the Howell torpedo in U.S. Navy trials. The Berdan dirigible torpedo, a refinement of the Callender torpedo patented in 1862, was a novel weapon incorporating some innovative technical and tactical concepts in its design. The propulsion system consisted of 12 (6-inch) rockets in three rows of 4 rockets each. The rockets were fired in sequential order, and the gases were directed through a nozzle to spin a geared turbine wheel that in turn drove the propeller shaft. The Berdan was not a true rocket torpedo, but it was the first torpedo to be powered by a solid-propellant propulsion system. Again, the performance was erratic with speeds varying between 24 and 43 knots during a single run.

The Berdan dirigible torpedo, a product of the 1880s, was designed to be used against anchored ships that were protected by massive armored torpedo nets designed to keep conventional torpedoes from hitting the side of a ship. The Berdan was really two torpedoes connected in tandem by a tow line. The lead torpedo was the slightly faster of the two so that the tow line was always taut during the run. The rear torpedo was equipped with a preset diving elevator that was inactive as long as the tow line was taut. When the lead torpedo hit the torpedo net and exploded, the tow line went slack, which caused the second torpedo to dive under the net until the line became taut again and caused it to rise again and explode against the bottom of the ship. It all sounds very impressive but information on how well this concept actually worked is lacking.

In the early 1890s, Patrick Cunningham of New Bedford, Massachusetts, designed still another submerged-launch, rocket-powered torpedo and submitted it to the U.S. Navy for testing. During 1893–1894, the Cunningham torpedo was evaluated at the U.S. Naval Torpedo Station in Newport. Although the torpedo incorporated spiral ribs on the outer case to spin stabilize it as it went through the water, like its predecessors, it was sadly lacking in directional stability, and everyone and everything in the area, including the firing vessel, was placed in jeopardy when one was fired.

Mr. Cunningham also used his torpedo to demonstrate that versatile rocket-powered propulsion systems could operate in any medium (under water, in the atmosphere, or in a vacuum). On July 4, 1897, after reportedly celebrating the holiday with a generous supply of good Irish whiskey, Cunningham rolled one of his torpedoes out into the street in front of his house and lit it off. The torpedo roared off down the street, panicking horses and scattering pedestrians. It finally scored a direct hit on a butcher shop, where it demolished the chopping block and embedded itself in the icebox, which it set on fire. Mr. Cunningham demonstrated that a rocket-powered weapon had amphibious potential and that its performance tended to be erratic in both media.

Many of the early torpedo designers thought that, if the energy to drive the torpedo could be supplied from an external source, the performance of the torpedo could be significantly improved because it would be possible to provide an essentially unlimited energy supply from a large ship or shore-based power source. Where the energy source was external to the weapons, they were generally called locomotive torpedoes. Since this type of torpedo had to be tied to the firing platform with some type of umbilical connection to provide the energy, most of the locomotive torpedoes also included a scheme to transmit steering commands, so they were also, by definition, controlled torpedoes. One example of the more interesting locomotive torpedoes was the Ericsson torpedo built, in the early 1870s, by John Ericsson, famous designer of the Civil War warship, the *Monitor*.

The Ericsson torpedo was powered by compressed air fed to it through a rubber hose that unreeled as the torpedo moved through the water. Extensive tests were conducted in Long Island Sound, during which numerous modifications were incorporated, and, finally, a second completely new torpedo was built. However, the bulky air hose, combined with the pressure drop over the length of the hose, severely limited both range and speed; the Ericsson torpedo, with a speed of only 3 to 4 knots, never became a serious contender.

The Sims-Edison torpedo was one of a number of electric-powered torpedoes that were powered by a generator or dynamo located on the firing platform. The wire was carried in the torpedo on a spool that unwound as the torpedo went through the water. The Sims-Edison torpedo had a speed of 10.5 knots. There were two configurations with different cable lengths—1 or 2 miles. This torpedo underwent extensive testing by the U.S. Army Torpedo Facility, also known as the Engineer School of Application, at Willets Point, New York Harbor. General Abbot, who commanded the Willets Point torpedo facility for almost a decade, was very impressed with the Sims-Edison torpedo as a harbor defense weapon. However, he thought that a higher speed was needed to make it effective.

Across the ocean, the British Government purchased the Brennan torpedo, patented in 1877, for a very large amount of money for use as a harbor defense weapon. The Brennan torpedo was unique among locomotive torpedoes in that it was wire powered—not electrically powered over a wire but actually powered by pulling on wires attached to the torpedo to make it go through the water. The torpedo contained two spools with almost 6 miles of 18-gauge piano wire wound on each of them; each of the spools was connected through suitable gearing to a propeller. The end of the wire was attached to a power-driven capstan onshore. When the capstan reeled in the wire off the torpedo spools, the propellers spun as the wire was stripped off the spools. With 6 miles of wire wound on the torpedo spool, the torpedo had a range of approximately 1½ miles.

The Brennan torpedo was considered quite a novelty because the faster the wire was reeled in, the faster the torpedo ran in the opposite direction. The Brennan torpedo had a speed slightly under 20 knots, and it could be given lateral steering commands by varying the tension between the two wires being reeled in. A substantial number of Brennan torpedoes were procured and placed at key locations in harbors and rivers along the English coast for use as harbor defense weapons. There is no record that the Brennan torpedo was ever fired in anger, but it does highlight the fact that Captain Giovanni di Luppis's original concept of a harbor defense weapon did become an operational reality.

Early torpedoes tended to be temperamental and at times unpredictable, and there were endless tales of erratic torpedoes hitting the wrong target or threatening the vessel that fired them. It is easy to understand why many naval professionals had strong reservations about firing uncontrolled torpedoes, particularly if their firing platforms had been attacked by one of their own torpedoes in an exercise and they couldn't shut it down or steer it away. Consequently, there were a lot of advocates of controlled torpedoes, who held strongly to the opinion that the torpedo should be under direct control of the firing platform right up to the time of target impact. The designers of early torpedoes were sensitive to this issue, and the table below identifies some of the controlled torpedoes developed during the early years.

Controlled Torpedoes

Name	Class	Type	Year
Sims-Edison	Locomotive	Electric	1877
Foster	Locomotive	Electric	1872
Nordenfelt	Automotive	Electric	1880s
Von Scheliha	Automotive	Compressed air	1871
Lay	Automotive	Carbonic acid	1872
Lay-Haight	Automotive	Carbonic acid	1881
Patrick	Automotive	Carbonic acid	1880s
Berdan	Automotive	Rocket/turbine	1880s
Brennan	Locomotive	Cable	1877
Maxim	Locomotive	Cable	1885
Ericsson	Locomotive	Compressed air	1873
Smith	Automotive	Carbonic acid	1872

These torpedoes came in all shapes and sizes, and some of the controlled torpedoes designed for use as harbor defense weapons were over 40 feet long and weighed several tons. Most of the controlled torpedoes utilized electrical signals over a wire link to steer them, although there were exceptions, such as the cable steering on the Brennan and the compressed-air steering commands for the Ericsson. John L. Lay, who built his first self-propelled torpedo in 1871, is a classic example of a 19th-century international entrepreneur who made efforts to sell weapons to any and all nations. Lay was a prolific inventor, with a tendency to design complex devices that were best operated by a person with at least three arms and six hands. As an engineering officer in the U.S. Navy during the Civil War, he had designed a spar torpedo that was successfully used to sink the Confederate ironclad *Albatross* in 1864. However, the weapon was so complicated that the operator, Lieutenant William Cushing, had to bite on the firing lanyard and pull it with his teeth to fire the explosive charge.

The Lay torpedoes were semi-submerged automobile torpedoes that traveled at speeds between 8 and 10 knots. They were powered by carbonic acid (the first chemical torpedoes!) and had a wire link to the firing platform over which electrical steering commands were sent. The surface float had a flag at each end; the flags were used by the observer to steer the torpedo visually and cause it to

collide with the intended target. At night, the flags were replaced with hooded lights that could be seen only from the rear, so that the torpedo could be steered in the dark.

The first Lay torpedo was built by Clute & Company of Schenectady, New York, in 1870 and taken to Egypt, where it was demonstrated and purchased by the Egyptian Government in January 1871. The second Lay torpedo, built in 1872, was purchased by the U.S. Navy for evaluation at the Naval Torpedo Station in Newport. For the next two decades, Lay traveled all over the world, to Egypt, China, Europe, South America, and Russia, demonstrating and selling various models of the Lay torpedo. It appears that most of his later torpedoes that were sold to foreign countries were manufactured by the Pratt & Whitney Company of Hartford, Connecticut, and that total production was probably less than 50 torpedoes.

The Russians purchased a number of Lay torpedoes with the manufacturing rights and used them for many years as harbor defense weapons; in fact, there are some references that even mention a Russian factory that produced Lay torpedoes for the Russian Government. Evidently, Lay achieved a high degree of skill in operating his controlled torpedoes and put on very impressive demonstrations to show potential customers how effectively they could be used against maneuvering targets.

However, the only Lay torpedo fired to sink an enemy ship showed the control feature to be more of a curse than a blessing. During a war between Chile and Peru in 1880, a Lay torpedo was fired by the Peruvian ship *Huáscar* at a Chilean ironclad. About halfway through the run, the torpedo turned around and headed back toward the *Huáscar*. Self-destruction was averted only when an officer jumped overboard and, at great personal risk, deflected the torpedo away from the ship. This incident raised some valid concerns about the value of controlled torpedoes when in the hands of poorly trained operators.

There is no way that all of the early torpedoes can be covered in a single chapter; undoubtedly some interesting torpedo concepts have been overlooked or neglected. However, one cannot help but be impressed both by the quantity and the quality of the early inventors that strove to improve on Whitehead's initial concept of an automobile torpedo. Many of these men, such as Ericsson, Edison, Nordenfelt, and Maxim, were world class inventors, and some of the manufacturers, such as Pratt & Whitney and Hotchkiss, were producers of high-quality ordnance. It is a tribute to Robert Whitehead that, against competition of this caliber, he was able to maintain his dominant role in the torpedo business. While the competitors were hard at work trying to break into the torpedo business, great naval theoreticians were also hard at work determining how the torpedo should be used to conduct naval warfare.

Chapter 7

THE EARLY YEARS

The torpedo as originally conceived by Whitehead was primarily a defensive weapon to be used in harbor defense or to deter enemy ships from conducting close blockades. Giovanni de Luppis's *Der Kustenbrander*, which provided the inspiration for the torpedo, was a coastal defense weapon, and Whitehead directed most of his early effort toward a covert weapon system that could be used for such defensive missions. From the limited information available, it appears that the Austrian Navy torpedo trials, conducted in 1868, evaluated the torpedo's effectiveness in such defensive roles.

The automobile torpedo was a totally new type of weapon; consequently, tactical doctrine on weapon employment did not even exist. Naval professionals were "concerned" that the torpedo would have a major impact on naval warfare, but there was little in the way of hard information examining how a torpedo actually could be used in time of war. When the Austrian Navy decided to purchase Whitehead torpedoes but declined the offer to purchase exclusive rights to the weapon, Whitehead automatically assumed a very powerful position in the international arms market. He had sold his torpedo to a major naval power, and he was the sole source available to other nations interested in acquiring automobile torpedoes. The British, as the world's leading naval power, were acutely aware of, and concerned about, the potential threat that Whitehead's torpedo posed. Since they had the world's largest navy, the British had the most to lose if the torpedo did revolutionize naval warfare.

Once the Austrians purchased Whitehead torpedoes and the French expressed a strong interest, the British navy could not risk ignoring this new weapon any longer. Vice Admiral Paget and Ambassador Bloomfield visited the STF facility at Fiume in 1868, and, after witnessing some torpedo trials, recommended that the British start negotiating with Whitehead to purchase torpedoes. In 1869, gunnery experts from the British Mediterranean Fleet witnessed more tests at Fiume and enthusiastically endorsed the new weapon. Finally, in 1870, the British invited Whitehead to bring his torpedoes to England for official Royal Navy trials.

The Trials Committee, consisting of Captain Arthur, chairman, Captain Singer, and Lieutenant Wilson, recording secretary, met Whitehead and his son-in-law, Count Hoyos, at Chatham where final arrangements for the trials were made. Whitehead directed the installation of an underwater torpedo tube in HMS *Oberon*, a paddle wheel steamer provided for the trials, and final preparations for the actual trials were made. The Royal Navy, and the Trials Committee, wanted to conduct a detailed examination of the torpedo, but Whitehead, because he had not patented his invention, would not permit any examination of its working parts until a contract had been signed. Understandably, Whitehead's desire for secrecy created a stressful relationship because each party was somewhat suspicious of the others intentions.

The actual trials, which went on for several months, consisted of about 30 runs with the 14-inch torpedo, and a 16-inch weapon was also evaluated in the final phase. During the trials, the Committee continued to press for an examination of the torpedo whenever a problem occurred, and Whitehead

steadfastly refused to allow them to examine his “secret.” The extensive Royal Navy trials were a severe test of Whitehead’s technical and business skills, and his hardheaded, businesslike approach finally won out. In fact, Lieutenant Wilson, the junior member of the committee, in later years became a close personal friend of Whitehead when he became the head of the Royal Navy, as Admiral of the Fleet, Sir Arthur Wilson, VC. In spite of a number of minor problems during the trials, and seemingly endless requests for additional special tests, the Trials Committee finally turned in a favorable endorsement and recommended that the Royal Navy purchase the Whitehead torpedo.

A final series of tests was required, allegedly to demonstrate that the torpedo could in fact sink a ship. However, this goal was subject to question because the *ex-Aigile*, a wooden corvette selected as the target, was protected by a special net 80 feet long and 12 feet deep, which suggested that the British had a stronger interest in examining how their precious warships could be protected against torpedo attacks. Obviously, since the British had the largest navy, they had the most to lose if the torpedo proved to be an effective ship killer, and they had a vital interest in learning how to defend their ships from this new weapon.

The *ex-Aigile* was moored in 20 feet of water with the torpedo net in place, and the firing ship, HMS *Oberon*, fired a 16-inch warshot torpedo at the target from a range of slightly over 100 yards. Unfortunately, the tide running across the range deflected the torpedo, and it just missed the edge of the net and exploded against the starboard quarter of the target. The *ex-Aigile* promptly sank, thereby winning the dubious honor of being the first ship ever sunk by a torpedo. Later examination revealed that the torpedo had struck the target 18 feet from the stern post and had blown a 10- by 20-foot hole in its side. Additional warshot tests were conducted against the defensive net, but these were an anticlimax. The fact that a torpedo had blown a hole in the *ex-Aigile* that was big enough to drive a carriage through firmly convinced the Royal Navy that the torpedo was a weapon that had to be taken seriously. The Royal Navy negotiated for both the purchase of Whitehead torpedoes and the right to manufacture them in a Royal Navy facility. By 1872, the Royal Arsenal, Woolwich, was producing Whitehead torpedoes, and the Royal Navy was hard at work learning how to defend itself from torpedo attacks and how best to employ the new weapon.

Early torpedoes had a depth control system (Whitehead’s secret) to keep the weapon at a preset depth, but they were truly uncontrolled projectiles because there was no mechanism to control course or heading. New torpedoes underwent proofing tests during which adjustments were made to the rudders and other controls until the torpedo passed a proof specification. Since each torpedo was a separate entity, performance varied widely because of manufacturing variations (propellers, control surfaces, body shape, air regulator, etc.), and the proofing process was essential to achieve a common performance envelope.

It was particularly important that the course and speed be accurately calibrated, and known, since these variables were used to calculate the impact point of the torpedo when it was fired. The British were quick to recognize this idiosyncrasy and provided a logbook for every torpedo to provide a permanent record of each torpedo’s performance during its operational life. This administrative procedure, combined with extensive torpedo exercises, quickly made the Royal Navy extremely proficient in firing torpedoes. The development even reached a point where individual torpedoes had nicknames and ships had favorite torpedoes used only in competitive exercises against other ships.

The British started out by modifying some of their existing ships to carry Whitehead torpedoes, and, in some cases, they provided large ships with special launches equipped to launch torpedoes. By the mid-1870s, the torpedo was influencing both offensive and defensive tactical thinking, and, in turn, this was reflected in ship designs. The *Inflexible*, laid down in 1874, was the first British battleship designed to use torpedoes: it had two deck-mounted torpedo batteries and two submerged tubes in the bow. It also had two 60-foot steam launches, carried on deck, equipped to launch torpedoes. Obviously, it didn't take long for the torpedo to impact ship designs, and this was only the tip of the iceberg.

One of the more interesting facets of the torpedo's early evolution is that it shows how active the military-industrial complex already was in the 19th century and how the industrialists had a strong interest in foreign military sales (FMS) profits, even at the expense of compromising the Royal Navy's effectiveness. A number of British shipbuilders, including John Thornycroft, Alfred Yarrow, Samuel White, and Armstrong and Laird of Birkenhead, undertook the design of small torpedo boats. The first torpedo boats used spar or towed torpedoes, but, when the Whitehead fish torpedo became available, it was quickly wedded to these small launches. The combination provided a very effective weapons system.

Georg Hoyos, Whitehead's son-in-law, was appalled at the abusive treatment the delicate torpedoes received when they were fired from the torpedo boat's above-water tubes, and Whitehead protested that his torpedoes were not designed to be fired out of cannons. However, the torpedoes survived the abuse, and torpedo boats became hot sellers in the FMS market. Thornycroft, Yarrow, and White sold hundreds of torpedo boats to foreign navies all over the world, including Austria, Greece, Russia, Italy, Chile, and France. A number of countries, such as France, purchased them in large numbers with the specific idea that they could be used effectively against the British navy in narrow seas such as the English Channel. These British shipbuilders did a lucrative FMS business selling torpedo boats, but this business threatened the supremacy of the British Royal Navy because they were willing to sell the torpedo boats to anyone who could pay the price, even if the buyer planned to use them against the British.

The proliferation of torpedo boats posed a serious problem for the Royal Navy because the sheer weight of numbers posed a significant threat to their vulnerable capital ships. The Whitehead torpedo presented the Royal Navy with a two-sided problem. They had to learn to effectively use this new weapon offensively to maintain their position of naval supremacy, and, at the same time, they had to invest heavily in torpedo defensive systems to protect their large fleet of ships from torpedo attacks.

The first Royal Navy ship designed and built specifically to employ the Whitehead torpedo was the 260-ton *Vesuvius* launched in 1874. This strange ship carried 10 torpedoes and was designed to use the torpedo as a stealth weapon by sneaking up on the enemy undetected to launch a salvo of torpedoes. It was powered by a Maudslay steam engine and employed a unique boiler that burned coke instead of coal to provide steam. The coke boiler did not require a tall stack to provide draft and did not generate the large amount of smoke that tended to make ships easily detectable at great distances. The coke fumes were exhausted through flush vents located along the side of the ship at

deck level, and provisions were made to seal up the engine room during an attack to reduce the risk of engine noise alerting the enemy.

The *Vesuvius*, with its inefficient coke boiler, could make only 9 knots, and this was slower than most of her intended victims. Unfortunately, if you can't catch them, you can't torpedo them, and the *Vesuvius* joined a multitude of other ships built during this transitional period as a one-of-a-kind experiment that didn't pan out. The stealth concept was sound, but, unfortunately, the technology to make it work was not in hand. Three decades later, covert torpedo attacks were tried again, using submarines, and the concept revolutionized naval warfare.

The first torpedo boats that British shipbuilders sold to foreign navies in the early 1870s were simply small steam launches modified to carry torpedoes. They had very limited endurance, and their small size made them dangerous to operate in open seas. Many of them only were only 50 to 60 feet long, with a displacement of 15 to 20 tons. Torpedo boats became very popular; soon all of the major naval powers, along with most of the smaller navies, were adding torpedo boats to their naval arsenals. The U.S. Navy went to the Herreshoff shipbuilding company in Bristol, Rhode Island, and, in the British style, had some steam launches built for use as torpedo boats.

Most of these early torpedo boats were simply small wooden steam yachts modified to carry two or more torpedoes. Their speeds were between 12 and 18 knots, they had no armor for protection, and the helmsman was fully exposed during an attack. These small craft took brutal punishment when operating in rough seas, and the crews of these early boats led a thankless existence trying to survive both hostile seas and the massive firepower of enemy battleships. Truly, this represented a case of "wooden ships and iron men."

The Royal Navy had tended to ignore torpedo boats until the rising public alarm over the expansion of rival European fleets forced the Admiralty, in 1877, to purchase its first torpedo boat from Thornycroft. The *Lightning*, displacing 27 tons, was 84 feet long, and its 460-hp steam engine gave it a speed of 19 knots. Originally designed to use a spar torpedo, it was converted to fire Whitehead torpedoes from above-water tubes in 1879. The *Lightning* provided a design base for the evolution of an ever-growing family of Royal Navy torpedo boats during the 1880s. As the new torpedo boats became available, they were incorporated into major fleet exercises to develop tactical doctrine and to evaluate the effectiveness of existing torpedo defense systems.

During the fleet exercises, the junior officers who operated the torpedo boats experienced much frustration because the senior officers who served as umpires found endless reasons why the hits claimed by the torpedo boats should be disallowed. The senior officers were all battleship sailors, and the Royal Navy was not particularly interested in proving that their mighty fleet was vulnerable to torpedo boat attacks. However, the exercises did show that the cumbersome nets used for protection were of limited value and that they severely restricted ship maneuverability. This concerned the British, who examined various alternatives to improve fleet defenses against torpedo attacks. Across the channel, the French were conducting similar fleet exercises, and the French umpires saw things differently, giving the torpedo boats high marks for their successful attacks against fleet units. Although it was the same game, when the British played it, the capital ships won,

and, when the French played it, the torpedo boats won. The question was what the outcome would be in a real war.

To counter the torpedo boat threat, the Royal Navy began to experiment with small gun boats called “catchers” to accompany the fleet and to defend against torpedo boat attacks. The first of these, the *Rattlesnake*, participated in fleet exercises in 1877. Unfortunately, as was so often the case, the *Rattlesnake* had been designed to counter the existing operational torpedo boats; by the time it was designed and built, a new generation of higher-performance torpedo boats had evolved. The *Rattlesnake* just didn’t have the speed to catch the new torpedo boats, and this led to a follow-on class of bigger and faster catchers. For shipbuilders such as Yarrow and Thornycroft, the 1880s and 1890s were the golden years. First, they sold torpedo boats; then, they sold catchers to counter the torpedo boats; then, they made and sold larger and faster torpedo boats; then, they made and sold larger and faster catchers. It seemed to be an endless cycle of making annual improvements and conducting fleet exercises to evaluate the latest designs.

The torpedo boats were eventually broken down into two classes. Second-class torpedo boats, generally under 60 feet in length, were designed to be carried aboard major warships and launched for use only when combat was imminent. First-class torpedo boats were larger craft designed to operate as independent fleet units. By the early 1890s, they had grown to over 140 feet long, displaced 130 tons, and were frequently called torpedo cruisers. The larger and faster catchers built to counter the first-class torpedo boats were then called torpedo destroyers because they were designed to sink torpedo boats. The torpedo destroyers continued to grow in size, and their performance steadily improved; with torpedo tubes added, they combined the best features of both the torpedo catcher and the torpedo cruiser in a single hull. A new class of small multipurpose combatants began to evolve. These vessels incorporated both offensive and defensive capabilities in an effective way with a balanced combination of guns, torpedoes, speed, and seaworthiness; they were the forerunners of modern destroyers.

The first Royal Navy destroyers, the *Havock* and *Hornet*, participated in the 1894 fleet exercises and stood up well under the very adverse conditions encountered in the Bay of Biscay. By 1897, the *Birkenhead*-class of 30-knot destroyers had grown to a length of 213 feet, displaced 300 tons, and had a radius of action of over 3,500 miles. These destroyers, equipped with a 12-pounder quick-firing gun, torpedo tubes, and five 6-pounder quick-firing guns, provided the fleet with both a defense against torpedo attacks and the offensive ability to conduct torpedo attacks at any time under any conditions. The new destroyers provided the fleet with significant new capabilities, and major changes in tactical doctrine soon evolved to exploit the potential of these versatile small combatants because they had the ability to sink the largest ships afloat during major fleet engagements. Although the lowly torpedo had yet to prove itself as a major weapon in battle, it was the dominant influence in the evolution of a major new class of warships, and, in turn, this led to major changes in naval strategies and the redesign of other major combatants.

The tremendous destructive power of a single torpedo warhead, when it exploded below the waterline, threatened even the largest warships, and this threat forced marine architects to initiate extensive redesigns of capital ships to improve survivability against torpedo attacks. This led to extensive compartmentation to isolate the damage, redundant subsystems to enhance survivability,

armored sides below the waterline, double bottoms, and improved damage control techniques, including controlled flooding to maintain stability after a hit. There is no doubt that these extensive design efforts had a positive impact on the overall survivability of new ships because the improvements increased the ship's ability to survive damage from collisions, groundings, or any other marine catastrophe. Much of this technology, particularly the compartmentation, was also incorporated into commercial ship designs to improve their survivability. Unfortunately, as the Titanic was to later demonstrate, although these features significantly improved survivability, there was no guarantee that a ship was unsinkable. Archimedes' principle was still valid: if enough water got into the ship, it would sink. Since torpedoes were designed to make large holes below the waterline, ships remained uniquely vulnerable to torpedo attacks in spite of the extensive measures taken to increase their survivability.

During the early years of its existence, there were surprisingly few cases of the torpedo being used in combat. The first case of a torpedo being fired in combat occurred in 1877 during one of the frequent South American revolutions. Insurgent Peruvian forces had captured the Peruvian armored turret warship *Huáscar* while it was anchored in the port of Callao. The *Huáscar*, built in 1865 by Laird of Birkenhead, was an 1,100-ton armored ship with a reinforced bow for ramming and two 11-inch guns mounted in a turret. At the time, it was one of the most powerful warships in South America. The rebels began to bombard various Peruvian ports, sparing them only if they paid a ransom. Within a few weeks, the rebels also began to attack foreign merchant ships; these attacks were considered outright acts of piracy.

The Peruvian Government disclaimed all responsibility for the actions of the *Huáscar*, so the Royal Navy's Pacific squadron, under the command of Admiral de Horsey, was given the task of hunting down the *Huáscar*. The flagship of the Pacific squadron, the fast steam-powered frigate *Shah*, was not an armored ship, but it had been recently retrofitted with the new Whitehead torpedoes, deck tubes, and second-class torpedo launches. On May 29, 1877, Admiral de Horsey finally located the *Huáscar* anchored in the port of Ilo. He immediately demanded her surrender for acts of piracy against British ships. Since the *Huáscar* was armored and had larger-caliber guns than the *Shah*, the rebel captain decided to fight it out.

The resulting battle was somewhat of a standoff. The *Huáscar*, attempting to exploit its shallower draft, stayed close to the shore, while the faster British warships steamed back and forth, shelling the *Huáscar*. The British gunnery was far superior, but this advantage was offset by the fact that *Shah's* 7- and 9-inch shells just bounced off the *Huáscar's* armor plating. Out of 70 hits registered, only one shell actually penetrated the hull. As sunset approached, the *Huáscar* built up speed and started to head directly toward the *Shah*. Evidently, the insurgents had heard about Admiral Tegetthoff's victory at Lissa and they intended to use their ram to sink the *Shah*. As the *Huáscar* approached the *Shah*, the British captain played his ace card and ordered a Whitehead torpedo to be fired at the approaching ship.

Royal Navy legend claims that the weapons officer on the *Shah* was appalled at the idea of using such an ungentlemanly weapon and requested a written order to fire the torpedo. In any case, when the torpedo was fired, the *Huáscar's* captain lost his nerve and turned tail back toward Ilo. The torpedo failed to hit the *Huáscar*. Some claimed that it wasn't fast enough to catch the retreating

ship. However, the firing of a single torpedo caused the enemy to abort an attempted ramming and break off the engagement. Later that evening, the *Shah* sent a launch, armed with a Whitehead and a spar torpedo, into the port of Ilo to attack the insurgents. In the interim, the rebels had slipped away through shoal water, and they surrendered to the Peruvian Navy at Iquique on the following day. The first torpedo fired in anger had failed to sink a ship, but this action showed that the new weapon got people's attention when it was employed.

Meanwhile, back in Europe, the Balkan powder keg was on the verge of exploding again as Russia and Turkey each claimed sovereignty over the Balkan Peninsula. The Russians declared war on Turkey in April 1877, and the Tsar's army crossed the Danube and pushed south into the Balkan Peninsula. Most of the early part of the war was devoted to this major land campaign and the siege of Plevna. On the naval front, the Turkish Navy had a powerful fleet of 15 ironclads in the Black Sea. The Russians had only the two weird circular floating forts designed by Admiral Popov, and these unwieldy monstrosities proved to be next to useless. The Russians immediately dispatched their agents to scurry around buying ships and weapons wherever they could find them. Their purchases included torpedo boats along with spar torpedoes, Harvey torpedoes, Lay torpedoes, Whitehead torpedoes, and just about anything else that was for sale. Some torpedo boat attacks were made against the Turkish ironclads operating on the Danube during June 1877. Both spar and Harvey torpedoes were used, and a Turkish ironclad was sunk by a spar torpedo during one attack. Because the spar torpedoes had to be used at point-blank range, the Russians had to pay a high price to achieve success, and their torpedo boats took an awful mauling every time they conducted an attack. The Russians modified some of their boats to carry Whitehead torpedoes and began to use these torpedo boats to conduct covert night attacks against the Turkish ships anchored in the harbor at Batum.

The first torpedo boat attack using Whitehead torpedoes was a total failure both for the Russians and for Robert Whitehead. The Russian torpedo boats *Tchesma* and *Sinope*, in total darkness, penetrated the roadstead at Batum, and each fired a Whitehead torpedo, from a range of approximately 60 yards, at the anchored ironclad *Mahmoudieh*. Both torpedoes missed the target. One hit a submerged rock and broke up; the other one ended up high and dry on the beach, where the Turks recovered it the next day. This particular torpedo gave Whitehead a bad case of heartburn. Since the Turkish had captured it from the Russians, they were under no obligation to respect the pledge of secrecy that Whitehead required all buyers to sign. Further, since Whitehead did not have a patent for his torpedo, the Turkish were free to copy the design if they so chose. Whitehead engaged in some delicate negotiations with the Turkish Government, and, before matters were straightened out, the Turkish got some torpedoes at bargain basement prices. This incident finally convinced Whitehead, much to the relief of his son-in-law Georg Hoyos, that he should patent the torpedo so that the designs would be protected.

The Russians conducted a second attack against the port of Batum on January 25, 1878; if one believes the Russian account of this attack, this date marks the first sinking of an enemy ship by a torpedo in combat. The torpedo boats *Tchesma* and *Sinope* again started to sneak into the roadstead at Batum, where the revenue ship *Intikbah* was acting as a guard ship stationed at the entrance to the harbor. From a range of 80 yards, both boats fired a Whitehead torpedo at the guard ship. Both

torpedoes scored direct hits, and, 2 minutes later, the mortally wounded *Intikbah* disappeared beneath the surface. Since the Turkish Naval staff refused to acknowledge the sinking of the *Intikbah*, there is some disagreement among naval historians as to whether the *Intikbah* really deserves the distinction of being listed as the first ship sunk by a Whitehead torpedo. Like so many wartime actions, the conflicting claims make it difficult to determine what actually happened, and it is unlikely that the truth will be established conclusively at this late date.

The next naval action involving the use of a torpedo occurred during the war between Peru and Chile that began in 1879. In this action, as mentioned earlier in the description of the Lay torpedo, the *Huáscar* again played a major role. This time, the *Huáscar*, serving as the flagship of the Peruvian Navy and outfitted with Lay torpedoes, qualified as a torpedo-firing ship rather than as a target for torpedoes. A number of spirited actions took place between the Peruvian and Chilean warships, and, in one of these actions, the *Huáscar* rammed and sank the Chilean warship *Esmeralda*.

On August 27, the *Huáscar* caught up with the Chilean corvette *Abato* and fired a Lay torpedo at the corvette rather than attempting to ram it. Unfortunately, the wire-controlled Lay torpedo malfunctioned, turned 180°, and headed back toward the *Huáscar*. The *Huáscar* won the dubious honor of being the first ship to experience being attacked by its own torpedo. Fortunately, a quick-thinking officer jumped into the water and, at great personal risk, deflected the torpedo away from the *Huáscar*. It is reported that this so unnerved the Peruvian Admiral, August Miguel Grau, that he had the two Lay torpedoes taken to a local cemetery and buried them. Obviously, torpedoes were too dangerous to use!

The next torpedo action was again set in South America, where, in 1891, a revolution had broken out in Chile between the Balmacedists and the Congressionalists. The Congressionalists had won the support of the Chilean Navy, which gave them a decided advantage. When two new British-built torpedo gunboats, the *Almirante Lynch* and *Almirante Condell*, arrived at Punta Arenas, the Balmacedists convinced the gunboat crews that they should join the rebel cause and fight against the Chilean Navy. The 21-knot torpedo gunboats, displacing 750 tons, had three 14-pounder quick-firing guns and carried five torpedoes. After a short series of shakedown cruises, the two boats set off to attack the Chilean fleet, reportedly anchored in Caldera Bay. When they arrived, on April 23, 1891, the only ship in the anchorage was the 3,500-ton Chilean battleship *Blanco Encalada*.

The *Condell* attacked first, firing three torpedoes at the anchored *Blanco Encalada*; all three weapons missed the target. This was sufficient to arouse the battleship's crew, and they began firing at the *Condell*. In the meantime, the *Lynch*'s approach, from an opposite quarter, went undetected, and three more torpedoes were fired at the *Blanco Encalada* from a range of 150 yards. One of the two torpedoes fired from the *Lynch*'s broadside tubes hit the *Blanco Encalada*, and there was a tremendous explosion. The Chilean battleship sank in less than 7 minutes, taking with it 11 officers and 171 men. The destruction of the *Blanco Encalada* represented the first undisputed sinking of a major warship by a Whitehead torpedo.

Less than 3 years later, in yet another South American revolution, the torpedo again proved its worth in battle. This revolution took place in Brazil when Admiral de Mello took over most of the

Brazilian Navy and the fortress island of Villegagnon at the entrance to the harbor at Rio de Janeiro. In the winter of 1893–1894, the rebels laid siege to Rio, while the Brazilian Government attempted to purchase ships and build up a new navy to challenge the rebels. Before long, the government had acquired a British-built Birkenhead torpedo gunboat and three German Schichau torpedo boats.

In April 1894, these four torpedo craft conducted an attack against the rebel flagship *Aquidaban* while it was anchored near Santa Catherine Island. The boats got separated in the darkness, and the battle turned into a melee, as four independent attacks were conducted. Numerous torpedoes were fired and missed their targets until, finally, the British-built torpedo gunboat *Gustavo Sampaio* fired a torpedo at point blank range that hit the *Aquidaban* near the bow. At this point, the *Aquidaban* stopped fighting and moved into shoal water, where it settled to the bottom in 22 feet of water. It was later salvaged and lived to sail another day. There remains some confusion about the torpedo that sank the *Aquidaban*; it was fired by a British-built boat that normally used Whiteheads, but several sources claim that a Schwartzkopff torpedo was used. The Brazilians had both types in their inventory, and, since they were the same size, it is impossible to say which weapon was actually used. One indisputable fact was that the disabling of the *Aquidaban* broke the back of the revolution and gave the Brazilian Government a victory.

The next major torpedo actions occurred half a world away in Asia in 1894, in a war between Japan and China. Since both nations had torpedo boats and inventories of the German Schwartzkopff torpedoes, this was the first major conflict in which significant numbers of torpedoes were fired. The only major fleet action of the war was the battle of the Yalu River on September 17, 1894, when China's five ironclads engaged Japan's seven armored cruisers. On paper, the two fleets were fairly evenly matched, but China appeared to have a major advantage because their ironclad fleet was augmented by four torpedo boats. The Japanese did not have any torpedo boats accompanying their fleet.

The battle started shortly after noon and quickly evolved into a big-gun duel between the two battle lines. The superior training and discipline of the Japanese fleet was soon evident as the Chinese ships took a terrible pounding. This was a rare opportunity for the Chinese torpedo boats to turn the tide of battle by attacking the Japanese. Unfortunately, the torpedo boat crews were poorly trained, and their Schwartzkopff torpedoes had not been properly maintained. Consequently, the Chinese torpedo boat attack was a disaster. The torpedoes were fired from too great a range, and many of the torpedoes malfunctioned. One torpedo went directly under a Japanese ship, but, because the delicate depth mechanism was set for a greater depth, it failed to hit the ship. The torpedo boats made no useful contribution to the battle since every torpedo they fired had missed its target.

The following day, the local fishermen concentrated their efforts on the bountiful supply of metal Schwartzkopff fish in the area and made a killing by selling them back to the Chinese Navy for \$100 apiece. Admiral Ting broke off the engagement and took his battered fleet into Weihaiwei harbor, and the Japanese set up a blockade force to keep the Chinese trapped in the harbor. Because the Chinese refused to surrender and their ships still represented a threat, the Japanese began meticulous preparations in the bitter cold winter of 1894–1895 to conduct torpedo boat attacks against the Chinese warships anchored in Weihaiwei harbor. Captain Togo, who later won fame as the Japanese

admiral that annihilated the Russian fleet at the battle of Tsushima, was in charge of the torpedo boat attacks.

On February 3, 1895, Admiral Ito addressed the following stirring message to his torpedo boats: “Your orders are to sink the enemy ships in the harbor forthwith. No such operation has ever hitherto been undertaken by any navy in the world. I am asking you to sacrifice your lives for your country and to earn undying fame for yourselves.” In two successive night attacks on February 3rd and 4th, the Japanese torpedo boats broke the back of Admiral Ting’s fleet by sinking four of his ships. The *Ting Yuen*, *Wei Yuen*, *Sei Yuen*, and *Chen Yuan* were torpedoed, and they sank to the bottom of the harbor. The well-disciplined Japanese, using properly maintained Schwartzkopff torpedoes, had destroyed the Chinese fleet, and they had also learned an important lesson about how torpedoes should be used in surprise attacks against a major fleet anchorage.

The Japanese learned this tactical lesson well, employing the same tactic against the Russian fleet at Port Arthur in 1903 and against the U.S. Navy at Pearl Harbor in 1941. The attacks at Weihaiwei were conducted in bitter cold weather. Some of the crewmen on the torpedo boats froze to death at their exposed posts on deck, and some of the torpedoes failed to fire because they were frozen solid in the exposed deck tubes. The attack on Weihaiwei ended the war and started Japan on a major program to expand its navy. Ironically, after the highly successful attacks with their Schwartzkopff torpedoes, the Japanese, in 1895, switched vendors and began to purchase their torpedoes from Silurificio Whitehead.

During the last three decades of the 19th century, the torpedo’s reputation had steadily increased to the point where it was considered a major naval weapon. Thousands of torpedoes had been manufactured, and all of the naval powers had torpedo inventories ready for use. Whitehead had two factories—Weymouth in England and Silurificio Whitehead in Austria—producing torpedoes. Also, most of the major powers had their own factories where torpedoes were built under license. Radical changes in ship designs had taken place, producing entirely new classes of combatants, to exploit the torpedo as a weapon and to defend against its lethal underwater attack. During South American revolutions, the torpedo had been shown to be an effective terrorist weapon when it was used to challenge existing naval forces. In Asia, exploitation of the torpedo had demonstrated that ships were no longer safe in protected fleet anchorages. The torpedo had been demonstrated as having world-class potential as a naval weapon. The stage was now set for the torpedo to make its debut in an engagement between major battle fleets on the high seas.

Chapter 8

THE TORPEDO COMES OF AGE

As the 20th century started, the torpedo had matured to the point where it was ready to play a major role in naval warfare. Thousands of torpedoes were stored in naval arsenals ready for use, and it had been shown that, under the right conditions, they could sink the mightiest warships afloat. The first major naval action of the 20th century occurred in 1904, during the Russo-Japanese war. At the conclusion of the war between Japan and China in 1895, the European powers had intervened and laid claim to various Chinese territories to keep the Japanese from occupying them. This included a Russian occupation of Port Arthur and Korea. The Japanese had bitterly objected to this intervention and had been negotiating unsuccessfully with the Russians for the return of this territory. The Russians were determined to keep Port Arthur since it provided them with an ice-free Pacific port that could be used year around. The Japanese were convinced that Port Arthur in Russian hands posed a major threat to Japan since it could be used as a naval base to attack the adjacent Japanese islands. The Russians dragged out the negotiations endlessly, and the Japanese became increasingly bitter and frustrated. Finally, the Japanese took a Clausewitzian approach: they decided to forego the diplomatic option and seek a military solution to the problem.

As an island empire, Japan was keenly aware that naval superiority was an essential prerequisite for a successful attack against the Russian forces on the mainland. The Russian Navy was numerically much larger than the small, but modern, Japanese fleet. However, the Russian Navy was divided into three widely separated fleets—the Baltic, Black Sea, and Pacific squadrons. To keep the Russians from massing their naval forces in the Pacific, the Japanese entered into diplomatic negotiations with the Russians to keep them off guard and at the same time began covert preparations for a surprise military attack.

Admiral Togo, who, as a captain, had led the torpedo boat attacks against the Chinese at Weihaiwei in 1895, now commanded the Japanese combined fleet, and his strategy was to initiate hostilities by conducting a preemptive surprise torpedo boat strike against the Russian Pacific squadron in their home anchorages of Port Arthur, Manchuria, and Chemulpo, Korea. On February 5, 1904, as the negotiations in St. Petersburg were abruptly broken off, Admiral Togo assembled his senior officers on his flagship, *Mikasa*, and presented them with his plan for a preemptive surprise attack against these two Russian bases. Admiral Togo's initial plan was to swoop down with the 1st Division of the Japanese combined fleet, consisting of six pre-dreadnought battleships, and the 2nd Division, consisting of four armored cruisers. These capital ships and cruisers were accompanied by some 15 destroyers and about 20 smaller torpedo boats.

Within the protection of the fortified naval base of Port Arthur, the Russians had seven pre-dreadnought battleships supported by a number of cruisers. However, the defenses of Port Arthur were not as strong as they could have been, largely due to Russian overconfidence and complacency. Admiral Togo had false information that the garrisons of the forts guarding the port were on full alert. Because the admiral was unwilling to risk exposing his precious capital ships to the Russian shore

artillery, he held back the main battle fleet. Instead, the destroyer force was split into two attack squadrons—one to attack Port Arthur and one to attack the adjacent Russian base at Dalny.

The Port Arthur attack squadron, consisting of 10 destroyers, encountered patrolling Russian destroyers early on February 9th. The first four Japanese destroyers approached the port without being observed and launched a torpedo attack against the cruiser *Pallada* and the battleship *Retvizan*. The *Pallada* was hit amidships, caught fire, and keeled over; the *Retvizan* was holed in her bow. Some of the other Japanese destroyers were less successful because many of their torpedoes were caught in the Russian defensive torpedo nets. Other destroyers arrived too late to benefit from surprise and made their torpedo attacks individually rather than as a coordinated group. They were, however, able to disable the most powerful ship of the Russian fleet, the battleship *Tsesarevich*.

Despite ideal conditions for a surprise attack, the results were relatively poor. Of the 16 torpedoes fired, all but 3 either missed or failed to explode. Each of the three that did hit their targets did so with significant effect because the most capable Russian battleships in port, the *Retvizan* and the *Tsesarevich*, as well as the cruiser *Pallada*, were put out of action for weeks.

In early August 1904, Admiral Wilhelm Vitgeft, commander of the Russian 1st Pacific Squadron, was ordered to sortie his fleet to Vladivostok, link up with the squadron stationed there, and then engage the Imperial Japanese Navy in a decisive battle. While executing this rendezvous, both squadrons of the Russian Pacific Fleet ultimately became dispersed and were rendered nonoperational for the remainder of the conflict during the battles of the Yellow Sea on August 10th and the Ulsan on August 14, 1904.

With the tightening of the Japanese noose around Port Arthur, the Russians dispatched part of their Baltic Fleet to the Far East to form the 2nd Pacific Squadron. It would consist of five divisions of the Baltic Fleet, including 11 of its 13 battleships. The plan was to relieve Port Arthur by sea, link up with the remains of the 1st Pacific Squadron that had been effectively blockaded in port by the Japanese, and again seek to overwhelm the Imperial Japanese Navy in a decisive naval battle. Unfortunately, due to the difficulties associated with the expeditious transit of 18,000 miles, the Russian fleet was in relatively poor condition for battle upon its arrival in the theater.

The 2nd Pacific Squadron, under the command of Admiral Rozhdestvensky, arrived in the Far Eastern waters in early May 1905. However, by this time the Japanese had captured Port Arthur, so the only option for the Russians was to head for the port of Vladivostok. Admiral Togo immediately set up scouting lines to intercept the Russians before they could take advantage of much-needed refurbishment in port. Since both the Russian ships and the men were worn out from the long voyage, Admiral Rozhdestvensky chose the most direct route to Vladivostok. The Russian admiral was also very concerned about night torpedo boat attacks, so he elected to sail through the narrow Tsushima Strait during daylight hours. As soon as Admiral Togo's scouts reported on the Russian fleet movements, he massed his combined fleet to intercept the Russians at Tsushima, and the stage was set for the great naval battle each side sought but for which only the Japanese were prepared.

The combined fleet of the Imperial Japanese Navy made contact with the Russian 2nd Pacific Squadron shortly after noon on May 27, 1905, and the battle started at 2 p.m. The early stage of the battle was primarily a big-gun duel between the two fleets, with the superior Japanese gunnery

mercilessly pounding the Russian ships into floating junkyards. By 3 p.m., the Russian formation was completely broken, Togo's ships were circling for the kill, and the Japanese destroyers and torpedo boats were unleashed to attack the Russian ships. The battleship *Oslabya* was sunk, the battleships *Alexander III* and *Borodino* were flaming wrecks, and the flagship *Suvorov* was badly damaged and out of control, with her steering gear shot away. The devastating destruction inflicted by Togo's big guns broke up the Russian formation, but the individual ships continued to fight on bravely. By sunset, the *Alexander III* and *Borodino* had gone to the bottom, and the *Ural* was finished off by a torpedo fired from a Japanese battleship. Among the thousands wounded in the battle was Lieutenant Isoroku Yamamoto, who lost two fingers when a shell fragment struck his hand. Thirty-six years later, Admiral Yamamoto masterminded the attack against Pearl Harbor.

As darkness fell, the battered and demoralized remains of the Russian fleet fled northward to seek the safety of their base at Vladivostok. The ever-cautious Togo was reluctant to commit his precious battleships in risky night operations, so he sent his destroyers and torpedo boats off to hunt down the remnants of the 2nd Pacific Squadron. It was a rewarding hunt, and it proved that the torpedo was a weapon to be reckoned with. The damaged Russian flagship *Suvorov* was attacked by torpedo boats and sunk; the battleship *Sisol Veliki* and the armored cruiser *Admiral Nakhimoff* were hit by torpedoes and sank the next day; the battleship *Navarin* was hit by four torpedoes and sunk with great loss of life; the armored cruisers *Vladimir Momomakh* and *Dmitri Donskoi* were torpedoed and sank the following day. The torpedo boats, or "small boys," had fired over 370 torpedoes while conducting sustained and aggressive night attacks against the Russian ships. They had dramatically demonstrated that the torpedo, when properly used, could do great damage in a major fleet action: even mighty battleships had been sunk by the lowly torpedo.

The battle of Tsushima was the first major battle in which modern armored battleships slugged it out. Admiral Togo's combined fleet had annihilated the Russian fleet, and Japan was firmly established as a major naval power. The brilliant victory was primarily a classic big-gun engagement that would be exhaustively studied at naval war colleges and by naval staffs. However, the torpedo had been used successfully in strikes against protected fleet anchorages, and it had sunk major combatants in a fleet engagement. The big gun was still the major naval weapon, but the torpedo could no longer be ignored!

Meanwhile, back in Europe, the Whitehead torpedo business was undergoing major changes. Robert Whitehead's son John, who was charged with managing the Whitehead torpedo business, became ill and died in 1902. This placed a heavy burden on the shoulders of Whitehead's son-in-law Georg Hoyos. Shortly after he took over, his health started to fail, and in 1904 he also died. The final blow came on November 14, 1905, when Robert Whitehead, who had been a semi-invalid for a number of years, died at Beckett Park. The father of the torpedo had lived long enough to see his weapon used in the battle of Tsushima, but now the closely controlled family business was in serious trouble because there were no family members left that were qualified to take over management of the privately owned company. In 1911, at the urging of the British Government, Vickers Ltd and Armstrong Whitworth each acquired enough shares to constitute, in combination, a controlling interest in the company, and the Whiteheads became minority stockholders. (In 1927, Vickers merged with Armstrong Whitworth, founded by W. G. Armstrong, to form Vickers-Armstrong Ltd.) As the

arms race heated up, additional plants were built in St. Tropez in France and in Naples, Italy. By the eve of World War I, there were four Whitehead plants producing torpedoes.

During this same period, the great naval armaments race between Germany and England was in its early stages as the “lessons learned” from the battle of Tsushima were used to support the design of a new generation of super battleships. The German Navy, under the leadership of Grand Admiral Alfred von Tirpitz, initiated a massive program to build a German High Seas Fleet that would surpass the British Royal Navy. The British were determined to maintain their leadership position and undertook an equally massive program to modernize the British Grand Fleet.

The British navy, under the dynamic leadership of First Sea Lord Admiral Sir John “Jackie” Fisher, initiated the design of a radical new all-big-gun battleship, the *Dreadnought*. The design concept, fostered by advocates of the big gun, such as Admiral Sir Percy Scott of the Royal Navy and Admiral William S. Sims of the U.S. Navy, dictated that all of the big guns should be of the same caliber and that salvo fire should be used to zero in on long-range targets. The *Dreadnought*, with a main battery of ten 12-inch guns mounted in pairs, had a fire power equal to three conventional battleships in firing ahead and two in broadside firing. This massive firepower, combined with its design speed of over 20 knots, established the *Dreadnought* as the baseline for a new generation of big-gun battleships. When one considers that the British had the largest number of battleships, it was a very bold move on Fisher’s part to build the *Dreadnought* since it made the existing inventory of battleships instantly obsolete.

Starting with the *Dreadnought* in 1904, Von Tirpitz and Fisher became the principal architects of a massive naval armaments race that would consume a substantial portion of the national wealth of their respective nations. For the next decade, each country tried to outstrip the other by building bigger and better dreadnoughts. The size of the ships steadily increased from 18,000 tons to over 28,000 tons; the main armament increased as 13-, 14-, and, finally, 15-inch guns were added; and the speed of the more lightly armored battlecruisers exceeded 27 knots. This was truly a major revolution in naval warfare, and the torpedo provided the primary justification for this massive undertaking. Naval experts were convinced that, as the torpedo’s range approached 3,000 yards, it posed a major threat to capital ships, and it was deemed essential that engagement ranges be increased beyond torpedo firing ranges. At Tsushima, the engagement range had been about 3,000 yards. By the eve of World War I, gunnery had improved to a point where salvo firing at ranges in excess of 10,000 yards was commonplace in fleet exercises.

New, larger destroyers were also being built, and the German Navy conducted fleet exercises in which a destroyer flotilla would conduct a mass torpedo attack against a capital ship to overwhelm its defenses. The French Navy had been experimenting with a new submarine vessel armed with torpedoes, and the French claimed that the submarines had successfully attacked battleships in fleet exercises. Not taking any chances, both the Germans and the British began to acquire submarines for their respective navies. The idea that a small submarine might destroy a mighty battleship was a matter of considerable concern. It was bad enough that fleet admirals had to worry about surprise torpedo boat attacks while in harbor and overt massed destroyer torpedo attacks while at sea. Now, the tactical situation became even more complex with the prospect of covert submarine torpedo

attacks that might come from any quarter at any time. It was getting to the point where the torpedo was giving the battleship admirals migraine headaches.

The technology and tactical lessons that were revolutionizing the design of naval warships was also impacting the design of torpedoes. In the 1870s and 1880s, a steady stream of improvements had been made to increase torpedo performance, and major advances in accuracy were in the offing. The torpedo had demonstrated that it could sink the mightiest ships afloat, but it had a glaring weakness in that it frequently deviated from the initial firing course. Even at modest 200 to 300 yard firing ranges, the torpedo often drifted off course and missed the target; consequently, torpedoes had to be fired at close ranges to ensure any hits. In the mid-1890s, Robert Whitehead's son John had become interested in using a new scientific curiosity called a gyroscope to control the torpedo's heading and increase its directional accuracy. He contacted the designer Ludwig Obry, purchased the rights for the device, and started experimenting with a gyro-controlled steering system for the torpedo. The gyro, once it was spun up to speed, always pointed in the same direction, so John designed a pneumatically powered steering motor that sensed the gyro heading and corrected the torpedo's heading any time it deviated from the preset gyro heading. Although Howell's flywheel powered torpedo used a crude form of gyroscopic steering, this was the first application of a gyroscope as a guidance device. John Whitehead, like his father, was a pioneering genius, and his successful design of a gyro steering system represented a major scientific achievement because it made the torpedo the first guided missile. The gyroscope could be preset for a specific heading (course), and the steering system would automatically maintain the torpedo on the preset heading by using the gyro heading to maintain the preset course. The tests with the new Obry gyroscope resulted in a spectacular increase in accuracy. The torpedo's deviation, or deflection, from the aimed course, was reduced to approximately 0.5° for a 7,000-yard range.

The conservative Royal Navy felt that their existing torpedoes were more than adequate and initially refused to adapt the new-fangled gyro-controlled models. However, when the results of actual tests were compared, it didn't take long for them to change their minds and seek permission from Whitehead to build the new gyro-controlled units. The Royal Navy had to pay Whitehead a royalty of £25 for each unit built, and, because the Royal Navy ultimately converted most of its torpedo inventory over to gyro-controlled units, this generated a substantial cash flow into the Whitehead bank accounts. Since this dramatic increase in accuracy meant the torpedo could be effectively used at longer firing ranges, it provided a strong incentive to increase both the range and speed of the weapon.

Slowly but surely, a series of incremental improvements were being introduced. Counter-rotating propellers had been introduced to eliminate the torpedo's heel during a run and to reduce the excessive roll experienced when it started a run. Four-bladed propellers were added during the 1890s, and a new nickel steel, used for air flask construction, permitted the air pressure to be increased to over 2,000 psi. In the United States, the E. W. Bliss Company, in Brooklyn, New York, was experimenting with a turbine-powered torpedo designed by Frank McDowell Leavitt. In Britain, the Brotherhood Company of Peterborough had designed a new higher-performance, four-cylinder radial engine for the Woolwich-designed Whitehead torpedoes. Each of these developments

provided a small improvement, but what was really needed was a major breakthrough in performance.

Exactly who made the first breakthrough is difficult to establish because Bliss in the United States, Whitehead in Austria, and Armstrong in England all began experimenting with heater systems to warm the air and increase the thermal efficiency of the torpedo right around the turn of the century. It appears that Frank McDowell Leavitt of the Bliss Company in the United States was the first designer to demonstrate an operational torpedo with a pre-heater. The revolutionary 21-inch-diameter, turbine-powered Bliss-Leavitt Mark 1 torpedo, purchased by the U.S. Navy in 1904, burned alcohol in a chamber upstream of the turbine to preheat the compressed air. This innovation essentially doubled the range of the weapon by increasing it to 4,000 yards at 27 knots.

An early clue about the value of warming the air was discovered in 1901 when the meticulous Armstrong Whitworth personnel at the Woolwich plant noticed that the torpedo ran slightly faster in warm seawater; evidently the water warmed the compressed air, and warm air had more energy than cold air! Experiments conducted with hot gas indicated that a major increase in performance could be realized, and Armstrong Whitworth took out patents on a dry heater in 1904. The device, in which fuel was burned to heat the compressed air, was called the Elswick dry heater, and it was demonstrated for the first time in 1905.

The Whitehead plant in Fiume heard about the work on heaters at Woolwich, and, within a year, the Fiume plant was producing a Whitehead “wet heater.” The conversion from cold air to hot gas as an energy source provided a major increase in thermodynamic energy, or enthalpy, and this meant major increases in torpedo performance were feasible because of the dramatic increase in propulsive efficiency. In turn, this increased efficiency could be translated into longer ranges, higher speeds, or larger warheads to increase the torpedo’s performance. In the Whitehead wet heater system, fuel and air were burned to generate hot gas, and water was sprayed into the combustion chamber to hold the combustion temperature down to about 1,000°F since higher temperatures would melt the engine. Because the cooling water flashed into steam when it was sprayed into the hot gas combustion chamber, the torpedoes equipped with Whitehead wet heaters were soon being mistakenly referred to as “steam torpedoes.” The diluent water did form steam, and the steam did increase the mass of the combustion gases and incrementally increased performance. However, the torpedo was in fact powered by a hot gas combustion system. It is not possible to correct this popular misconception at this late date, so, henceforth, weapons using the Whitehead wet-heater cycle will be called steam torpedoes, per the commonly used terminology.

The heater increased the speed of the Fiume Mark 3 torpedo by 9 knots, and, within a short period of time, a whole new generation of higher-performance torpedoes started to appear. In 1906, the Germans increased the diameter of their torpedoes to 500 mm (19.7 inches), and this started the evolution of the famous family of German G-type torpedoes. In 1908, the British picked up on Bliss-Leavitt’s new, larger torpedo by introducing a 21-inch (533-mm) weapon; within a decade the 21-inch weapon became the standard for most of the major navies. The Japanese seemed to be interested in larger torpedoes, and they had ordered an experimental 24-inch torpedo from the Fiume factory in 1898. A few years later, they had an even larger, 27.5-inch-diameter, torpedo built. In the United States, the turbine-powered Bliss-Leavitt torpedoes, equipped with heaters and Whitehead gyros, had

become the favored design. Variants of this extremely well-designed torpedo would continue to be used by the U.S. Navy right through World War II.

The hot gas combustion systems and the larger size resulted in spectacular increases in torpedo performance. By the eve of World War I, ranges well in excess of 10,000 yards had been demonstrated, and, at shorter ranges, speeds in excess of 40 knots had been achieved. In spite of the massive effort to reduce the risk of torpedo damage to ships by increasing engagement ranges, the lowly torpedo was actually closing the gap. At Tsushima, the maximum torpedo range was about 1,000 yards, and the engagement range for the big guns was around 3,000 yards. Clearly, the big gun had the longer reach. By World War I, the engagement range of the new dreadnought-type battleships were salvo firing at ranges approaching 15,000 yards. The firing range had been increased by an impressive factor of five. By 1913, the German H-8 torpedo had a range of over 18,000 yards at 28 knots. The torpedo had demonstrated an order-of-magnitude increase in performance. In spite of the massive national investments in new big-gun battleships, the torpedo represented a greater threat than ever, because its performance had improved to the point where the range of the torpedo and the big guns were approaching unity.

When World War I started, the Whitehead family was split into two factions because some of the family lived in Austria, which was allied with Germany, and the rest of the family had moved back to England. When Robert's son John died in 1902, his wife and children moved back to Austria to live with her family at Fiume. In 1908, the Fiume plant received a contract from the Austrian Government to build submarines. John's daughter, Agathe Whitehead, met a young Austrian naval officer, Kapitänleutnant Georg Ritter von Trapp, who was assigned to oversee the construction of the submarine. In a manner very similar to her Aunt Alice's courtship with Count Georg Hoyos 30 years earlier, she fell in love with the handsome young officer. When the U-5 was launched the following year, she christened it, and, in 1911, on her 21st birthday, she married Von Trapp.

During World War I, Von Trapp commanded the Austrian submarine U-5 and distinguished himself by torpedoing and sinking the French armored cruiser *Leon Gambetta*. When the war was over, Austria lost its coastal provinces to Italy, and Von Trapp became an unemployed naval officer in a country that no longer needed a navy. In 1922, tragedy struck when Agathe died of diphtheria, and Von Trapp was left with five young children. He then hired a governess, Maria Augusta, and the family proceeded to gain fame as the Trapp Family Singers. Strange as it may seem, five of the children that became so famous when Rodgers and Hammerstein wrote the great musical hit "The Sound of Music" were the great grandchildren of Robert Whitehead, the father of the torpedo.

Chapter 9

WORLD WAR I

By the start of World War I, both the British and the Germans had made huge national investments to modernize their respective navies. The British Grand Fleet and the German High Seas Fleet had been engaged in an unparalleled naval armaments race, and the British had managed, in spite of the massive German challenge, to maintain a quantitative lead. Britain had the larger fleet, and it was generally acknowledged to be more highly trained than the German Navy. Consequently, at the onset of hostilities, the British enjoyed a superiority, but the German High Seas Fleet represented a major threat to the island nation. Because England could not survive without imported food and raw materials, it was absolutely essential that the Royal Navy maintain control of the seas. The Germans were well aware of this, and their long-term naval strategy was to isolate the island nation and, if necessary, starve it into submission.

Britain's very survival depended on the Grand Fleet, and this dictated conservative naval tactics to ensure that the fleet was not risked in any precipitous action. Fleet superiority had to be maintained at all costs since it was a matter of national survival. It had become evident that the torpedo substantially increased the element of risk or uncertainty in naval warfare. The Royal Navy, painfully aware of this fact, adopted extremely conservative tactical doctrine in an effort to protect its precious capital ships from undue exposure to German torpedoes.

By an odd coincidence, both of the great naval leaders, Admiral Fisher in England and Admiral von Tirpitz in Germany had, at the same time in 1885, commanded their respective torpedo establishments. Both men had a detailed understanding of, and a healthy respect for, the torpedo. They were both sensitive to the increasing role that the torpedo would play in any naval war, and there was much debate about what tactics should be employed to reduce the risks that the torpedo introduced. As mentioned earlier, the dreadnoughts were built to increase the engagement range and reduce the risk of capital ships being randomly sunk by torpedoes during well-structured fleet engagements. Unfortunately, the torpedo's performance had also increased, and, by the eve of World War I, the torpedo was a greater threat than ever. The naval professionals, being advocates of the big gun, were very uncomfortable with the uncertainty that the torpedo introduced into their tactical planning. The British were particularly concerned, since it was essential for their national survival that they maintain a naval superiority.

The torpedo also had an adverse impact on naval strategic planning. The tradition-bound Royal Navy thought in classic terms of close blockades to seal enemy ports and of great sea battles, such as Trafalgar, to annihilate the enemy fleet. War plans were prepared accordingly, and the prewar war games confirmed that close blockades would be a very risky business if the harbor were protected by torpedo boats. Capital ships were extremely vulnerable to night attacks by destroyers and torpedo boats, and it introduced an unacceptable risk to commit them to a close blockade where they would be routinely exposed to night torpedo attacks. The balance of naval power might shift if too many capital ships were lost to torpedoes while attempting to maintain a traditional close blockade.

It was also noted that the torpedo made fleet engagements infinitely more complex, since massed torpedo attacks by destroyers had a way of disrupting the big-gun engagements, which introduced both confusion and risk. Night engagements, because they had to be fought at close ranges, were uniquely dangerous since destroyers could close in the dark and make effective torpedo attacks without being exposed to the murderous fire of the big guns. The ever-conservative Royal Navy was not inclined to take any such risks, and their standard tactic was to break off the engagement at dusk and steer clear of night battles. Because of the torpedo, close blockades were too risky, night battles were too risky, fleet engagements could be undertaken only under favorable conditions, and submarines posed a new threat to capital ships. The torpedo was making it increasingly difficult to plan an orderly naval war.

It reached a point, at the start of World War I, where it seemed that the British strategy was reduced to protecting their Grand Fleet at all costs to ensure a continuing superiority over the German High Seas Fleet. It can be argued that the torpedo introduced an unacceptable element of uncertainty into naval warfare, and this forced both the British and the Germans to adopt extremely conservative naval tactics during World War I. Consequently, neither country was willing to risk their precious capital ships in aggressive fleet actions.

This concern about torpedoes also existed at the operational level. Admiral Sir John Jellicoe, Fisher's hand-picked choice for Commander-in-Chief of the Grand Fleet, was an advocate of the big gun, but he frequently expressed the need for caution in dealing with torpedoes since one torpedo hit could cripple or sink a capital ship. In fact, Admiral Jellicoe conducted a theoretical study in which he concluded that the entire British battle line could be wiped out in a single massed attack by the 88 destroyers of the German High Seas Fleet. Since the Commander-in-Chief of the Grand Fleet, as the chief tactician of the Royal Navy, was paranoid about the torpedo threat, there was little reason to anticipate that the Grand Fleet would engage in aggressive high-risk operations against the Germans.

When World War I started in August 1914, the Royal Navy initiated a North Sea blockade to cut off all war materiel being shipped to Germany, and the Grand Fleet anchorage was moved to Scapa Flow in the north, which was closer to the German ports across the North Sea. It didn't take long for the newest type of warship to make its debut. On September 3rd, the German submarine U-21 torpedoed and sank the British light cruiser HMS *Pathfinder*. This was a historic event in that it was the first time in modern warfare that a submarine had sunk a warship. The U-21, commanded by Otto Hersing, had opened a new era in naval warfare. Ten days later, the British submarine E-5, operating near Heligoland, sank the German cruiser *Hela*, and each side had demonstrated that torpedoes used from submarines were a potent threat. While patrolling off the Dutch coast on September 22nd, the German submarine U-9, Otto Weddigen commanding, encountered three British armored cruisers and immediately attacked them. In a brilliant and tenacious attack that exhausted his supply of torpedoes, Weddigen proceeded to sink HMS *Aboukir* followed by HMS *Hogue* and, with his last torpedoes, HMS *Cressey*. Over 36,000 tons of warships went to the bottom with a loss of 1460 men. The U-9 dramatically demonstrated that naval warfare would never be the same again, and Weddigen was awarded Germany's highest award, the Pour le Merite (or Blue Max), for his brilliant action. The British were loath to believe that a single submarine had sunk three armored cruisers in broad daylight, and there was understandable shock and confusion.

The submarine threat had to be taken seriously, but the Royal Navy had a critical crisis. It had neither a defense against submarines, nor weapons to attack submarines. The U-15 had been rammed and sunk by the cruiser HMS *Birmingham* on August 10th, but it was just a stroke of luck that the cruiser had caught the U-boat on the surface where it was vulnerable. Primitive though they were, ramming and the use of minefields were the only defenses the British had to fend off the U-boat assault during the early days of the conflict. Fleet anchorages lacked adequate defenses, and, when U-boats were detected trying to penetrate the anchorage at Scapa Flow, the Grand Fleet was issued emergency sailing orders. Everybody seemed to be spotting periscopes, and it was both expensive and embarrassing to send the mighty Grand Fleet to sea every time someone reported a periscope sighting.

October 17, 1914, was a black day for the Royal Navy. Admiral Jellicoe ordered the fleet to evacuate Scapa Flow and take up temporary bases in Northern Ireland. The unthinkable had happened. The mightiest navy in the world had evacuated its home anchorage and was reduced to hiding in creeks and bays far from home to escape being torpedoed by submarines. This was a bitter pill for the British and a tremendous victory for the U-boats. The war was less than 3 months old, and the submarine, with the torpedo as its weapon, was already exercising a profound and unprecedented influence on naval warfare. Another first in submarine warfare occurred on October 18th, when the British submarine E-3 was torpedoed by the U-27 while on a scouting mission off the German coast. The E-3 was the first submarine to be destroyed by another submarine.

The wisdom of Admiral Jellicoe's conservative doctrine to protect his precious battleships from submarines was driven home when the U-24 encountered the Royal Navy's 5th Battle Squadron proceeding down the English Channel for gunnery practice. The eight battleships were steaming in line ahead formation, and, at 2:25 a.m. on January 1, 1915, the U-24 launched a torpedo attack against the last ship in the line. The battleship HMS *Formidable* was hit in the boiler room and began to list and settle in the water. At 3:15 a.m., the U-24 fired another torpedo, and it was evident that the 15,000-ton battleship was doomed. It rolled over and went to the bottom with a loss of 547 British sailors. The loss of a mighty battleship to a submarine humiliated the British navy and caused much dismay at Whitehall. The Admiral commanding the 5th Battle Squadron was relieved of his command the following day.

A short time prior to this, a seemingly insignificant event occurred that was to have major consequences on how the war at sea would be conducted. The U-17, on patrol off the Norwegian coast, stopped the British merchant ship *Glitra* and ordered the crew to abandon ship. The British sailors were allowed to collect their belongings and launch the lifeboats. A German prize crew then went aboard the *Glitra*, opened the seacocks, and scuttled the ship. The U-17 then proceeded to tow the lifeboats until they were close to shore. Although Kapitänleutnant Feldkirchner conducted the first sinking of a merchant ship strictly in accordance with international law, he was concerned that he might be court-martialed for the unauthorized sinking. Instead, he found that the German High Command had been considering the use of U-boats against merchant shipping and that his sinking of the *Glitra* had demonstrated the feasibility of such a strategy.

The British, on November 2, 1914, declared the North Sea a military area under British blockade. This was generally considered to be an infringement of international law, and the Germans, along

with neutral countries including the United States, were incensed by the British action. In retaliation, Admiral von Pohl, German Chief of the Naval Staff, proposed that U-boats be used to conduct war against British merchant shipping. The German Navy wanted to conduct unrestricted warfare, but the Kaiser, not wanting to alienate neutral countries, directed that attacks against merchant ships be conducted in accordance with international law. A new era in naval warfare was initiated when the U-boats were authorized to conduct a restricted campaign against British shipping. There were also some instances where U-boats torpedoed ships without any warning, which provided an indication of how ruthless unrestricted submarine warfare could be.

The German Navy continued to press for authorization to conduct unrestricted warfare, and, on February 5, 1915, Admiral von Pohl finally got the Kaiser to decree the waters around Great Britain and Ireland a war area. The Germans declared that, starting February 18th, a submarine blockade would be in effect and that all enemy merchant shipping would be subject to attack. Unrestricted submarine warfare was authorized as Germany started an all-out offensive to isolate Great Britain. The campaign against commerce was to be prosecuted with all possible vigor and all hostile merchant ships were to be destroyed.

The German Navy started the offensive against British merchant shipping with a total of 58 U-boats; of this number, only about one-third were at sea at any given time. Because of the bitter winter weather, the offensive got off to a slow start. However, by spring, the U-boats were averaging destruction of over 100,000 tons of enemy shipping per month. The number of ships being sunk clearly exceeded new ship construction, and the British were feeling the pressure. In an effort to reduce their losses, British ships frequently used neutral flags as a ruse de guerre, and it wasn't long before neutral ships in the war zone were fair game for the U-boats since so many British ships were flying neutral colors. The United States was incensed by the sinking of U.S. merchant ships and strenuously protested to the German Government.

On May 7, 1915, the U-20, Kapitänleutnant Walther Schwieger commanding, torpedoed the British liner *Lusitania* and sent it the bottom with a loss of 1,200 lives. This single submarine attack had far-reaching implications and may have actually changed the course of World War I. Although it was vigorously denied at the time, the *Lusitania* was carrying guns and ammunition, which made it a valid target. Unfortunately, it was also carrying a lot of U.S. citizens as passengers, and over 100 of them lost their lives when the *Lusitania* went to the bottom. The Germans appeared to be winning the unrestricted submarine war, but the British were winning on the political and propaganda fronts. After the sinking of the *Lusitania*, U.S. public opinion started to tilt against the Germans because of the alleged atrocities that the U-boats were committing, and there were several strenuous protests by the U.S. Government that it would not tolerate unrestricted submarine warfare, in violation of international law.

This became a matter of serious concern to the Kaiser and his political advisors because they wanted the U.S. to stay neutral, and, in September 1915, he called off the unrestricted submarine offensive in the Atlantic. Since there was very little U.S. shipping in the Mediterranean, U-boats in that theater were allowed to continue to attack under the unrestricted ground rules, and the aggressive U-boat skippers proceeded to turn the Mediterranean into a ship graveyard.

In the 8 months of the first unrestricted submarine offensive, the U-boats had seriously hurt the British by sinking over 855,000 tons of merchant shipping, and the British had found no effective means of countering the U-boat offensive. In the Mediterranean, the unrestricted warfare continued, and a small contingent of German and Austrian U-boats turned the Mediterranean Sea into their happy hunting grounds. Much of Britain's raw material and food came from Australia via the Suez Canal, and the ill-fated Gallipoli operation required large numbers of Allied warships and transports in the Eastern Mediterranean. An impressive number of major warships, including eight French and British battleships, and large troop transports were destroyed along with hundreds of merchant ships. Most of Germany's great U-boat aces (Von Arnould, Forstmann, Valentiner, Rose, Steinbrinck, etc.) achieved their greatest successes while operating in the Mediterranean. Korvettenkapitän Lothar von Arnould de la Periere, Germany's ace of aces with over 400,000 tons of ships destroyed, sank 54 ships and registered 91,150 gross tons on a single patrol in the Mediterranean.

The situation became so desperate that the British were forced to abandon their Mediterranean trade route, and ships from Australia were ordered to take the much longer Cape of Good Hope route to escape the U-boats. The spectacular success enjoyed by the U-boats in the Mediterranean supports the contention that Britain might have been forced to capitulate if Germany had also continued its unrestricted U-boat warfare in the Atlantic in 1915 rather than giving in to political pressure. The number of U-boats had increased from 58 to 99, and, at this point in the war, the British had not yet developed any effective way to counter U-boats. Even with the restrictions reimposed on the U-boat offensive in the Atlantic, torpedoes launched from U-boats continued to pose a major threat, requiring a massive commitment of scarce British resources to build additional ships and to develop defenses against submarines.

Jutland, the only great naval battle of World War I, was somewhat of an anticlimax because of the conservative tactics employed by both the Grand Fleet and the High Seas Fleet. Volumes have been written examining the battle of Jutland in great detail, but the torpedo is largely ignored since it did not play a major role in the actual battle. The uncertainty introduced by the torpedo, however, was the major factor leading to the conservative tactics employed. When the two great fleets started to slug it out in a Trafalgar-like big-gun duel, massed torpedo attacks by British and German destroyers were executed to make the battle lines turn away and break off the engagement. It was simply too dangerous to ignore the torpedoes, and, when the precious capital ships disengaged to take evasive action, their primary gunfire mission was interrupted. By turning away to comb the torpedo wakes, the battle line was generally successful in eluding the torpedoes, but this also broke off the big-gun duels and tended to make the whole action both confusing and inconclusive. It appears that this concern about torpedoes had some justification because the only battleship sunk during the battle, the German pre-dreadnought *Pommern*, was the victim of a British destroyer torpedo.

During the battle, both Admiral Jellicoe and Admiral Scheer conducted massed destroyer torpedo attacks, and the German High Seas Fleet extricated itself from the jaws of the British Grand Fleet by firing a 33-torpedo salvo that forced the British to turn away and break off the engagement just when they were gaining a strong tactical advantage over the Germans. Admiral Jellicoe managed to position the Grand Fleet between the High Seas Fleet and their home ports, which effectively isolated them so that he could use his marked quantitative superiority to destroy the High Seas Fleet. However,

Admiral Jellicoe was not about to commit the Grand Fleet to a risky night action where massed torpedo attacks might randomly change the outcome.

As darkness approached, the British fleet formed up in a compact night formation designed to block the Germans from returning to their ports so that the battle could be resumed on the following day. Although numerically outnumbered, the Germans were better trained in night fighting, and Admiral Scheer broke through the destroyer flotillas guarding the van of the Grand Fleet to the safety of Horns Reef and harbor. The conservative tactics employed in the battle of Jutland were largely influenced by the torpedo threat, and these conservative tactics led to an indecisive battle in which neither side could claim a clear-cut victory.

There were a number of other minor actions between elements of the two great fleets, but each side wanted a clear-cut advantage before entering into a major engagement, which led to a strategic stalemate. When Admiral Scheer took command of the High Seas Fleet, he developed battle plans that called for the fleet and his U-boats to function as a single combined force in attacks against the Grand Fleet. The primitive command, control, and communications capabilities that existed made it extremely difficult to conduct such complex operations, and Scheer's limited attempts to employ a combined force bogged down primarily because of poor communications. When the unrestricted submarine campaign started, the U-boats were no longer available to work with the fleet, and the idea died. It is interesting to note that Admiral Gorshkov, the chief of the Russian Navy, in his prolific writings, frequently echoed Admiral Scheer's doctrine by stating that, in battle, the surface fleet and the submarine fleet must function as a single integrated force. The major difference is that Admiral Gorshkov reversed the pecking order. Submarines are identified as the primary attacking force, and surface ships have the support role.

By 1916, trench warfare had bogged down the armies, and the land war was largely stalemated, while, on the home front, the German population was slowly starving due to the British blockade of Germany. There was mounting pressure to reinitiate the unrestricted submarine campaign against Allied shipping in the Atlantic and press for a decisive victory at sea. However, the German Government, still concerned about U.S. protests, authorized only a restricted campaign in October 1916, in which, to pacify the U.S. Government, prize regulations were to be adhered to. The campaign was a qualified success, and, in the following months, U-boat operations accounted for over 300,000 tons per month of ships destroyed. For the British, these were staggering losses.

Admiral Jellicoe was promoted to First Sea Lord and given specific responsibility to counter the submarine threat. The German naval staff estimated that twice this tonnage would have to be destroyed to make Britain give up the struggle, and they continued to press for an unrestricted campaign. In January 1917, the German Government finally concluded that the only means of ending the war favorably in a reasonably short time was an unrestricted submarine campaign to strangle Britain economically and sever her sea lines of communication. It was thought that the United States would shortly enter the war on the British side, and it was essential that Britain be isolated before the massive U.S. industrial output started to arrive.

On February 1, 1917, the German Government declared a large area around the British Isles and the French coast to be a forbidden war zone in which all ships would be attacked and sunk without

warning. The Germans had approximately 140 U-boats of all types, and only about 40 of these would be available for combat patrols at any given time. With the authorization to conduct unrestricted warfare, this modest fleet of U-boats attacked with unprecedented fury; the sinkings (listed below) actually surpassed the optimistic German Naval Staff projections:

February 1917	520,000 tons
March 1917	564,000 tons
April 1917	860,000 tons
May 1917	616,000 tons

The losses far exceeded new ship construction, and the British were hard-pressed to maintain their war effort in the face of such staggering losses. The British stepped up construction of destroyers, trawlers, and Q-ships; introduced depth bombs as the first ASW weapons; and employed hydrophones and underwater nets to detect submerged submarines. All of these made it increasingly difficult for the U-boats, but they expected losses and the hunting was good. During the 6-month period from February through July 1917, the U-boats destroyed a total of 3,850,000 tons of shipping. The U-boats and their torpedoes were being used to accomplish a strategic objective, and they were coming perilously close to cutting off the lifeblood of an island nation. Food was in short supply, and oil supplies reached a critically low level that threatened military operations. Strict rationing was imposed, and emergency measures were taken to import oil in converted cargo ships. The inconceivable had happened. The torpedo deployed from submarines had brought the world's greatest sea power to the brink of collapse.

Some of the British Government leaders proposed that convoys be formed to protect merchant ships from submarines but most of the Royal Navy professionals opposed the concept. They claimed that the convoys would drastically slow the flow of material and that there weren't any warships available for convoy duty. Dashing naval officers were not interested in the mundane task of shepherding slow merchant ship convoys when they could be out chasing submarines. However, Admiral Sims, while on his way to England as a passenger in a U.S. merchant ship, got some first-hand experience when a U-boat torpedoed the U.S. ship he was on and he became a survivor. Admiral Sims, who was Commander-in-Chief of the U.S. Navy operating from Great Britain during World War I, had been strongly opposed to convoys. After his personal experience, he became a strong proponent of convoys. Ultimately, Admiral Jellicoe was relieved as First Sea Lord, and the Royal Navy was ordered to convoy merchant ships. There was some foot-dragging and lack of enthusiasm on the part of the Royal Navy; however, the first small convoys sailed in May 1917.

When the ships started sailing in protected convoys, there was a dramatic reduction in sinkings. As the use of convoys spread, the number of sinkings by U-boats continued to decline. By November 1917, a complete ocean convoy system was in operation, and loss rates were reduced to 1.23% of sailings. Losses to U-boats dropped to 140,000 tons per month, and U-boat losses started to climb substantially because they were exposed to heavy counterattacks by the armed escorts of the convoys. In the Mediterranean, the U-68, Oberleutnant Karl Dönitz commanding, aggressively attacked a Malta-bound convoy and ended up a prisoner of war when the escorts fatally damaged his U-boat. The future leader of Germany's World War II submarine forces clearly understood the risk involved in attacking a convoy protected by armed escorts.

There is no doubt that the convoy system was the key factor in reducing Allied shipping losses from the U-boat menace, and this reduction was a major factor in the overall Allied victory. Kommodore Bauer, the commander of the German U-boats, recognized that the convoys substantially reduced the effectiveness of his U-boats because the convoys were difficult to locate and an attack by a single U-boat against a well-protected convoy was generally ineffective. He proposed that the supply submarine *Deutschland* be outfitted as a command and communications submarine so that he could direct his U-boats at sea and conduct coordinated submarine attacks against the convoys. Fortunately, he was overruled, and it was not until World War II that “wolfpacks” were used to attack convoys.

The use of convoys to counter the submarine threat was the single most important lesson learned in naval warfare during World War I, and, unfortunately, when World War II started, the lesson had to be learned all over again. During the war, the U-boat offensive had resulted in the unbelievable total of over 5,000 ships being destroyed, and the first primitive ASW weapons, including hydrophones and depth bombs, had come into common use.

In the Mediterranean, during the Gallipoli operations, the British used a seaplane carrier, the *Ben-my-Chree*, that was equipped with Short Type 184 seaplanes to conduct aircraft torpedo attacks against Turkish ships in the Dardanelles. Although these early aircraft could barely get off the water with a heavy torpedo, they did successfully attack and sink some Turkish vessels, thereby demonstrating that torpedoes could be used by airplanes to sink surface ships. This new weapon system was to play a major role in World War II.

Because the torpedoes used compressed air as an oxidant, the nitrogen and exhaust gases produced a visible wake. When a torpedo was fired, the wake frequently alerted the target, allowing it to take evasive action. The torpedo wake also disclosed the location of the firing submarine. Late in the war, the Germans developed a wakeless electric torpedo that neither alerted the enemy nor disclosed the location of the firing submarine. When the war ended, the Germans quietly transferred this technology to a neutral country, and it reappeared in World War II as the highly successful G7e torpedo.

By the end of World War I, there was absolutely no doubt that the torpedo was an awesome weapon that had dramatically changed naval warfare. It had been successfully used by all types of surface ships, including battleships, cruisers, destroyers, Q-ships, and small speedboats. It had destroyed just about any surface vessel, including huge battleships, ocean liners, and square-rigged sailing ships. Submarine torpedoes had decimated the British merchant fleet and had come perilously close to achieving a major strategic victory by severing Britain’s essential sea lines of communication.

Its successful use from aircraft completed the cycle, as the torpedo became a universal weapon used by surface ships, submarines, and aircraft. With over 10,000,000 tons of shipping destroyed and thousands of lives lost, there was no doubt that the torpedo was an effective weapon. However, because of the ruthless way that the weapon was used, the word “torpedo” soon took on a sinister meaning, and the torpedo became the most hated and feared weapon ever conceived by man. Total war is brutal, and everyone was sickened by the torpedoing of hospital ships, passenger liners, and

unarmed merchant ships. Even professional naval officers had no great love for the torpedo because it had upset so many of their cherished doctrines. The torpedo got most of the blame, but the decision to conduct total war was made by national leaders at the highest levels, with the orders issued by flag rank officers. There were many available leaders and officers to share the glory for the successes; but the torpedo, like the private, was responsible for executing the orders, and it got all the blame for the suffering and death that resulted.

Chapter 10

WORLD WAR II

When World War II started in September 1939, the war at sea was essentially a continuation of World War I, only on a grander scale. In World War I, the torpedo had been demonstrated to be a major naval weapon, so surface ships, submarines, and aircraft were all armed with torpedoes when World War II started. Battleships had grown in size to over 40,000 tons with 16-inch guns, and a new type of combatant, the aircraft carrier, had joined the fleet to challenge the battleship's role as "queen of the fleet." During the 1930s, the Germans had started a major program to rebuild their surface navy, but, when the war started in 1939, only a few of the new ships had been completed and the German Navy was again hopelessly outclassed by the British navy. Admiral Erich Raeder, Commander-in-Chief of the German Navy, was forced to realign his priorities and dedicate his limited resources to an expanded submarine construction program.

Germany had continued to work covertly on submarines after World War I, and significant improvements had been made. The new submarines were much quieter, could stay under water longer, and had more efficient batteries. Also, improved long-range radios made coordinated operations feasible. Torpedoes had also been improved. Electric propulsion systems provided wakeless operation to minimize alert and detection, and a new magnetic influence exploder had been developed to increase warhead effectiveness by having the torpedo explode under the keel of the ship. When the war started in September 1939, the German Navy had only 57 submarines, and the majority were small coastal units. Only 22 oceangoing submarines were available for North Atlantic operations, and, in spite of the expanded building program, for the first year of the war, new deliveries were limited to two units per month.

On September 27, 1935, Captain Karl Dönitz was selected to command the new Weddigen U-boat flotilla, and he postulated that submarines used against merchant shipping in conventional *guerre de course* warfare would not be effective. Expanding on the concept proposed by Kommodore Sauer, the German U-boat commander in World War I, Dönitz developed a centralized command and control system so that he could direct U-boat operations from a shore-based command post and orchestrate concentrated attacks against merchant ships whenever they were detected. He also planned to concentrate his U-boats in the Atlantic so that he could cut off the seaborne flow of material to Great Britain and isolate the island nation. Exercises, using small coastal submarines, were held in the Baltic Sea during the late 1930s to conduct coordinated attacks, and the concept of the World War II wolfpacks was born as Dönitz directed the attacks from a shore-based command post. The Germans signed the London Submarine Protocol of September 3, 1936, agreeing to adhere strictly to prize law and to provide for the safety of merchant ship passengers and crews in time of war. German U-boat commanders were ordered to adhere to the agreement.

Just prior to hostilities, all available U-boats were surge deployed, and the 22 U-boats in the Atlantic were advised by radio on September 3, 1939, that hostilities had started. On the second day of the war, the U-30, commanded by Korvettenkapitän Fritz-Julius Lemp, encountered a zigzagging blacked-out ship off the normal shipping routes. Lemp identified the ship (incorrectly) as an

auxiliary cruiser (a large merchant ship armed as an escort or patrol vessel) and torpedoed it. Unfortunately, it was the passenger ship *Athenia* with more than 1,400 passengers aboard, and 120 men, women, and children lost their lives when the ship went to the bottom. The U-30, maintaining radio silence, did not report the sinking, so the German Government denied the sinking and claimed it was a British attempt to discredit them. When the U-30 returned to port and the truth became known, the Germans refused to admit their mistake, and the London Submarine Protocol went to the bottom with the first ship sunk by a U-boat in World War II.

On September 17, 1939, Korvettenkapitän Otto Schuhart, commanding the U-39, demonstrated that the newest capital ship, the aircraft carrier, was also vulnerable to torpedoes. He fired three torpedoes at the British aircraft carrier *Courageous*, and it sank in 15 minutes with the loss of 518 crew members. Aircraft carriers were to play a major role in World War II, but, before the war was a month old, the ability of the torpedo to destroy this new type of warship had been demonstrated. Less than a month later, on Friday, October 13th, the U-47 successfully penetrated the main British fleet anchorage at Scapa Flow and sank the British battleship *Royal Oak*, the only battleship in the anchorage at the time, with a loss of 833 lives. The sinking of a battleship in the British fleet's home anchorage was a bitter pill for the British to swallow. Gunther Prien, the commander of the U-47, received the Knight's Cross of the Iron Cross and became a German national hero. The feat was even more impressive because the first attack against the *Royal Oak* failed when the torpedo influence exploders malfunctioned. Prien had to reload his torpedo tubes inside the anchorage and conduct a second attack to sink the *Royal Oak*.

Early in the war, the Germans had problems with their new magnetic influence exploders, and a number of ships escaped when the exploders failed to go off or exploded prematurely. On September 14, 1939, the U-39 had fired three of the new torpedoes with influence exploders at the British aircraft carrier *Ark Royal*. All three torpedoes exploded prematurely and left the *Ark Royal* unscathed; the U-39 was damaged and lost in the counterattack by the *Ark Royal*'s escorting destroyers. In spite of these problems, the torpedo was again demonstrating that it was a "giant killer" and that capital ships of all types and in all locations were vulnerable to torpedo attacks.

In April 1940, all U-boats were recalled from the Atlantic as the Germans massed their naval forces for the invasion of Norway. During the first 6 months of the war, the Germans had only about 15 U-boats operational in the Atlantic, and most of these were concentrated near the approaches to Britain to conduct submerged daytime attacks against unescorted merchant ships. Approximately 222 ships totaling 765,000 tons were sunk during this initial phase. In April, during the invasion of Norway, the torpedo exploder problem came into sharp focus as duds and prematures dramatically reduced the effectiveness of U-boat operations. Gunther Prien, the hero of Scapa Flow, commented bitterly that "you couldn't win a war using wooden rifles." The use of influence exploders was immediately discontinued, and Admiral Dönitz initiated a major investigation to find out why his torpedoes were malfunctioning. It was estimated that over 300,000 tons of shipping escaped because of torpedo failures during the first few months of the war.

During the Norwegian campaign, British submarines were also very active, attacking German naval and merchant ships. The British submarine *Truant* sank the light cruiser *Karlsruhe*; the *Spearfish* heavily damaged the "pocket battleship" *Lutzow*; and British submarines sank

approximately 100,000 tons of tankers, transports, and supply ships during the campaign. The German forces heading for Oslo had to force their way up the narrow Oslofjord, and, during this operation, a Norwegian shore-mounted torpedo battery sank the German heavy cruiser *Blucher*. The Norwegians had defensive 12-inch guns and torpedo tubes at a narrow point in the fiord, and the *Blucher* won the dubious honor of being the only major warship ever sunk by a torpedo fired from a shore battery. As soon as Norway was occupied, German naval surface units returned to their home ports, and the U-boats were redeployed.

When the U-boats were redeployed in June 1940, the increased effectiveness of British ASW measures made some basic changes in tactics necessary. The use of radar and aircraft combined with the increasing number of escorts and the use of convoys for ships under 15 knots made it difficult to conduct submerged daytime attacks. Most attacks were conducted at night on the surface and, although there still were not enough U-boats available to form wolfpacks, some coordinated attacks were conducted against convoys farther out in the Atlantic. When France fell in June 1940, French ports became available: this substantially reduced U-boat transit time and risks because the French ports were right on the Atlantic coast. In August, Italian submarines also deployed into the Atlantic to help the Germans by concentrating on shipping south of Lisbon. During this period, Italian submarines actually outnumbered German units by 25 to 18, but their performance was disappointing because they would not operate on the surface and use their mobility to seek out targets.

Once Dönitz discovered that most of the traffic was coming in through the northwestern approaches, the U-boats achieved substantial successes almost at once by concentrating on this patrol area. Between June and October, 274 ships were sunk, totaling 1,400,000 tons. The sinking rate started out with three ships sunk per month by each U-boat; by October, the average was five ships sunk per month for each U-boat on patrol. The loss of shipping was at a rate twice as fast as new ships were being built, and the British were hurting. However, when the Germans overran the Allied countries in Europe, over 3 million tons of shipping had become available; combined with highly efficient use of available bottoms, this reduced the magnitude of the crisis. Nevertheless, there was a pressing need for additional ships to support military operations, particularly in the Mediterranean.

The U-boat operations depended heavily on the submarine's ability to use its high surface speed to converge on a convoy once it was located. This mobility was badly hampered by aircraft since the submarine had to dive to escape attack every time an aircraft appeared, which severely increased transit time. Aircraft were not considered particularly dangerous, but they were effective in restricting the mobility of the U-boats. This was sufficient cause to move the U-boats to areas where they could operate undisturbed by aircraft patrols.

During 1941, the number of operational U-boats slowly began to increase as new boats became available, and the conflict intensified. However, the Germans also received some setbacks. In an attack against convoys OB 293 and HX 112 in early March, the Germans lost five submarines, including three of their greatest aces—Gunther Prien in the U-47, Otto Kretschmer in the U-99, and Joachim Schepke in the U-100. Each of these skippers had sunk over 200,000 tons, and Kretschmer, with 266,629 tons, was the war's greatest ace. The loss of these highly experienced officers was a severe blow for Admiral Dönitz. In spite of the losses, the U-boat attack continued, and the total

tonnage torpedoed continued to grow at an alarming rate. In the first 10 months of 1941, the U-boats sank 372 ships for a total of 1,847,000 tons.

During the second half of 1941, increasing difficulties were encountered by the U-boats. They had to move farther out into the Atlantic to escape air patrols, which increased their transit time, and the increasing number and effectiveness of escorts made attacks increasingly difficult. In the western Atlantic, convoys were being escorted by U.S. Navy destroyers. In spite of restrictions to avoid incidents, U-boats torpedoed and damaged the U.S. destroyer *Kearney* and sank the *Reuben James*. This led to a further deterioration in relations between Germany and the United States. In addition to submarines, the Germans also used long-range aircraft to attack convoys, and aircraft torpedoes sank hundreds of thousands of tons of merchant shipping during these aircraft attacks. German torpedo bombers operating from northern Norway severely mauled many of the convoys bound for Russia.

The merchant ship losses in 1941 again exceeded new ship construction, and the size of the British merchant fleet continued to decline. By the end of 1941, it was 3 million tons smaller than at the start of the war. Although neutral shipping on charter and American assistance largely offset this loss, civil and military shipping demands were reduced to essential requirements. During this early phase, the Germans had only about 25 to 35 U-boats on station in the Atlantic, and the staggering losses inflicted by these units gives credence to the claim that Britain would have suffered a strategic defeat if sufficient U-boats had been available at the start of the war to choke off the seaborne flow of food and raw material. In September 1941, the German High Command made a decision to cut back on the strategic battle against British shipping in the Atlantic and redeploy some of the U-boats into the Mediterranean to provide direct tactical support for the North African Campaign. The Italian Navy was in trouble, and the German U-boats were taking over.

At the start of World War II, the Italians dominated the Central Mediterranean Sea, and the British, from Gibraltar and Alexandria, controlled the eastern and western ends of the sea. The British also tenaciously hung on to the island of Malta near the boot of Italy, and this base caused the Axis powers much heartburn since it sat right on the supply lines to North Africa. On November 11, 1940, the British achieved a first in naval warfare when the aircraft carrier HMS *Illustrious* attacked the Italian fleet anchorage at Taranto in southern Italy. *Fairey Swordfish* torpedo bombers conducted a daring night attack from the *Illustrious* against one of the most heavily defended harbors in the world. These were open-cockpit fabric-covered biplanes affectionately known as “Stringbags.” In this air strike, launched from a single aircraft carrier, the torpedo again demonstrated its effectiveness as a major weapon—one battleship sunk, one left sinking, a third heavily damaged, and three cruisers damaged. This aircraft torpedo attack was a brilliant tactical success, and it had strategic implications because it changed the naval balance of power in the Mediterranean. The Japanese displayed a keen interest in this action since it demonstrated that aircraft torpedoes could be used successfully in a shallow fleet anchorage. A year later at Pearl Harbor, the Japanese were to employ the same tactics, only on a grander scale.

A few months later, in March 1941, an Italian naval force of eight cruisers, 13 destroyers, and a battleship sortied into the eastern Mediterranean to support their German allies during the Greek campaign. This sortie resulted in the battle of Cape Matapan, the first major naval battle since Jutland in World War I. Torpedoes launched by torpedo planes from the carrier HMS *Formidable*

damaged the Italian battleship *Vittorio Veneto* and the heavy cruiser *Pola*, which demonstrated the new fleet role of carrier-based torpedo bombers and set the stage for a major British naval victory. Torpedoes launched from British destroyers sank the *Pola* early the following day. The entire operation cost the British one aircraft and its crew, while the Italians lost three cruisers, two destroyers, and 3,000 sailors.

In May 1941, when the *Bismarck* escaped into the Atlantic, it was brought to bay when an aircraft torpedo launched by a Stringbag from the carrier HMS *Ark Royal* jammed its steering gear. The *Bismarck* engagement was also unique because it was one of the extremely rare occasions when a battleship (HMS *Rodney*) actually fired a torpedo at another battleship (*Bismarck*) and hit it. The torpedo, used by carrier-based aircraft, was demonstrating itself to be a potent new ingredient in naval warfare, for attacking ships in fleet anchorages and in fleet engagements.

Since neither the British nor the Italian Navy could gain absolute control of the Mediterranean Sea, it became a fertile ground for covert submarine operations. German, British, French, Italian, Greek, and Dutch submarines operated in the Mediterranean and sank large numbers of naval and merchant ships. British and German submarines conducted very aggressive operations and played a major role in the seesaw battle to control North Africa because troops, fuel, and ammunition all had to be transported by ships. British submarines, operating under great difficulty from bomb-ravaged Malta, interdicted the Axis sea lines to North Africa during 1941 and 1942 and sank approximately 1 million tons of shipping. The British also used long-range land-based torpedo aircraft to attack shipping, and air-delivered torpedoes accounted for another million tons of Axis shipping in the Mediterranean. Although these torpedoes were used to sink ships at sea, they had a direct tactical impact on the land battles in North Africa because the lack of fuel and supplies brought Rommel's Afrika Korps to a standstill in the desert and allowed the British to regain the initiative. British submarines were also effectively used to harass the Italian Navy by torpedoing a number of major surface units when they ventured to sea.

In September 1941, Hitler ordered Admiral Dönitz to move twenty U-boats into the Mediterranean to support the Italians because Rommel's sea lines of communication were being threatened. They had an immediate effect: on November 13th, the U-81 torpedoed the aircraft carrier *Ark Royal*, and it sank the next day. Twelve days later, the U-331 torpedoed and sank the battleship HMS *Barham*, and, on December 11th, the U-557 sank the cruiser HMS *Galatea*, off Alexandria. Also during December, the Italian submarine *Scire* achieved a new first in torpedo warfare when manned torpedoes, called chariots, penetrated the fleet anchorage at Alexandria and conducted an audacious attack on the anchored British fleet. The charioteers successfully placed their charges under the battleships HMS *Valiant* and HMS *Queen Elizabeth*, seriously damaging both of them and putting them out of action for some time. Who would have believed that two men riding a torpedo like a horse could successfully attack and damage mighty battleships that ruled the seas? It was a black day for the Royal Navy. Taken together, these actions represented a serious defeat for the British, since their only aircraft carrier in the Mediterranean had been sunk and the complete battle fleet in the eastern basin was out of action.

There were never more than 25 U-boats in the Mediterranean at any one time, and, initially, most of their activity was against naval vessels. During the first year, they sank a battleship, two aircraft

carriers, three cruisers, and twelve destroyers. They also sank HMS *Medway*, the only submarine tender the British had in the Mediterranean, and this severely hampered British submarine operations during a critical period. The U-boats also sank 95 merchant ships, totaling almost half a million tons, thereby forcing the Allies to use convoys for all Mediterranean traffic. The Mediterranean was a very active theater of operations: both the Axis and the Allies employed the torpedo with a vengeance. Torpedoes destroyed hundreds of vessels, thousands of sailors and soldiers, and millions of tons of critical war materiel. There is no denying that the torpedo played a major role in the seesaw battle for the Mediterranean Sea.

On December 7, 1941, the Japanese launched a preemptive multi-carrier strike against the U.S. naval base at Pearl Harbor, Hawaii, and the war expanded into the Pacific Ocean as Japan and the United States joined the conflict. The six-carrier task force crippled the U.S. Pacific Fleet in a highly successful surprise air attack against a sheltered fleet anchorage. The attack heavily damaged the ships and planes based at Pearl Harbor, and again the torpedo played a major role. Aircraft-delivered torpedoes sank or capsized four of the five battleships in the outside row at Ford Island (*Oklahoma, West Virginia, California, and Nevada*). This massive destruction, by carrier-borne torpedo planes, was a major factor in elevating the aircraft carrier to the role of premier capital ship. The delivery platforms were aircraft, but the heavyweight weapon that put the holes below the waterline and sank the battleships was the torpedo. During the early part of the Pacific campaign, the U.S. Navy was largely on the defensive because of the losses suffered at Pearl Harbor. As a consequence, submarines were employed to conduct many of the early offensive operations against Japanese naval and merchant shipping. The U.S. Navy was building new long-range submarines capable of transpacific operations, and these were to prove highly effective both in military and *guerre de course* operations.

When the U.S. entered the war, the Germans moved their longer-range Type VII and IX submarines across the Atlantic to interdict the dense, but unprotected, shipping along the U.S. East Coast. The ships along the East Coast, sailing without escorts, were easy targets, and the U-boat skippers referred to this phase of the war as the “happy time” since the targets were plentiful and easy to sink. Success was immediate and impressive as the U-boats conducted unrestricted warfare against unescorted ships. The U-123 sank eight ships off Cape Hatteras in a single 24-hour period. In January, U-boats torpedoed and sank 58 ships totaling over 300,000 tons in the western Atlantic, half of which were valuable tankers. There were never more than a dozen U-boats on station in the western Atlantic at any one time, but, during the first 7 months of 1942, they sank 681 ships or 3.5 million tons of shipping with the loss of only 11 U-boats. The toll would have been even greater if Hitler had not interceded, directing that 20 U-boats scheduled for the western Atlantic be diverted to other operational areas. By June, coastal convoys were in use all the way down into the Caribbean Sea. As the stiffer ASW defenses took hold, the “golden” times came to an end, and the U-boats moved back out into the North Atlantic to attack the huge convoys heading for Europe. The German U-boat offensive off the U.S. East Coast and in the Caribbean in the first half of 1942 was an outstanding success.

When the U-boats returned to the North Atlantic, the convoy battles quickly intensified. Defenses had stiffened: there were now over 400 escorts and 500 aircraft committed to the battle against the U-boats. The escorts had radio direction finding (RDF) equipment and radar to locate the U-boats,

and airborne radar was a major factor in locating surfaced U-boats and driving them off before they could attack the convoys. Also, the allies were forming hunter-killer groups with small escort carriers to hunt down U-boats once they were detected. To counter these technological advances, the Germans built special search receivers to warn them when radar-equipped planes were near, and U-boat tankers (“milch cows”) were deployed to resupply the U-boats on station.

U-boat production was in full swing, and the number of operational U-boats steadily increased. By the end of the year, almost 100 were on station. In spite of the improved defenses, the U-boats were able to average 100 sinkings, or half a million tons per month, during the last half of 1942. To accomplish this, they lost about 10 U-boats per month, but this exchange ratio—one U-boat lost for every 10 ships sunk—did not cause the Germans any great concern. Although the Allies had been able to support their military operations, there was still a shipping crisis. By the end of 1942, the Germans had sunk almost 8 million tons of shipping, mostly with U-boats, and this had slowed the military buildup. However, the massive U.S. shipbuilding program was paying off, and 7 million tons of these losses had already been replaced by new construction: there was no longer a fear that starvation or raw material shortages would shut down war industries.

Early in the war, Allied intelligence experts made a major breakthrough that enabled them to read German and Japanese codes. This vital intelligence capability, frequently referred to as the “Ultra Secret,” was highly classified and very closely held. In fact, the secret role of the code breakers did not become public knowledge until 20 years after World War II was over; during the war, only a small, select group of people had access to Ultra. Admiral Dönitz directed his wolfpacks by radio from his headquarters, and the code breakers were frequently able to decipher his messages and to determine German intentions. This ability to read their message traffic combined with the use of radio direction finders to locate them put the operational U-boats at a severe disadvantage. Convoys could be routed away from the U-boats, and the hunter-killer groups could be vectored toward the wolfpacks. In the Pacific campaign, similar intelligence information was used to provide U.S. submarines with vital clues on Japanese naval and merchant ship dispositions. Because the code-breaker information remained classified long after the war was over, most of the early analyses of World War II submarine operations were badly distorted since this critically important information was missing. Technology and tactics were important, but the “black” world of intelligence played a vital role in the final outcome, and its importance had been largely ignored by the analysts and historians.

During early 1943, there were over 200 U-boats available for operational use and another 200 in the refit and training pipelines. When convoys were located, Admiral Dönitz formed his U-boats into wolfpacks, directed by radio from his headquarters, to conduct concentrated attacks against the convoys. As more long-range aircraft became available, the U-boats were forced out into the Central Atlantic, and, with the introduction of small escort carriers, the whole Atlantic was blanketed with ASW aircraft looking for U-boats. The aircraft, supplied with RDF and intelligence information, were extremely effective in locating transiting U-boats on the surface, which severely hampered the U-boats’ ability to utilize their high surface speed to converge on a convoy once it was detected. Also, the aircraft were now using a new secret ASW acoustic homing torpedo, and there was a dramatic increase in U-boat sinkings by aircraft.

In March, the U-boats sank 108 ships totaling 627,000 tons and lost only six U-boats in attacks on convoys. By May, only 26 merchant ships were sunk, and 27 U-boats were lost in the attacks. The significant fact was the rapid rise in U-boat losses. Forty one U-boats were lost in a single month, which was nearly twice the building rate. Admiral Dönitz reluctantly withdrew his U-boats from the Atlantic, and the campaign against shipping collapsed. New U-boats were equipped with snorkels that allowed them to recharge their batteries while submerged, but, because of aircraft, they could no longer conduct high-speed surface transits; this fundamental loss of mobility drastically reduced their effectiveness. The U-boats continued to operate off the coast of England, but the great strategic offensive against shipping was essentially over. During their offensive, the Germans had lost 250 U-boats, but their submarine fleet had grown from 57 in 1939 to over 400 at the peak of their operations. The U-boats sank over 12.8 million tons of shipping and came perilously close to achieving victory. They failed only by a narrow margin. If the U-boat fleet had been built up more quickly, or if the massive U.S. shipbuilding program had faltered, the outcome would have been different.

The Germans initiated a crash program to build new submarines and torpedoes that would be capable of high-speed submerged operations for extended periods so that they could attack convoys without exposing themselves to attacks by aircraft. This was a major technological undertaking, and the Germans experienced considerable delays in getting these new systems operational. The new high-performance Type XXI and XXIII submarines, equipped with homing and pattern-running torpedoes, showed great promise but, fortunately for the Allies, the war ended just as the new submarines were ready to begin operating.

In the Pacific theater, less than a week after the U.S. Navy battleships were torpedoed at Pearl Harbor, Japanese land-based torpedo bombers attacked and sank the British battleships HMS *Repulse* and HMS *Prince of Wales*. The success of this attack dramatically demonstrated that torpedoes were making life awfully difficult for the mighty battleships. They were not safe either in a sheltered fleet anchorage or at sea. The torpedo played a major role in the Pacific campaign, and it was used extensively by both sides during many great sea battles. Early in the war, in the battle of the Java Sea, the Japanese decimated an Allied task force of American, British, Dutch, and Australian (ABDA) ships when they dramatically demonstrated the effectiveness of their high-performance Type 93 (“Long-Lance”) torpedoes. The existence of these oversized, wakeless, oxygen-fueled torpedoes was a closely held secret, and their brutal effectiveness in destroying Admiral Doorman’s ABDA Task Force of five cruisers and nine destroyers was a rude introduction to these new cruiser-destroyer torpedoes. In spite of the fact that they didn’t have radar, Japanese destroyers and cruisers were extremely proficient at conducting night torpedo attacks, and the U.S. Navy suffered substantial losses to Long-Lance torpedoes during the early phases of the Pacific campaign.

At the start of the war, the U.S. Navy used small torpedo boats (PT boats) to delay the Japanese invasion of the Philippines. As the war progressed, U.S. destroyers in Destroyer Squadron 23 (DESRON 23), under “31 knot Burke,” and in Destroyer Division 12, under Commander Frederick Moosbrugger, used the smaller and less effective U.S. Mark 15 destroyer torpedo in some highly successful operations against Japanese fleet units. During the Battle of Guadalcanal, the bottom of

“Iron Bottom Sound” was littered with Japanese and American ships of all sizes and types that were sunk by torpedoes during the long series of sea battles.

Later in the war, during the Battle of Leyte Gulf, the effectiveness of torpedoes launched from surface ships was again demonstrated when the “small boys” (destroyers and PT boats) of the U.S. Navy decimated Admiral Nishimura’s Southern Task Force during the Battle of Surigao Strait. Admiral Oldendorf’s destroyers and PT boats, operating in the narrow strait, conducted sustained night torpedo attacks against Nishimura’s force of two battleships, a cruiser, and four destroyers. Only one Japanese destroyer, the *Shigure*, escaped the onslaught. During the same Battle of Leyte Gulf, Admiral Kurita’s Central Force of five battleships, 12 cruisers, and 15 destroyers successfully penetrated San Bernardino Strait and were in position to annihilate Admiral Sprague’s small “Jeep” escort carriers and the huge, unprotected invasion fleet that the small, lightly armed escort carriers were providing air cover for. Admiral Sprague had only three destroyers and four destroyer escorts (DEs) available to defend his slow fragile carriers, and he immediately ordered them to lay smoke and conduct torpedo attacks against the vastly superior Japanese force. These small ships took a savage mauling from the Japanese battleships, but their torpedoes did delay the Japanese task force so that they were instrumental in saving the invasion fleet. During the Pacific campaign, surface ship torpedoes were particularly effective when used in narrow seas (Java Sea, Guadalcanal, Surigao Strait) since the target ships were limited in their evasive actions to escape the torpedoes.

The attack on Pearl Harbor and the sinking of the *Repulse* and *Prince of Wales* dramatically demonstrated that aircraft torpedoes had joined the ranks of major weapons. Torpedoes were the heavyweight weapon used by aircraft to sink ships, and, during the Pacific campaign, aircraft-launched torpedoes played a major role in many of the great sea battles. The torpedo was instrumental in making the carrier the premier capital ship, and it was also the archenemy of the carrier. Most of the carriers sent to the bottom of the Pacific Ocean were sunk because torpedoes had made large holes below the waterline!

U.S. Navy carrier doctrine was to use a simultaneous high-low attack by dive bombers and torpedo bombers against enemy surface ships. In the Battle of Midway, the first major sea battle in the Pacific War, unprotected torpedo bombers attacked the Japanese fleet before the dive bombers arrived, and they became the “turkeys” for Japanese gunners and fighter aircraft. In fact, Torpedo Squadron Eight from the carrier *Hornet* was totally destroyed. However, the Japanese fighters, low on fuel and ammunition, had to return to their carriers. When the dive bombers arrived, the Japanese fighters were back on deck being refueled, which allowed the dive bombers to successfully attack the carriers and inflict severe damage. As the war progressed, the high-low attack techniques were perfected, and carrier-based aircraft took a heavy toll on Japanese ships. In the closing days of World War II, carrier aircraft from Admiral Mitscher’s Task Force 58 sank the Japanese super battleship *Yamato*, which provided a final demonstration that torpedo-equipped carrier-based aircraft were effective “giant killers.” The world’s mightiest battleship sank to the bottom of the Pacific Ocean because U.S. Navy Mark 13 torpedoes had made numerous large holes below the waterline, which caused the ship to fill with water and sink.

The performance of the Japanese submarine force in World War II was, at best, mediocre. The Japanese had a modern, well-equipped submarine force, and their Type 95 torpedo, with pure oxygen

as the oxidizer, was both reliable and effective. However, the submarines were poorly employed. They were frequently used in a direct fleet support role as scouts or to form picket lines, but there was no major campaign against U.S. merchant shipping. They did sink or damage a number of major U.S. Navy ships, but, as the war progressed, submarines were increasingly used as underwater supply vessels to transport essential supplies to isolated garrisons that had been bypassed. The Japanese seemed fascinated with mini-submarines and, starting with Pearl Harbor, they were used a number of times to attack ships in sheltered harbors. Late in the war, Kaitens, or “human torpedoes,” which were the underwater equivalent of the kamikaze aircraft, replaced the mini-submarines. These suicide weapons sank a few ships, but their effectiveness was very limited because they were difficult to deploy.

SUBPAC got off to a modest start, but, as the war progressed, it became evident that the new, large, 300-foot-long, 1,700-ton fleet submarines, with 10 torpedo tubes and 24 torpedoes, were superb fighting machines and ideally suited for the Pacific. These submarines provided a firm foundation for a brilliant U.S. Navy submarine campaign. Immediately after the attack on Pearl Harbor, the United States directed that unrestricted air and submarine warfare be conducted against Japan, and a half a dozen fleet submarines were dispatched to Japanese home waters to implement this directive. Japan, as an island nation, was nearly totally dependent on seaborne lines of communication, importing 35% of her raw materials and 20% of her food. An attack on shipping, therefore, offered a decisive way to defeat Japan. During 1942, some 500 attacks were made on merchant ships, and approximately 140 ships totaling over half a million tons were torpedoed and sent to the bottom while the U.S. Navy lost only four submarines.

The SUBPAC submarines were off to a respectable start, but the high number of missed attacks suggested that there was a serious torpedo problem. Admiral Lockwood, who served as Commander, Submarines, Pacific Fleet, during most of the war, ordered controlled tests to be conducted to verify a suspected torpedo depth-keeping problem. The Bureau of Ordnance in Washington and the Naval Torpedo Station at Newport were reluctant to even admit there were any problems. Admiral Lockwood got involved in a bitter bureaucratic paper war to correct a number of serious torpedo deficiencies, including depth-keeping errors, erratic influence exploders, and faulty contact exploders. It took almost 18 months to correct all of the problems, and it was not until late in 1943 that the U.S. Navy had reliable torpedoes. Since all U.S. Navy torpedoes were similar in design, these problems were common to submarine, surface ship, and aircraft-launched torpedoes and adversely affected the performance of all of these weapons during the early part of the war. Early in the war, a German electric G7e torpedo was captured, and the design was duplicated by Westinghouse Company for the U.S. Navy as the Mark 18 torpedo. Approximately 1 million tons of ships were sunk by the wakeless Mark 18 torpedo, which became operational in 1943.

In 1943, as more new submarines became available, the attack on commerce intensified as the average number of submarines on patrol rose to 18. In January, the *Wahoo*, under Commander “Mush” Morton, attacked a convoy off New Guinea, sank three ships (about 12,000 tons), and damaged a fourth. In March, in the Yellow Sea, the *Wahoo* sank nine additional ships (nearly 20,000 tons). By September, there were enough submarines available to experiment with wolfpacks. The first wolfpack (*Cero*, *Shad*, and *Grayback*) sank 24,000 tons, and the second (*Snook*, *Harder*, and

Pargo) sank 32,000 tons of shipping. Since the *Trigger* sank four ships (26,000 tons) by herself during September, the value of wolfpacks remained undetermined. During 1943, submarine-caused shipping losses averaged over 100,000 tons per month, growing to over 200,000 tons in November. Over 300 ships were sunk, and total losses amounted to over 1,800,000 tons. The Japanese made an immense effort to replace their shipping losses by building over 800,000 tons, but their tonnage was steadily declining. Supplies of food and raw material were growing critically short.

In 1944, with the delivery of 66 new boats, SUBPAC had 123 submarines operating in the Pacific. With the torpedo problems resolved, they really began to hit their stride. By this time, the Ultra, or “codebreaker,” information was being used efficiently to identify enemy ship movements and to deploy the submarines to areas that were rich in targets. In January, they sank 50 ships totaling close to 250,000 tons, and they did even better in February. The newly developed SJ search radar was now installed on all the boats, and, by midyear, wolfpacks were tearing apart Japanese convoys. In July, “Donk’s Devils” (*Picuda*, *Redfish*, and *Spadefish*) sank 13 ships for over 64,000 tons—the highest wolfpack score to date.

The *Tang*, skippered by Commander Richard O’Kane, was one of the top boats in SUBPAC when it went out on patrol in September 1944. O’Kane had a highly successful patrol, sinking 7 ships, which raised his total to 24 ships and made him the leading U.S. ace in terms of ships sunk. When O’Kane fired his last remaining torpedo, a Mark 18, at a Japanese ship, it malfunctioned, circled, and sank the *Tang*, in a rare documented case of a firing vessel sunk by its own torpedo. Fortunately, O’Kane survived the sinking and became a prisoner of war. After the war, he became an admiral. He received the Congressional Medal of Honor, three Navy Crosses, three Silver Stars, and the Legion of Merit for his exploits. The last 3 months of 1944 sealed the doom of the Japanese merchant fleet as the monthly totals of shipping lost grew to 300,000 tons. During 1944, SUBPAC submarines sank over 500 ships, totaling over 2.5 million tons.

The Japanese were running out of food, oil, and raw materials, but the ships needed to transport these materials were in critically short supply. U.S. Navy submarines had severed the vital sea lines of communications, and the collapse of Japan was only a matter of time. In addition to their brilliant success in guerre de course warfare, U.S. Navy submarines were also a major factor in the naval war, accounting for almost one-third of all the warships sunk during the conflict. The final year of the war was somewhat of an anticlimax since there weren’t many ships left to sink. At the end of the war, Admiral Lockwood and SUBPAC claimed that U.S. submarines had sunk about 4,000 ships, totaling about 10 million tons. After the war, these figures were reviewed by the Joint Army-Navy Assessment Committee (JANAC) and reduced to 1,314 ships sunk, for a total of 5.3 million tons. The true number lies somewhere between these two estimates.

The vast majority of the torpedoes used with such devastating effectiveness in World War II were very similar to the torpedoes used in World War I with minor improvements. The Germans completed their electric propulsion development and introduced the wakeless electric G7e torpedo. The Japanese, using pure oxygen, produced their high-performance Type 93 and 95 torpedoes. In World War II, torpedoes, fired from all types of platforms, destroyed thousands of ships and an awesome amount of critical war materiel. These staggering losses severely taxed the industrial capacity and resources of the nations involved, and huge investments in defensive systems (escorts,

aircraft, hunter-killer groups, etc.) were required to protect shipping. Additionally, these huge defensive requirements tied up resources that were urgently needed for offensive operations. In World War II, the torpedo played a major role both at the tactical and the strategic level, and it was demonstrated to be the most destructive weapon ever conceived by man for destroying ships. With the exception of the nuclear bomb, the torpedo had the greatest single impact of any single weapon used in World War II.

Early in the war, German, British, and U.S. scientists embarked on highly classified research programs to develop passive acoustic homing systems that would allow torpedoes to home on the radiated noise generated by ships or use active sonar to “ping” and home on target ships. The German efforts concentrated on a passive homing torpedo to be fired from their new Type XXI and Type XXIII submarines in true underwater attacks where the submarine’s periscope would not have to be exposed, thereby substantially reducing the possibility of counterattacks by surface ships and aircraft. The G7es (T5) Zaunkönig (Wren) was an acoustic torpedo called the GNAT (German Navy Acoustic Torpedo) by the British. These primitive homing torpedoes were used against convoy escort vessels in 1943–1944 from conventional U-boats but with limited success. During interrogation of a captured U-boat sailor, intelligence experts had learned about these new “wonder weapons,” and this information was used to develop a towed acoustic noisemaker (codenamed “Foxyer”) to decoy the acoustic torpedoes. The Foxyer proved to be a very effective countermeasure. Once again, good intelligence played a major role in offsetting the effectiveness of a new weapon and saved countless ships and men. However, the results might have been different if the Germans had managed to get their Type XXI and Type XXIII submarines operational: the homing torpedoes could have been fired from fully submerged submarines of these types without alerting the target.

On the other side of the Atlantic, Dr. Vannevar Bush’s National Defense Research Committee (NDRC) pursued a major technological initiative to develop acoustic homing torpedoes for use against submarines. This major pioneering scientific effort on acoustic torpedoes was directed by Dr. James Conant of Harvard University, and the development effort was led by Western Electric Company. This highly successful effort culminated in the air-delivered passive acoustic torpedo Mark 24 (designated a Mark 24 mine for security purposes) being delivered to the U.S. fleet in 1943. The existence of an operational acoustic torpedo was a closely held secret during the war. However, it was used extensively by U.S. and British aircraft: over 50 U-boats were sunk or damaged by the Mark 24 mine (torpedo) during the latter part of the war. The U.S. Navy also developed an anti-escort homing torpedo designated a Mark 27 mine (torpedo) and an anti-surface ship weapon designated a Mark 28 mine (torpedo). Late in the war (1944–1945), Marks 27 and 28 torpedoes were used by SUBPAC submarines against Japanese naval and merchant ships. Over 100 of these weapons were fired by SUBPAC submarines, and they sank or damaged approximately 35 ships.

By the end of the war, the acoustic homing torpedo had been used successfully by both the U.S. and German Navies in combat operations. These revolutionary new weapons sank both submarines and surface ships in combat operations, thereby demonstrating the versatility of the new homing torpedo. A half century earlier, the torpedo had become the first guided missile when the gyro was installed; with the introduction of acoustic homing systems, it became the first successful homing

missile. This new “first,” achieved in the crucible of wartime combat operations, indicated major new roles for acoustic homing torpedoes in naval warfare.

Our complex modern society is critically dependent on seaborne trade to maintain a vitally needed exchange of food, raw materials, and finished goods. In World Wars I and II, the torpedo was demonstrated as a weapon with an awesome ability to sever seaborne lines of communication and isolate island nations. There is a real need to examine and understand the full impact of this often ignored weapon because it, like nuclear weapons, represents a potential strategic threat that can cause the total population of a nation to undergo great suffering. For example, if all seaborne oil imports to the United States were suddenly terminated, it would have a devastating impact on our modern industrial society. Also, the modern acoustic homing torpedo has provided the keystone for the development of extensive new weapon systems since it provided the foundation for the development of billions of dollars’ worth of air, surface, and submarine ASW systems in the postwar years. During the first half of the 20th century, the torpedo had grown from a naval curiosity to become the most destructive naval weapon ever conceived by man.



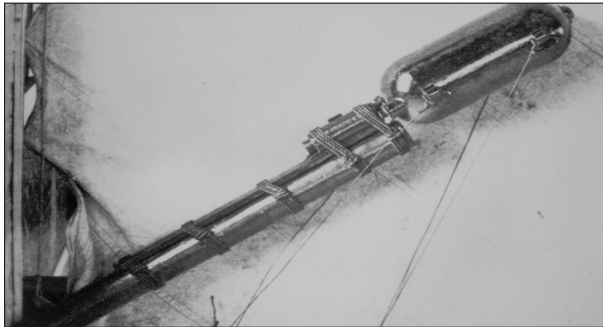
GREEK FIRE

The Byzantine Empire's ships used pressurized nozzles to spray incendiary liquid onto enemy ships through pressurized hoses, causing intense fires that were difficult to extinguish.



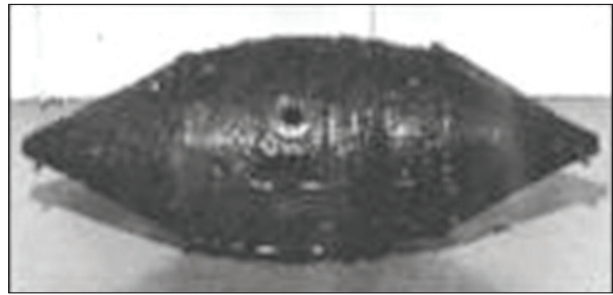
HM OLYMPIAS

A reconstruction of an ancient Athenian trireme with its ram. With trained oarsmen, the ram became an early and effective naval weapon.



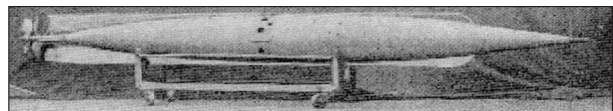
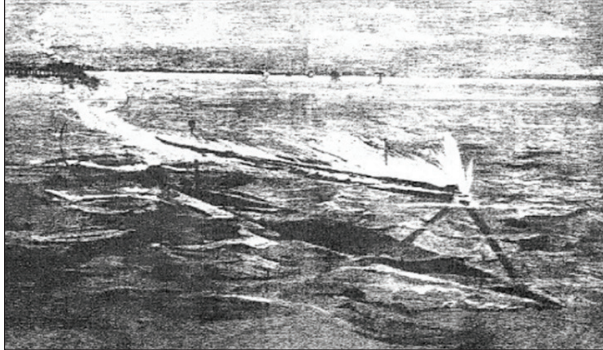
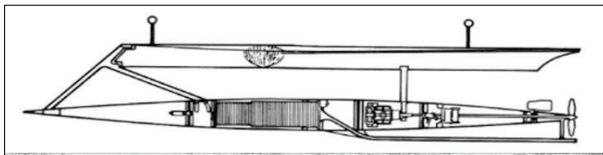
SPAR TORPEDO

Spar torpedoes were used with some success during the Civil War (1861–1865). In 1873, NTS Newport conducted a series of experiments on these weapons in an effort to increase their combat effectiveness.



BUSHNELL KEG MINE

In 1777, Bushnell constructed several floating torpedoes consisting of submerged kegs filled with gunpowder that were supported at the desired depth by buoys floating on the surface. The kegs were designed to explode when the buoy collided with any object.

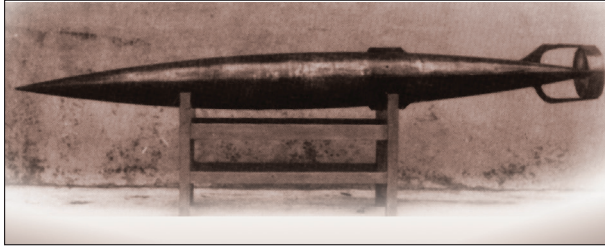


EARLY WHITEHEAD TORPEDO

In 1866, an English engineer named Robert Whitehead designed a freakish new naval weapon called an automobile or fish torpedo that was a self-propelled underwater projectile powered by a compressed-air engine with a secret depth control system.

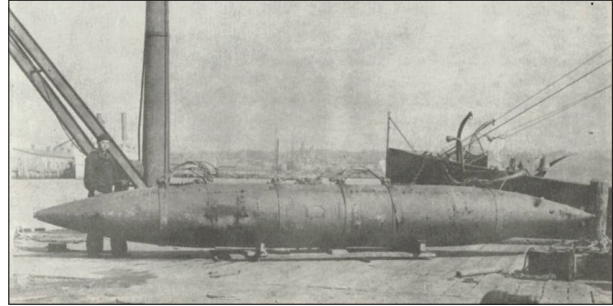
SIMS-EDISON TORPEDO

An electric-powered torpedo powered by a generator located on the firing platform. The wire was carried in the torpedo on a spool that unwound as the torpedo went through the water



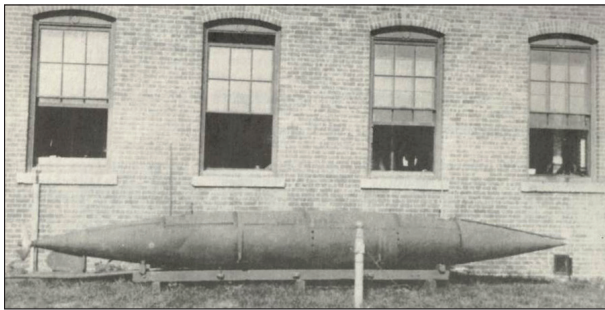
“FISH” TORPEDO

In 1871, Admiral Porter directed NTS Newport to “examine closely into the subject and ascertain if torpedoes of this plan [similar to the early Whitehead designs] cannot be gotten up.” The NTS Fish torpedo, the Navy’s first self-propelled torpedo, was built by NTS Newport later that year.



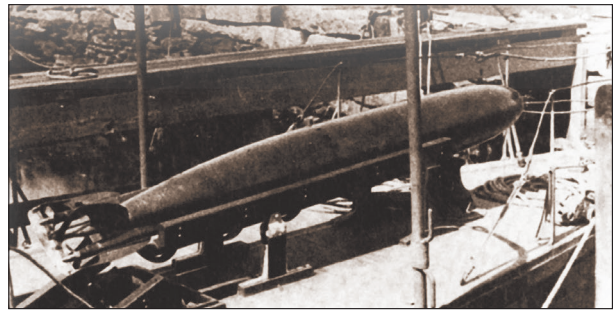
CUNNINGHAM TORPEDO

In the early 1890s, Patrick Cunningham designed a submerged-launch, rocket-powered torpedo. Although there were spiral ribs on the outer case to spin stabilize it, the torpedo lacked directional stability.



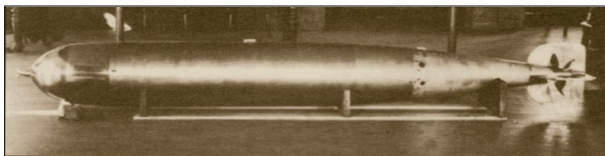
LAY TORPEDO

A chemical torpedo propelled on the surface by a reciprocating engine operated by superheated carbonic acid gas. Two cables were payed out from the torpedo to the controlling ship or station to allow the operator to steer the torpedo by electrical signals (1872).



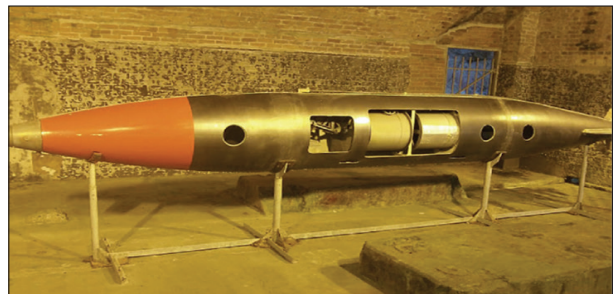
HOWELL TORPEDO

Circa 1880, LCDR J. A. Howell (later RADM Howell) developed the first U.S. torpedo to achieve production status. Powered by a 132-pound flywheel, the Howell torpedo was in service from 1890 to 1898. It was manufactured by the Hotchkiss Ordnance Co. of Providence, RI. Photograph shows a Mark 1 Howell torpedo on the deck of torpedo boat *Stiletto* at NTS Newport in 1898.



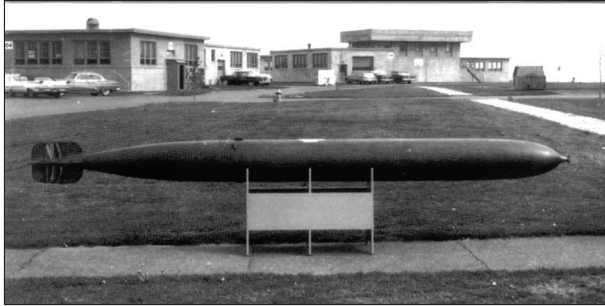
MARK 1 WHITEHEAD TORPEDO

The longer version of the Mark 1 carried an explosive charge of 220 pounds and had the Obry steering gear (gyro control in azimuth). The torpedo’s three-cylinder reciprocating engine ran on cold, compressed air.



BRENNAN TORPEDO

This locomotive torpedo was propelled by onshore power-driven capstans reeling in piano wire from two spools in the torpedo. Each spool was attached to a propeller shaft with suitable gearing so that the propeller shaft rotated with the connected spool as the wire was pulled by the capstan.



SCHWARTZKOPFF TORPEDO

German torpedo based on the Whitehead fish torpedo but using bronze rather than steel for added corrosion resistance. Designed in 1873. The Russian navy adopted it circa 1904.



BLISS-LEAVITT MARK 7 TORPEDO

An 18-inch diameter torpedo with a range of 6000 yards and a speed of 35 knots was introduced in 1912 with the next significant step in technology: a water spray introduced into the combustion pot along with the fuel spray made a steam torpedo a reality. The German G7a was a similar steam-driven torpedo.



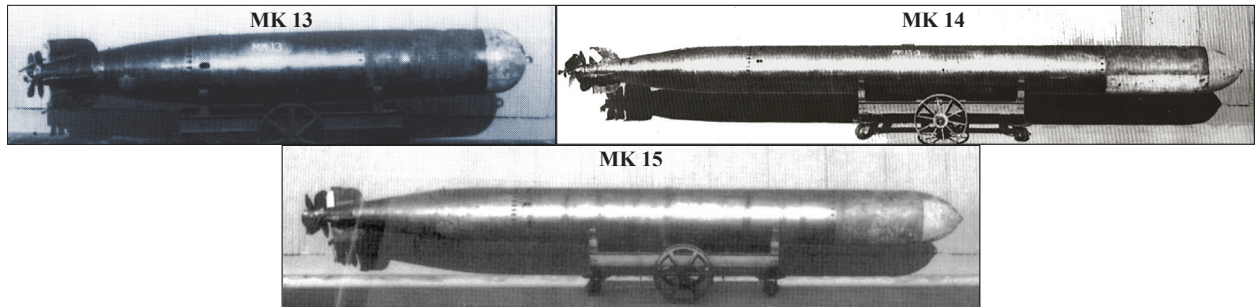
BRITISH MARK VIII TORPEDO

The British improved their basic Whitehead torpedo with a semi-internal combustion, or “burner-cycle,” engine that significantly reduced the expendables consumption rate, but the new British Mark VIII torpedo was still essentially an improved Whitehead torpedo similar to those used in World War I.



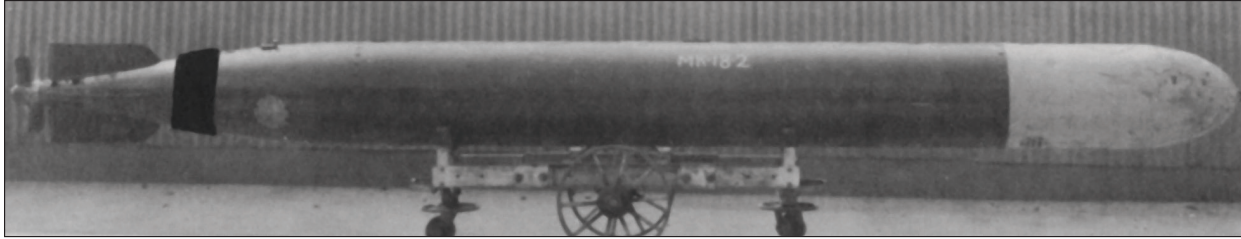
JAPANESE TYPE 93 TORPEDO – THE “LONG LANCE”

This WW II surface-launched torpedo was almost 30 feet in length and 24 inches in diameter. It had a 1080-pound warhead. The Type 95 torpedo was the submarine-launched variant. The Long Lance was designed to cripple or sink battleships. Its large warhead made it vulnerable to air attack and the possible detonation of the warhead while on the ship.



MARK 13, MARK 14, AND MARK 15 TORPEDOES

During the 1930s, the U.S. Navy initiated development of a new family of modern, turbine-powered torpedoes with large warheads. The 22.5-inch-diameter, 2200-pound Mark 13 torpedo with a 600-pound warhead was authorized by the Navy in 1930 to provide a new torpedo designed specifically for use by aircraft. This was followed by the 21-inch by 246-inch-long Mark 14 torpedo with a 643-pound warhead for use by submarines. The Mark 15 was a 21-inch-diameter, 288-inch-long torpedo with an 825-pound warhead, designed for use on destroyers.



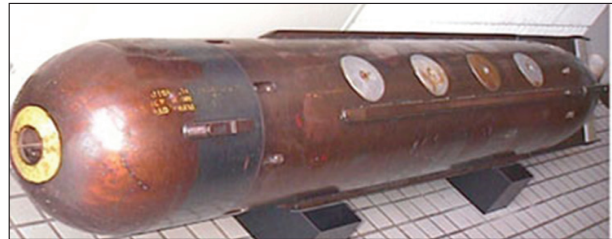
MARK 18 TORPEDO

The Mark 18 was an electric torpedo that was “cloned” from a captured German G7e torpedo for the U.S. Navy. It was a wakeless electric torpedo, which greatly reduced the possibility of alerting the target during daytime attacks. The Mark 18 was used by SUBPAC submarines to sink over 1 million tons of Japanese shipping during the latter part of the war.



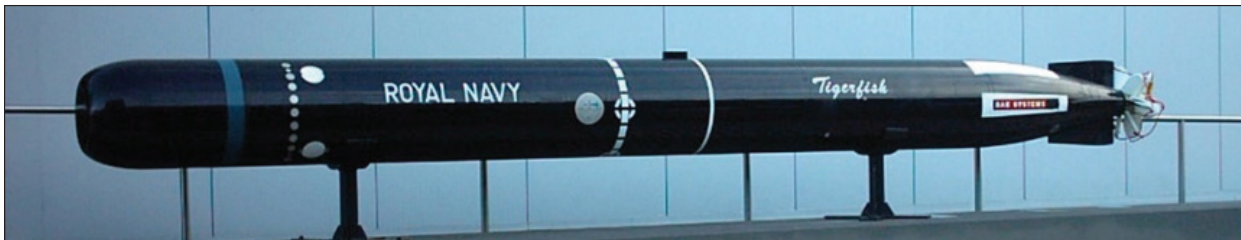
G7ES (T5) ZAUNKÖNIG (WREN) TORPEDO

Developed early in WWII by Germany, the G7es had a passive acoustic homing system that would allow torpedoes to home on the radiated noise generated by ships. The torpedo was to be fired from their new Type XXI and Type XXIII submarines in true underwater attacks where the submarine’s periscope would not have to be exposed.



MARK 27 TORPEDO

The Mark 27 passive homing torpedo was developed for use by U.S. submarines in the Pacific to attack Japanese escorts. About 106 of the Mark 27 Mod 0 torpedoes, introduced in late 1944, were fired during the final year of the war, with 33 hits (31%) resulting in 24 ships sunk and 9 ships damaged.



BRITISH SPEARFISH TORPEDO

The British began developing this heavyweight torpedo in the early 1980s. It is a wire-guided weapon with a sophisticated computer-based homing system. It utilizes an Otto Fuel-powered, turbine-driven, thermal propulsion system.



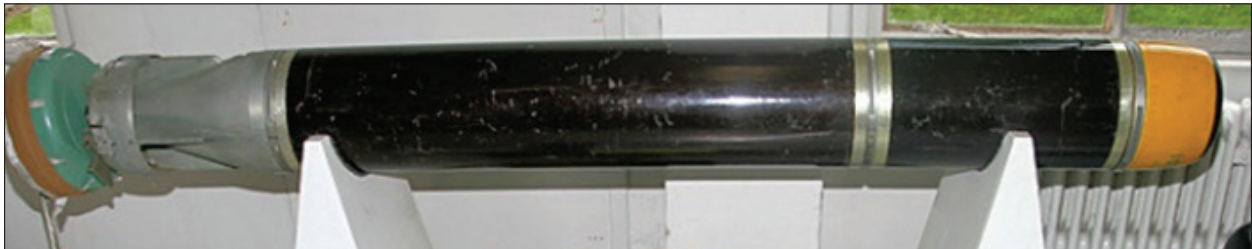
MARK 45 TORPEDO

During the 1950s, the U.S. Navy generated a requirement for a submarine-launched torpedo with a nuclear warhead. The torpedo development, conducted by the Westinghouse Corporation, produced a 19-inch-diameter, 225-inch-long, seawater battery-powered electric torpedo with wire guidance capability and a nuclear warhead. The Mark 45 nuclear anti-ship anti-submarine torpedo, which went into production at Westinghouse in 1959, was restricted to use by the U.S. Navy.



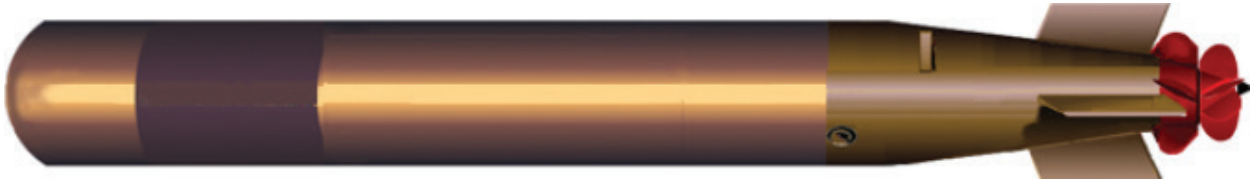
MARK 37 TORPEDO

When the Mark 37 torpedo, with an active/passive homing system, was issued in the early 1950s, the U.S. Navy submarine force got its first torpedo designed specifically for the new ASW mission. Shortly after the Mark 37 torpedo entered the fleet, the Navy decided that the firing submarine should have the capability to control the torpedo during its run to the target, so a mid-course guidance system was needed. The improved wire-guided Mark 37 Mod 1 torpedo entered the fleet in the early 1960s.



MARK 43 TORPEDO

The Mark 43 was the U.S. Navy's first lightweight multiplatform ASW torpedo. Intended for deployment from early helicopters, the Mark 43's smaller diameter and light weight allowed it to be deployed from ASW helicopters, fixed-wing aircraft, and surface ships and also as a rocket-thrown standoff weapon.



MARK 46 TORPEDO

The Mark 46 Mod 1, an excellent ASW torpedo, was designed to effectively counter the first-generation nuclear submarine threat. It was widely used on U.S. Navy and Coast Guard surface ships equipped with multi-barrel Mark 32 torpedo tubes as a payload for the Antisubmarine Rocket (ASROC) surface ship ASW standoff weapon, as well as on land- and carrier-based ASW aircraft, and on ASW helicopters. The Mark 46 Mod 1 torpedo was also approved for foreign military sales and was purchased by a number of foreign countries.



MARK 50 TORPEDO

The Mark 50, designed with the latest high-technology subsystems, was the first of a new generation of scientifically designed torpedoes. The Mark 50 torpedo has a closed-cycle thermal propulsion system, a new high-energy warhead design, and a computer-based, software-controlled active/passive homing and guidance system.



MARK 48 TORPEDO

The Mark 48 is designed to combat fast, deep-diving nuclear submarines and high-performance surface ships. The Mark 48 Mod 1 had an advanced homing system with significantly improved countermeasure resistance, and it used the new Otto Fuel monopropellant to drive a swashplate piston engine. It became operational on U.S. Navy submarines in 1972. The ADvanced CAPability (ADCAP) upgrade provided a totally new digital homing and guidance system that employs a two-way wire guidance system to share target information with the submarine during its run.

Chapter 11

TORPEDOES FROM SURFACE COMBATANTS

When Robert Whitehead invented his automobile torpedo, the British Royal Navy, as the undisputed ruler of the seas, had a vital interest in this new weapon. The vast British Empire was held together by seaborne trade, and it was essential that the Royal Navy maintain control of the seas to ensure trade and communications. If this new weapon could sever the sea lines of communications or challenge the supremacy of the Royal Navy, the British Empire would be threatened. Since they had the world's largest navy, the British had the most to lose if the torpedo proved to be a major threat to traditional naval power. The astute British were sensitive to this risk, and both the Royal Navy and British shipbuilders displayed a keen interest in Whitehead's new weapon. The Royal Navy was the first major sea power to purchase manufacturing rights from Whitehead in 1871, and they built their own factory to build torpedoes in the Royal Laboratory at the Royal Arsenal, Woolwich. The British also began to experiment with above-water torpedo tubes mounted on the ship's deck. These tubes used either compressed air or a small powder charge to impulse the torpedo out of the tube and into the water. Whitehead objected to these launchers; he claimed his delicate torpedoes were not designed to be fired out of cannons. However, the torpedoes did survive the above-water impulse launchings, and, within a few years, this was the most popular method of launching torpedoes from surface ships.

By 1874, the British were designing their new ships to carry torpedoes, and they also initiated a retrofit program to modify some of their existing ships to carry torpedoes. British shipbuilders, such as John Thornycroft, Samuel White, and Alfred Yarrow, were quick to see the potential of the torpedo, and they started building small high-performance steam launches designed to launch torpedoes in attacks against capital ships. These little "giant killers" were a popular item for sale to foreign navies, and, much to the dismay of the Royal Navy, hundreds of them were built and sold to navies all over the world. The French acquired a fleet of over 200 torpedo boats, and they had visions of using them to overwhelm the mighty Royal Navy in the narrow English Channel with massed torpedo attacks. The British were leaders in using the new torpedo for naval warfare: within a few years, they were installing torpedoes on all types of vessels, from 5-ton launches to battleships.

The *Inflexible*, laid down in 1874, was the first British battleship designed to include torpedoes as part of its offensive armament. She had two underwater Whitehead-type torpedo tubes mounted in the bow, two 14-inch above-water torpedo launchers on the main deck, and two 60-ton second-class torpedo launches on deck skids. This was a pretty extensive torpedo suite, and it indicated that the British were serious about using the torpedo. Most of the other navies followed the British lead, so most of the battleships built during the last quarter of the 19th century were armed with torpedoes. Underwater bow-mounted torpedo tubes became standard equipment on most of the new battleships. In fleet exercises, British battleships used their small deck-carried torpedo launches, much like modern torpedo boats, to attack other warships without exposing themselves to counterattacks. On occasion, the launches were also used to attack enemy ships that were in shallow water or in a

protected anchorage. Japanese battleships fired some torpedoes during the battle of Tsushima in 1905, but they had no bearing on the outcome of this great sea battle.

Although early battleships did not make extensive use of torpedoes as offensive weapons, defense against torpedo attacks was a major concern. Navies undertook extensive defensive measures to protect battleships from torpedoes, including massive nets to protect capital ships when they were anchored. Battleship design modifications included armored sides below the waterline and double bottoms, extensive secondary armament to fight off torpedo boats, and compartmentation to increase survivability. Damage control measures including controlled flooding, and ship speeds increased dramatically. Also, the size of the big guns steadily increased in an effort to keep engagement ranges beyond torpedo firing ranges. Naval tacticians considered that torpedoes introduced an unacceptable element of uncontrolled risk in fleet engagements and that longer-range guns were an obvious way to eliminate this problem.

By the turn of the century, it was evident that revolutionary changes in battleship designs were in the offing. When Admiral Sir John “Jackie” Fisher became First Sea Lord of the Royal Navy in 1904, he initiated the design of a revolutionary all-big-gun battleship, the *Dreadnought*, which made all previous battleships obsolete. With the big guns all of the same caliber and mounted in centerline turrets, the new dreadnought-type battleships, with the addition of larger 15- and 16-inch guns, had engagement ranges that exceeded 10,000 yards and approached 20,000 yards. However, even with this dramatic increase in engagement ranges, Admiral Fisher was reluctant to give up his torpedoes, so the new dreadnought designs included underwater bow-mounted torpedo tubes. Ultimately, the British developed long-range, oversized torpedoes for battleship use. These Royal Navy Torpedo Factory (RNTF) Mark 1 torpedoes were 24.5 inches in diameter, with a 742-pound warhead. With a 20,000-yard range, they could be fired at maximum engagement ranges. During World War II, the battleship HMS *Rodney* fired two Mark 1 torpedoes at the German battleship *Bismarck*, scoring the only torpedo hit ever made by a battleship on another battleship in World War II.

The torpedo was the mortal enemy of the battleship, and extensive measures were taken to protect the precious battleships from torpedo attacks. The big-gun dreadnought battleships extended the engagement range out beyond the range of torpedo attacks, but new improved torpedoes quickly closed the gap. The addition of the gyro and hot gas combustion systems dramatically increased torpedo performance, and, by the time the new dreadnoughts were operational, torpedo ranges had extended from 3,000 yards to over 10,000 yards. With the extended engagement ranges, the torpedo remained a significant threat and drove naval tacticians to very conservative tactical doctrine to reduce the risks from torpedo attacks. British doctrine was to avoid night engagements at all costs since, before radar, the battleships might be badly mauled in nighttime destroyer torpedo attacks.

During the Battle of Jutland in World War I, Admiral Jellicoe adhered to this doctrine and broke off the engagement as darkness approached. This allowed the German High Seas Fleet, which was trained in night operations, to cut through the British Grand Fleet and get safely back into port. Because of their fear of night torpedo attacks, the British employed conservative tactics, and they gave up the opportunity to achieve a major sea victory. Nelson’s fighting spirit displayed at Trafalgar had been replaced by a conservative doctrine to avoid torpedoes at all costs. Perhaps this was a sound choice, since the only battleship sunk at Jutland, the *Pommern*, fell victim to British

destroyer torpedoes during a night action. On the rare occasions when battle fleets engaged in big-gun duels, destroyers routinely conducted torpedo attacks to break off the engagements. When the destroyers launched their torpedoes at the battle line, the standard evasion tactic was to turn 90° away and let the torpedoes comb the wakes as the ships steamed away. Again, these conservative tactics led to short, inconclusive engagements because the battleships spent much of their time in evasive actions to avoid torpedo attacks.

Modern battleships were touted to be the mightiest fighting ships ever conceived by man, but, because of the torpedo, they were very conservatively employed and they failed to play a major role in modern naval warfare. The aircraft carrier is often cited as the reason that battleships, like dinosaurs, became a dying breed. However, if one were to take an inventory of all the 20th-century battleships lying on the ocean floor, the vast majority of them have large holes below the waterline made by torpedoes. The hard evidence indicates that torpedoes were the reason why so many expensive battleships ended up on the bottom of the sea.

Destroyers represent a unique class of high-performance warships that can be traced directly to the torpedo. During the 1880s, when larger seagoing torpedo boats appeared, the British built a new type of fleet escort called a “catcher” to catch and destroy enemy torpedo boats when they attacked the fleet. Rigorous evaluations of the catchers, or torpedo boat destroyers, and the torpedo boats were conducted during annual fleet exercises, and their size steadily grew as annual improvements were incorporated into the designs. During the early 1890s, the Royal Navy prepared a specification for a single high-performance hull that would combine the offensive capabilities of the torpedo boat and the defensive role of the catchers in a single vessel, and design proposals were solicited from private shipyards. Yarrow and Thornycroft were each selected to build two of these new torpedo boat destroyers (TBD), and the first to be completed was the *Havock* in 1893. The *Havock* got high marks, easily reaching her 26-knot design speed and demonstrating good seaworthiness by staying at sea for 24 hours in rough weather. The new destroyers had torpedoes for strikes against capital ships, quick-firing guns to ward off torpedo boats, the high speed required to catch torpedo boats or attack battleships, and they were seaworthy enough to operate with the fleet. However, nobody could call them comfortable, and the men who served in them led a hard life, with the constant pounding, vibration, cramped quarters, and dampness.

By 1894, the Royal Navy had 40 of these small 250-ton destroyers, and in spite of the habitability problems, the new TBDs passed their trials with flying colors. The first generation of destroyers was collectively known as the “27 knotters” in spite of the fact that the individual designs varied because they were built by a number of different shipyards. In 1896, a new class was specified, and 28 of the new “30 knotters” were ordered. Foreign navies were quick to take note of the new “destroyers,” and soon most of the other major naval powers were building similar vessels. The French were particularly fascinated with this new class of warship and began to build a whole series of torpilleurs ranging from 250 to over 400 tons. The 300-ton torpilleur d’escadre proved to be the most popular design. The next major technological innovation occurred in 1899 when the British started experimenting with modified “30 knotters” powered by a Parsons turbine. The turbine power plant dramatically reduced vibration, and HMS *Viper*, an outstanding success, ran for 1 hour at 36 knots, a speed far in

excess of previous destroyers. Within 5 years the British were evaluating oil-fired boilers in destroyers, and the basic design base for the modern destroyer was in hand.

During the first decade of the 20th century, all the major powers climbed on the bandwagon, and there was a proliferation of new destroyer designs. The British built the *River* and *Tribal* classes, and, then in 1909, the robust *Beagle*-class destroyers joined the fleet. The rugged, 27-knot, 1,000-ton *Beagle*-class destroyers, with their new, larger 21-inch torpedoes, provided the design base for the destroyers used in World War I. During the battle of Tsushima in 1905, destroyers had to close to 2,000 yards or less to fire their short-range torpedoes, and they took a terrible beating from gunfire at these close ranges. The new higher-performance, 21-inch torpedoes, with accurate gyros and ranges exceeding 10,000 yards, allowed attacks from ranges of 5,000 yards or greater. By the eve of World War I, most of the major naval powers were building new, larger-sized destroyers, approaching 1,000 tons in size, and equipping them with longer-range, high-performance torpedoes.

Fleet destroyers operated in flotillas or squadrons of 12 to 20 destroyers under the command of a captain and his staff. The flotilla commander, known in the Royal Navy as Captain-D, generally embarked on a light cruiser, also armed with torpedo tubes, or in an oversized destroyer with staff accommodations known as a destroyer leader. The flotillas were broken into divisions, each headed by a commander, with three or four destroyers in each division. The size of the units varied from navy to navy, but the tactical doctrine was quite consistent. In a fleet engagement, destroyers were used to conduct massed torpedo attacks against the enemy battle line. Destroyers attacking capital ships in daylight were exposed to very heavy fire and took a fearful pounding in spite of the use of smoke screens to mask daytime attacks. A single 12-inch shell from a battleship could rip open the fragile 1/8-inch-steel hull of a destroyer and cause immense damage.

A flotilla of destroyers could launch between 50 and 100 torpedoes in an attack, and, theoretically, the entire battle line could be destroyed by a single successful destroyer torpedo attack. Destroyer torpedo attacks in foggy weather or at night considerably reduced the risk of gunfire damage since the battleships needed good visibility for accurate long-range gun fire. However, operating a flotilla of destroyers under battle conditions in total darkness required extensive training, superb seamanship, and lots of luck. Communications were very primitive, target identification was difficult, and destroyers frequently lost contact with one another during night attacks. Collisions and attacks against other friendly ships were not uncommon during night destroyer torpedo attacks.

When World War I started in August 1914, it was generally assumed that there would be a major sea battle in the North Sea within a few days. In fact, nothing of the sort happened. Neither the British nor the Germans were prepared to risk their precious capital ships in such a reckless undertaking. Rather it was left to the light forces to contest the possession of the North Sea, and destroyers quickly became the workhorses of the fleet. The first shots of the naval war were fired by the British destroyer HMS *Lance* on August 5th, when it attacked and sank the German minelayer *Konigin Luise* in the North Sea. Destroyers were used to conduct raids against enemy anchorages, to harass shipping, to patrol sea lanes, and even to serve as high-speed minelayers.

When the submarine menace appeared, destroyers were ideally suited for submarine hunting, and they were soon assigned this additional task. The versatile destroyers were in great demand for all

types of duties, and, while the great battleships stayed in harbor, the destroyers became the hardest-working and most sought-after units in the navy. In the Mediterranean, during the Gallipoli operations, destroyers were used as amphibious transports, for gunfire support during landings, and even as minesweepers in the Dardanelles. With all their new duties, the destroyers still had a primary duty to protect the battleships; every time the fleet went to sea, the destroyers had to accompany the capital ships to protect them from torpedo attacks.

In May 1916, the British Grand Fleet and the German High Seas Fleet finally clashed in the battle of Jutland, the only major sea battle of the war. At Jutland, the Grand Fleet was supported by 80 destroyers, and the High Seas Fleet had 62 destroyers or large torpedo boats accompanying it. Although the battle of Jutland was at best inconclusive, the destroyers were aggressive participants, and it was conclusively demonstrated, by both the British and the Germans, that a battle line would not stand up to a massed destroyer torpedo attack. The destroyers took a terrible pounding while conducting torpedo attacks, but, once the torpedoes were launched, the battleships broke off the engagement and veered away to comb the tracks and avoid the torpedoes. The destroyers took a brutal pounding from the 12- and 14-inch guns at close range, but they did make the battle line give way. Further, the only battleship sunk at Jutland, the German pre-dreadnought *Pommern*, was the victim of a destroyer torpedo.

As the submarine menace increased, destroyers were used extensively to hunt submarines and, later, to escort merchant ships when convoys were formed. In fact, the destroyer became the mainstay of the ASW effort, and there was a great demand for additional destroyers for ASW tasks. When the United States entered the war in 1917, it was desperately short of destroyers. In the typical American way of war, a massive crash shipbuilding program was initiated to build a large fleet of destroyers. Two similar flush-deck designs were selected, and 111 of the *Wickes*-class destroyers (DDs), followed by 162 of the *Clemson*-class DDs, were built in record-breaking time. For example, USS *Reid* (DD 21) was commissioned only 45.5 days after the keel was laid, and over 200 of the new “four pipers” were completed before the war ended. Eighty-five of the U.S. Navy destroyers served in the European theater of World War I, and they played an important role in countering the U-boat threat. By the end of the war, with the addition of minelaying, escort, and ASW missions and weapons, the size of new multipurpose destroyers was approaching 1,500 tons. During World War I, the destroyers, or “tin cans,” proved to be very versatile warships; by the end of the war, those tin cans had justly earned a reputation as the hardest-working ships in the navy.

During the 20 years of peace between the two World Wars, the various navies continued to experiment with new destroyer types, but austere national budgets limited the large-scale production of any new classes. Immediately after the war, the British built the *Scott* and *Shakespeare* classes. These 1,550-ton craft with 4.7-inch guns and six 21-inch torpedo tubes were, at the time, considered the most powerful destroyers in the world. The Italians soon followed with the *Carlo Mirabello* class of 1,780-ton destroyers with a speed of 35 knots and a 6-inch gun. The French felt threatened by the new high-performance Italian destroyers; in the 1920s, they built a series of new *contre-torpilleurs*, or destroyers. In 1930, the French built the *Le Fantasque* class of 2,610-ton destroyers, which were in fact fantastic craft. These destroyers, equipped with five 5.5-inch guns and nine torpedo tubes,

were real “greyhounds,” with trial speeds between 40 and 45 knots—a staggering achievement that has never been duplicated.

Immediately after World War I, the Japanese initiated a major effort to modernize their navy and make it the most powerful fleet in the Pacific. In 1923, the Japanese started to build their famous *Fubuki*-class destroyers. These 390-foot, 1,750-ton craft, capable of 38 knots, were powered by 50,000-hp geared turbines. Their armament included six 5-inch guns in three enclosed twin mounts and nine 24-inch torpedo tubes in three triple banks. They also carried nine reload torpedoes in special deckhouses. These destroyers were more heavily armed than many light cruisers and were far more impressive than any contemporary destroyers. Although the Japanese destroyers were very heavily armed, they demonstrated some shortcomings. The Japanese 6th Fleet got caught in a typhoon, and several destroyers experienced extensive structural damage. Examination revealed that the massive weapon suite made them dangerously top-heavy. To correct this problem, extensive modifications were made during the late 1930s, including lightening the superstructure, strengthening the hull, adding ballast, and reducing the torpedo reloads from nine to six weapons. Although these modifications increased the weight by 250 tons and reduced the top speed to 34 knots, the *Fubuki*-class DDs were still formidable destroyers, and they performed well during World War II. In 1933, the Japanese secretly replaced their 24-inch Type 90 destroyer torpedoes with a new high-performance Type 93 “Long Lance” torpedo that used pure oxygen instead of compressed air. The oxygen significantly boosted performance, and this oversized torpedo could deliver a half-ton warhead at well over 30,000 yards at speeds over 40 knots. Most conventional 21-inch destroyer torpedoes had ranges of about 10,000 yards at 40 knots and 600- or 700-pound warheads. The Long Lance was an outstanding torpedo, and its existence was a well-kept secret until it started putting very large holes in U.S. Navy ships at the start of World War II.

The massive over-production of destroyers during World War I made it extremely difficult for the U.S. Navy to justify funds for new destroyers during the 1920s, especially since a large number of essentially brand-new “four-piper” destroyers had been mothballed and were available for use. During the 1930s, as other navies starting building larger modern destroyers, the U.S. Navy began to experiment with new destroyers and destroyer leaders. Clear deck space for mounting the large torpedo tubes was at a premium in new designs, and the number of torpedoes per mount steadily increased. The single mounts became double mounts; then a third tube was put on top to make a triple mount. As the destroyers grew larger, a quadruple mount and, finally, a quintuple mount made it possible for a destroyer to fire 10 torpedoes in a double salvo. During the early 1930s, several new designs were built, including the *Porter*, *Somber*, *Gridley*, and *Mahan* classes. The *Livermore*, *Benson*, *Bristol*, and *Sims* classes followed in the late 1930s. On the eve of World War II, the U.S. Navy selected a new flush-deck destroyer design, and a new class of destroyers was introduced, starting with USS *Fletcher* (DD 445), which was commissioned in June 1942.

The *Fletcher*-class destroyers were turbine-powered with double gear reduction for economy. They had five single-mount enclosed gun turrets with 5-inch guns and 10 torpedo tubes in two quintuple mounts. Selected for serial production, 175 of the *Fletcher*-class destroyers were built and delivered to the fleet during World War II. The *Fletcher* DDs weren’t the biggest, the fastest, or the most heavily armed destroyers to see service in World War II. However, they had a rare combination

of good range, firepower, and seaworthiness. The *Fletcher* DDs were rugged and reliable, and they are generally acknowledged to be the best all-around destroyer of World War II.

When World War II started in 1939, there were no great battle fleets poised for a massive engagement, so the destroyers quickly assumed their role as workhorses of the fleet. It is often said that “no job was too small, no task too great” for the destroyers. During the German invasion of Norway, German and British destroyers fought some fierce engagements. In the battle for Narvik, the Germans lost 10 destroyers and the British lost 2 destroyers plus 1 severely damaged. When the Germans overran France and the British had to evacuate their trapped expeditionary force from Dunkirk, the destroyers were called in again. The destroyers had to protect the flanks to prevent German torpedo boat attacks, and they also evacuated 103,339 men out of the total of 338,226 evacuated. The British destroyers took a terrible beating during the Dunkirk operation; after the evacuation of France, the British had 162 destroyers left, but only 74 were undamaged and ready for operational use.

With the escalating U-boat offensive, a threatened invasion of England, and major commitments in the North Sea and the Mediterranean, the British were desperately short of destroyers and sought U.S. assistance. The pressure was relieved somewhat when, in exchange for a 99-year lease of selected British bases, the United States provided the British with 50 World War I four-piper destroyers. In the Mediterranean, British and Italian destroyers engaged in fleet actions such as the battle of Cape Matapan. Also, they conducted ASW operations, conducted special missions, provided gunfire support, and functioned as fast troop transports and supply vessels to provide critically needed supplies to the armies fighting in North Africa. The overworked destroyers took a terrible beating, but they again demonstrated that “tin cans” could get the job done.

As the German U-boat offensive stepped up in intensity during 1940, additional destroyers were desperately needed to escort convoys in the Atlantic and to conduct ASW patrols. The British destroyer was equipped with the underwater detection device called ASDIC (called sonar by the Americans) and depth charges. (The British acronym ASDIC was derived from “ASD” for the Anti-Submarine Division and “ic” from the ending of the word “supersonic,” although this derivation was kept secret throughout the war). The destroyer had become the primary ASW surface vessel, and large numbers were urgently needed to counter the U-boat campaign against merchant shipping. British and (later) American tin cans in the North Atlantic probably had the roughest physical duty encountered by destroyers during World War II. Destroyers, designed for speed and light weight, are tender in rough seas, and the destroyers conducting escort and ASW duties in the violent winter months took an awful pounding. These little ships, operating under deplorable conditions, were on battle alert for weeks on end as they shepherded merchant convoys and tracked down U-boat contacts. Escorting convoys and hunting down submarines were demanding tasks that required special skills and a willingness to work to the limits of exhaustion. The operational pressure was continuous, and, during the winter months, the destroyers were frequently covered with tons of ice from frozen spray. Destroyers escorting convoys to Murmansk were also subject to heavy air attacks from German aircraft operating from northern Norway: in the bitterly cold waters where they operated, there was essentially no chance of survival if a ship went down. Even though the newer destroyers had dual-purpose 5-inch guns that could fire at aircraft, it became very evident that

destroyers were vulnerable to aircraft attacks and that there was a need for additional anti-aircraft (AA) guns. Throughout the war, additional 20-mm and 47-mm anti-aircraft guns were added; by the end of the war, destroyers fairly bristled with anti-aircraft guns, which made them extremely dangerous ships for aircraft to attack.

In the Pacific campaign, destroyers functioned as workhorses for both the Japanese Navy and the U.S. Navy. However, with two large battle fleets, there were also more opportunities for the destroyers to engage in traditional fleet torpedo attacks. Early in the war, during the Battle of the Java Sea, the Japanese demonstrated their superb training in night torpedo attacks and the brutal effectiveness of their secret weapon, the oversized Type 93 “Long Lance” torpedo. On paper, the two fleets looked reasonably matched, but the Allied American, British, Dutch, and Australian (ABDA) task force, commanded by Dutch Admiral von Doorman had never fought as a team, and there were serious communications problems among the Dutch, Australians, British, and American ships. The highly trained Japanese force executed long-range torpedo attacks with their Long Lance torpedoes, and, one by one, the allied task force ships started to disappear as the torpedoes took their toll. The cruisers *Java* and *De Ruyter* and the destroyers *Kortenaer* and *Jupiter* were all sunk, while the *Houston* and the *Exeter* were badly damaged. Some of the ships never knew what hit them. The wakeless Long Lance torpedoes were fired from ranges exceeding 20,000 yards: ships didn’t even know they were under attack. When the *Jupiter* disappeared in a cloud of smoke, it was assumed that she had hit a mine because there weren’t any ships within (normal) torpedo range.

The series of vicious sea battles fought during the Guadalcanal campaign continued to demonstrate that the Japanese were experts in night torpedo operations in spite of not having radar. In a nearly continuous series of sea battles, Japanese and American units slugged it out in the waters adjacent to Guadalcanal, and Savo Sound was renamed “Iron Bottom Sound” because of the large number of ships sunk during these hard-fought battles. Destroyers, and their torpedoes, were major participants in most of the engagements, and a majority of the ships on the bottom of Iron Bottom Sound have large torpedo holes in them. Perhaps the outstanding destroyer leader of the war was Rear Admiral Razio Tanaka, who had command of the Japanese destroyers during the Guadalcanal campaign. When the Japanese garrison on Guadalcanal was isolated, Admiral Tanaka’s destroyers had the job of resupplying them at night. Over 60 of these night runs, which came to be known as the “Tokyo Express,” were made by Admiral Tanaka’s destroyers. The tough little destroyers, overloaded with troops and supplies to resupply the garrison on Guadalcanal, fought their way down the slot night after night, and Admiral Tanaka became known as “Tenacious Tanaka.”

In the Battle of Tassafaronga, the U.S. Navy set up a special task force (TF 67) with five cruisers and six destroyers under Admiral Wright to ambush the Tokyo Express and put Tenacious Tanaka out of business. The task force had an operational plan, radar, the element of surprise, and a superior force of five cruisers and six destroyers versus eight Japanese destroyers, seven of which were heavily loaded with troops and supplies. The Americans fired the first torpedo salvo, which missed, and the Japanese, alerted by the wakes of the U.S. Mark 15 torpedoes, immediately initiated a counterattack. The lead Japanese destroyer came under intense gunfire and was quickly reduced to a floating wreck, but the other units made a fast turn and fired a full salvo of Long Lance torpedoes at the distant gun flashes. They then reversed course and headed for home while their big Type 93

torpedoes made a shambles out of the U.S. cruisers. Two torpedoes hit the *Minneapolis* and *Northampton*, the bow was blown off the *New Orleans*, and the *Pensacola* was hit and caught fire, cremating many of the crew. Task Force 67 learned the hard way that Tanaka's destroyers were "alley cat tough" and knew how to hit and run in order to survive. Tassafaronga was a bitter experience for the U.S. Navy, but it clearly demonstrated that torpedoes, in the hands of well-trained destroyer crews, were indeed lethal weapons.

U.S. Navy destroyers were also busy training for radar-directed night torpedo attacks against enemy ships. In August 1943, Destroyer Division 12, under Commander Frederick Moosbrugger, got a chance to try their skill against a Tokyo Express run in Gizo Strait. Moosbrugger had specially trained his destroyers in radar-controlled night torpedo attacks. He had modified his torpedo tubes to hide the powder flash when they were fired, and he insisted that the temperamental influence exploders in the Mark 15 torpedoes be disconnected and all torpedoes be fired in the contact exploder mode. In the Battle of Vella Gulf, Moosbrugger conducted a textbook-perfect operation in a radar-directed night torpedo attack against four Japanese destroyers that were loaded with supplies and racing down the slot. The three Destroyer Division 12 destroyers fired radar-directed spreads of eight torpedoes at the Japanese destroyers from a range of 4,000 yards. The Japanese were caught completely by surprise, and the destroyers *Kawakaze*, *Arashi*, and *Hagikaze* were destroyed by the torpedo salvo. Only the *Shigure* escaped. Later, when the *Shigure* was drydocked, a hole was found in its rudder: a torpedo had gone through the rudder without exploding. The Mark 15 torpedoes were still plagued with exploder problems, and the lucky *Shigure* had been hit by a dud. Vella Gulf demonstrated that the U.S. destroyers were getting their act together.

As the war progressed, U.S. destroyers became more proficient: the tin cans demonstrated their ability to dish it out in spite of their smaller torpedoes. Captain Arleigh "31 knot" Burke and his DESRON 23 distinguished themselves during the Battle of Empress Augusta Bay. Later in the war, during the Battle of Leyte Gulf, U.S. destroyers again covered themselves with glory when their torpedoes decimated Admiral Nishimura's task force in Surigao Strait. When the "small boys" valiantly held off the Japanese Fleet that was attacking the U.S. jeep carriers and invasion fleet in the Battle of San Bernardino Strait, they proved that even battleships were reluctant to press on in the face of determined torpedo attacks. In the Pacific campaign, both Japanese and U.S. destroyers engaged in extensive torpedo operations, and they demonstrated time and again that the tin cans armed with torpedoes were potent adversaries. The small boys carried a big punch.

U.S. destroyers conducted extensive ASW operations in the Pacific: destroyers and destroyer escorts sank over half of the 130 Japanese submarines destroyed during the war. The destroyer escort *England* rolled up a Japanese picket line by sinking five Japanese submarines—the I-16, the RO-106, the RO-104, the RO-108, and the RO-116—and assisting in sinking the RO-105, all during a single 12-day period. The *England* was the top submarine killer in the Pacific. During the final phase of the Pacific war, as surface targets grew scarcer and the kamikaze aircraft threat increased, the torpedo tubes were removed from many destroyers and additional anti-aircraft guns were installed. Toward the end of the war, destroyers were used as radar pickets to warn of kamikaze attacks, as lifesaving vessels to pick up downed aviators, and as AA platforms to protect the fleet.

After World War II, when there wasn't any major naval threat, the anti-surface ship torpedo tubes were taken off, and the destroyers became primarily ASW vessels configured to hunt submarines. The threat posed by the large Russian submarine fleet led to larger and more sophisticated ASW destroyers with powerful hull-mounted sonars. By the mid-1970s, when the U.S. Navy introduced its new *Spruance*-class (DD 963) destroyers, the size of these gas-turbine-powered destroyers had grown to 7,800 tons, and the only torpedoes carried were small anti-submarine homing torpedoes. In 1962, the Russian Navy achieved a technological first when they introduced the *Kashin*-class destroyers. These were the first all-gas-turbine-powered destroyers. Although they are heavy on fuel consumption, they are capable of very rapid acceleration, which provides an important tactical advantage. The Russians have continued to install large anti-surface ship torpedo mounts on their new destroyers; considering their tactical doctrine, it makes sense for them to do so. The Russians frequently employ a destroyer as a close "tattletale" to accompany U.S. Fleet units. In the event of hostilities, this expendable tattletale would provide targeting information for missile or air strikes. When hostilities are initiated, its close-in position also puts it in an ideal position to launch a very destructive preemptive salvo of modern anti-ship homing torpedoes at nearby U.S. Fleet units. Modern Russian destroyers are still equipped with anti-ship torpedoes, which strongly suggests that they have a plan to use these torpedoes in the event of hostilities.

The torpedo boat was the first vessel designed exclusively to exploit the torpedo, and the concept of these small "giant-killers" has remained popular throughout the years. The first torpedo boats, built in England by Thornycroft, Yarrow, and White, were small steam launches modified to carry Whitehead torpedoes. These small vessels evolved from steam launches, frequently called "Davids," that were used in the U.S. Civil War to conduct spar torpedo attacks against enemy vessels. These fragile wooden vessels, with the helmsman standing fully exposed, could operate only in calm waters; their speeds were generally under 20 knots; and they were vulnerable to damage from the small rapid-fire weapons carried on warships. However, one torpedo could sink a major warship, so the torpedo boat was very popular, particularly with smaller navies that could not afford to build large capital ships. The British shipbuilders were quick to recognize this potential market for torpedo boats: during the last three decades of the 19th century, hundreds of small torpedo boats were built by British shipbuilders and sold to any and all buyers. Many of the buyers, such as the French, presented a direct threat to the Royal Navy, but this did not stop the free enterprise system from selling torpedo boats. Profit was the primary goal of the shipyard owners, and a lot of money was made selling torpedo boats. In the end, even the Royal Navy was forced to buy torpedo boats, and still more money was made selling torpedo boats and torpedo boat catchers to the Royal Navy.

Since torpedo boats offered an inexpensive way to counter battle fleets, almost all of the naval powers had torpedo boats by the late 1880s, and they had also become a sought-after item for local revolutions and terrorist activities. Torpedo boats were a hot item on the 19th-century arms market, and there was a rush to buy torpedo boats every time a local war broke out. During the Russo-Turkish war in 1877, the Russian Navy was totally unprepared, so Russian agents scurried around buying torpedo boats wherever they could. Two of these Russian torpedo boats, the *Tchesma* and the *Sinope*, allegedly torpedoed and sank the Turkish guardship *Intikbah* on January 24, 1877. This is the first

reported sinking of a ship in wartime by a torpedo, but the claim is controversial because the Turkish Navy refused to acknowledge the sinking.

South America was in a state of revolutionary turmoil during the 1880s and 1890s, and torpedo boats were involved in several of the endless wars of liberation. In 1891, during a Chilean revolution, the rebel forces used British-built torpedo gunboats to challenge the Chilean Navy. The rebel torpedo boats *Almirante Lynch* and *Almirante Condell* attacked the 3,500-ton Chilean warship *Blanco Encalada*, and a Whitehead torpedo fired by the *Almirante Lynch* sank it. This was the first undisputed sinking of a warship by a torpedo in wartime, in which a torpedo boat demonstrated that large warships were vulnerable to surprise torpedo attacks.

As torpedo boats continued to grow in size, the British navy broke them down into two classes. The first-class torpedo boats were larger seagoing types, generally over 100 tons, that could sail independently with the fleet. As they grew larger, they became known as torpedo gunboat destroyers and finally as destroyers. The second-class torpedo boats were smaller vessels, generally under 80 tons, that were used primarily for harbor defense missions. Some second-class torpedo boats were also carried on board battleships and launched to conduct torpedo attacks when an engagement was imminent. These second-class torpedo boats were really the early versions of the high-performance torpedo boats that were used in World Wars I and II.

At the turn of the century, small internal combustion engines with good power-to-weight ratios were under development, and these new power plants opened up new possibilities for building small high-performance motorboats. Yachting was a very popular sport in Britain. In 1903, Sir Alfred Harmsworth started to sponsor an annual motorboat race for the British International Trophy. There was much interest in small, fast motorboats, and the British, Americans, Italians, French, and Germans all got racing fever. Soon, motorboats were tearing through the water at previously unheard-of speeds as radical new hull shapes were designed to reduce the drag of the traditional displacement hulls and further increase speed. In 1907, an American, Clinton Crane, challenged for the British International Trophy with the *Dixie*, a new semi-planing hull design. The *Dixie* won the trophy with a speed of 27 knots, and this was the beginning of a fierce and very popular competition in speedboat racing between the two nations. Within a few years, planing hulls were in use, followed by stepped hydroplane designs. To reduce weight, an Englishman, Linton Hope, did away with the traditional rib and plank design and built a monocoque-type hull. Another Englishman, S.E. Saunders, reduced the hull weight by 35% by developing laminated hulls with alternate, thin, diagonal layers of cedar and mahogany that allowed radically shaped curved hulls. By 1910, the racers had reasonably reliable high-powered engines and lightweight high-performance hulls. Sabers were beginning to rattle in Europe, and, as World War I approached, the European powers became interested in a military application for this new technology. The famous Lürssen yard in Germany built an experimental 31-foot speedboat, the *Boncourt*, fitted to fire torpedoes. With a speed of 43 knots, this high-performance craft was the forerunner of modern motor torpedo boats.

When World War I started, there was a proliferation of small, fast, torpedo-carrying motor boats as the British, Germans, and Italians all became involved in developing these small craft. The British called their craft coastal motor boats, or CMBs. They were built in a number of different versions by Thornycroft in lengths up to 55 feet. Most had a single-step hydroplane hull and, depending on the

engine installed, had speeds between 33 and 40 knots in calm seas. Typically, the torpedo was carried in a trough in the stern and was slid off the stern backwards while the boat headed for the target at high speed. Once the torpedo entered the water, the boat had to turn quickly to get out of the way before it got run over by its own torpedo. At best, this unique launching system left something to be desired. The CMBs were short-range craft best suited for short-range attacks on known targets in calm seas. Since the North Sea was anything but calm and considerable endurance was needed for search and attack missions, the CMBs met with only limited success. They sank a German destroyer and a few other small vessels, and, after the war, the British employed them in the landlocked Caspian Sea to attack Bolshevik shipping.

Unlike the British, the German Navy specified motor torpedo boats capable of good performance even in heavy seas and with sufficient endurance to conduct patrols off the English coast. The result was a wooden semi-displacement hull with a round bilge that was somewhat longer and heavier than the British CMBs. The 56-foot-long, Lürssen-built, motor torpedo boats had a speed of over 30 knots and were powered by the famous Maybach gasoline engines that were used in Zeppelin airships. Unfortunately, the Germans did not aggressively employ them to attack shipping; instead, they were frequently employed to destroy anti-U-boat mine nets. The German boats provided the basic design for the highly successful fast-attack Schnellboots, or S-Boats, used in World War II.

The most successful use of motor torpedo boats in World War I was by the Royal Italian Navy. The Italian boats, powered by the excellent Isotta Fraschini engines, were known as MAS boats, and about 350 of these were operational by the end of the war. These boats were successfully used against the Austrians in the relatively calm waters of the Adriatic and Mediterranean Seas. The only battleship ever sunk by motor torpedo boats, the Austrian battleship *Wein*, was the victim of torpedoes fired from two Italian MAS boats. This served notice to the battleship admirals that their mighty capital ships were uniquely vulnerable to small, fragile, wooden speedboats, particularly if they were armed with Whitehead torpedoes.

During the years between the two World Wars, there was little official interest in developing new motor torpedo boats, but smaller foreign navies, including Siam, Japan, China, Spain, Sweden, Greece, Finland, and the Netherlands, continued to purchase motor torpedo boats from British shipbuilders. Competition for the British International Trophy, or Harmsworth Cup, resumed, and hull designs underwent further improvements. The American sportsman Garfield "Gar" Wood built a series of highly successful speedboats, all called *Miss America*, that combined the high-powered Packard-built Liberty aircraft engine with a new stepless planing hull. By 1928, Gar Wood had built a *Miss America* with a stepless monohull powered by 1,000-hp Packard engines that was capable of 90 mph. Gar Wood met his nemesis in H. Scott-Paine, owner of the British Power Boat Company, who challenged and, on occasion, defeated Wood with his *Miss England* and *Miss Britain* lightweight racing hydroplanes. During the early 1930s, the Germans, Italians, and the French were again experimenting with new torpedo boats, and the Royal Navy suddenly developed interest in a new generation of motor torpedo boats powered by aircraft engines and utilizing the new planing hulls. H. Scott-Paine and the British Power Boat Company submitted a design based on a 64-foot crash boat they were building for the Royal Air Force. Six of these boats were built in 1936, but the stern-launched torpedoes posed a continuing problem. A new improved design was called for. Scott-Paine

proposed a 70-foot design powered by three Rolls-Royce Merlin aircraft engines, and Peter Du Cane of Vosper proposed a very similar craft that was powered with Italian Isotta-Fraschini engines. The Royal Navy managed to alienate both designers during the selection process. They finally picked the Vosper design but elected to import the engines from Italy rather than build a plant in England to produce them. When Italy allied with the Germans, this left the British without any engines, and the Vosper Motor Torpedo Boat (MTB) hulls had to be cobbled up to accept American Packard engines on a crash basis.

Meanwhile, the U.S. Navy, which had done away with torpedo boats early in the century, had become interested in motor torpedo boats. In 1938, the U.S. Navy solicited proposals for the design of 54-foot and 70-foot boats, and a small number of experimental boats were purchased and evaluated. It was concluded that the 54-foot design was too small, so the design effort concentrated on a larger 70- to 80-foot patrol torpedo boat (PT boat) that could carry four torpedoes and would have a cruising range of over 500 miles. The Elco division of the Electric Boat Company became interested in the PT boat competition and purchased a Scott-Paine 70-foot MTB from the British to provide a state-of-the-art prototype for their design efforts. This effort, secretly sanctioned by the U.S. Navy, provided a Scott-Paine boat as the design base for additional U.S. developments, so that U.S. Navy PT boats are frequently referred to as “Scott-Paine designs” regardless of who built them. The competition soon narrowed to two shipyards, Elco in New Jersey and Higgins Industries of New Orleans. After an initial order to Elco for 24 of their 70-foot boats, the Navy increased the size again. The 70-foot design was lengthened to 77 feet, and a new specification was issued for PT boats between 75 and 80 feet in length. Higgins submitted a design for a 78-foot PT boat; Elco’s final design was for an 80-foot craft. The contract was let just as the war with Japan started, so the designs were frozen and volume production was initiated. The Higgins and Elco PT boats were very similar in appearance, but there were many subtle differences in the designs.

During World War II, the British used their 72.5-foot Vosper MTBs to harass German coastal shipping that moved along the coast at night, to lay mines in shipping channels, and to ambush German naval units as they left port. The British MTBs had been repowered with American-built 1,250-hp V-12 Packard engines; these 55-ton boats, initially armed with two obsolete Mark 5 torpedoes, had a top speed of 38 to 40 knots with a radius of action of about 140 miles. Night after night throughout the war, these small craft operated in the enemy’s front yard, disrupting shipping and attacking coastal convoys. Although they sank only a modest number of ships, they had a high harassment value because the Germans had to tie up a large number of men and small craft for coastal defense and to escort coastal shipping throughout the war.

Across the channel, the Germans had built new diesel-powered Schnellboots, called “E-boats” by the Allies, to attack the British. The E-boats were several types of German motor torpedo boats. In general, they tended to be larger and more seaworthy than the British MTBs. For example, the S-30 class E-boats were 108 feet long, weighed 82 tons, and carried two 21-inch torpedoes. The German E-boats conducted frequent raids against English shipping in the channel, and they were a constant source of irritation with their hit and run raids. The E-boats also escorted U-boats and German naval units when they were operating in the English Channel. As they were also used extensively in the Mediterranean and in Northern Europe, countering the E-boat threat required the expenditure of

considerable resources. The E-boats were used quite effectively to attack congested Allied invasion fleets both in Italy and at Normandy. The U.S. destroyer *Rowan* (DD 405) was sunk off Salerno; USS *Nelson* (DD 623) had its stern blown off by an E-boat torpedo at Normandy.

The highly successful Japanese attack at Pearl Harbor on December 7, 1941, threw the U.S. Navy on the defensive. During those dark days, since the Navy had precious little good news to hand out, maximum propaganda use was made of the Navy's 29 operational PT boats. These Elco 77-footers, each armed with four obsolete Mark 8 torpedoes, formed three PT boat squadrons. Two were in the Pacific—Squadron Two at Pearl Harbor and Squadron Three in the Philippines. When the Japanese invaded the Philippines, the PT boats were soon the only surface units left to oppose the powerful Japanese Navy, and Lieutenant John D. Bulkeley, the commander of Squadron Three, became a national hero as the Navy heralded the heroic accomplishments of the PT boats. The PT boats of Squadron Three did a superb job under extremely difficult conditions. During the 5 months they were in combat, Squadron Three claimed four sinkings, including a Japanese cruiser, and they undertook all types of dangerous special missions, including getting General MacArthur off Corregidor. However, the heavy press exposure combined with the need for some positive American accomplishments created a greater-than-real-life myth that PT boats were “secret super weapons,” and the legend, once created, lives on. To this day, Americans still consider PT boats a special breed.

When the war started, Elco had their new 80-foot design in volume production, and the Higgins new 78-foot design was starting volume production. As new boats became available, additional PT boat squadrons were formed. When the Solomon Islands campaign started in August 1942, PT boats were requested to support the invasion of Guadalcanal. The first boats arrived in September and were rushed into combat within weeks. The U.S. Navy was still desperately short of major warships during the Guadalcanal campaign, and the PT boats were frequently the only forces available to throw against the Tokyo Express as Admiral Tanaka's destroyers came down the slot into Iron Bottom Sound with supplies. From September 1942 through February 1943, the PT boats were in continuous action night after night, seeking out the Japanese. The fragile PT boats took a tremendous beating, and several of them were blown to splinters or run down by Japanese warships. PT 109, skippered by Lieutenant John F. Kennedy, is undoubtedly the most famous PT boat sunk during the campaign. However, on numerous occasions, the PT boats singlehandedly turned back the Tokyo Express, and their obsolete World War I vintage Mark 8 torpedoes took a toll on the Japanese warships. On one occasion, they torpedoed and sank Admiral “Tenacious” Tanaka's flagship, the brand-new Japanese destroyer *Terutsuki*. The Admiral survived the sinking, but he had a first-hand demonstration that PT boats were a real threat to his destroyers.

As U.S. naval strength grew and the island-hopping offensive started, PT boats found an important new role as “barge busters.” During the island-hopping campaign, Japanese strongholds were frequently bypassed, and the Japanese invested considerable resources trying to get supplies to these isolated garrisons. They frequently used small ships and barges to ferry supplies at night. With their new radar, the PT boats were given the job of hunting down these small coastal convoys operating in shallow waters. The PT boats, armed with 37-mm and 40-mm cannons, were well suited to this type of mission, and they were spectacularly successful in cutting off the flow of supplies and isolating the bypassed Japanese forces. Large numbers of barges loaded with troops and supplies

were destroyed, and the PT boats continuously harassed the Japanese by conducting surprise raids and shooting-up their bases. By mid-1943, the newer Mark 13 aircraft torpedo was available for PT boat use. The lighter-weight, high-performance Mark 13 was designed to be launched from a “roll off” launcher over the side, which eliminated the need for the heavy steel launching tubes and their troublesome black powder firing charges. The Mark 13 torpedo, with its larger warhead and higher reliability, was a major improvement over the Mark 8, and the new launching technique saved weight and eliminated the need for black powder charges to impulse the torpedo out of the tube. Several PT boats were lost when the black powder charges “flashed” during night attacks, disclosing the location of the boat and providing a beacon for concentrated counterfire that blew them out of the water.

During the Battle of Leyte Gulf, in October 1944, the PT boats again showed their value in narrow waters when Admiral Oldendorf used his PT boats and destroyers in the Battle of Surigao Strait to attack Admiral Nishimura’s Southern Force as it transited the Strait. The PT boats, although assigned primarily scouting missions, conducted successful night attacks against the Japanese task force and claimed hits on a cruiser and two destroyers. By the end of World War II, the U.S. Navy had built over 700 PT boats, and 40 PT boat squadrons had been activated. The PT boats were employed in all theaters of war. Throughout the war, they did a magnificent job of plugging the gaps when no other assets were available, and their aggressive torpedo attacks kept the enemy off balance during critical periods.

The torpedo has had a major impact on the evolution of naval surface ships during the 20th century. The torpedo threat has heavily influenced the design of modern warships, and whole classes of new ships have been built to exploit the torpedo and capitalize on its destructive power. The torpedo has clearly demonstrated itself to be the most effective weapon ever conceived for sinking ships. However, since it is a close-in weapon that must be fired at relatively short ranges, surface ships generally took an awful pounding when they closed to conduct torpedo attacks unless they could surprise the enemy. With the advent of radar and radar-controlled gunfire, the element of surprise was lost, and the risks escalated to an unacceptable level in many tactical situations. Consequently, conventional anti-ship torpedoes have been taken off most surface ships. The Russians still equip surface ships with torpedo tubes, and a number of other countries, such as Germany and Sweden, that must operate in confined seas, such as the Baltic, continue to build new surface combatants equipped with wire-guided anti-ship torpedoes.

Chapter 12

TORPEDOES AND SUBMARINES

The most destructive conventional weapon system ever created by man came into existence when Whitehead's automobile torpedo was wedded to the submarine. The torpedo, as a covert underwater weapon, was ideally suited for use from a submerged vessel, such as a submarine, to provide a highly effective covert underwater weapons system. Since both the firing vessel and the weapon were essentially invisible when submerged beneath the water, it was extremely difficult to detect them or to take evasive action. The modern submarine is a 20th-century phenomenon, and, in its first century of existence, it has revolutionized naval warfare. The submarine has had a major impact on naval warfare both at the tactical and strategic levels, and it dramatically demonstrated that both warships and merchant ships were extremely vulnerable to submarine torpedo attacks. Man, in his quest for mass destruction, had finally conceived a weapon system that was capable of severing the vital seaborne arteries that maintain the flow of essential materials to support the life of a modern industrial nation. It was now possible to isolate a nation to achieve a strategic victory as the isolated nation's economy slowly ground to a standstill.

At the tactical level, the covert submarine has radically altered traditional naval tactical doctrine. Submarines have successfully attacked and sunk every type of major warship, including battleships and aircraft carriers, in substantial numbers during two world wars. Whether naval professionals admit it or not, a modern nuclear submarine is a major warship capable of inflicting immense damage. At the strategic level, submarines have been used to conduct *guerre de course* warfare against merchant shipping: island nations have been brought to the brink of collapse as millions upon millions of tons of food and raw material were destroyed in unrestricted submarine warfare campaigns against merchant shipping. The submarine, with its torpedoes, is the only conventional (non-nuclear) weapon system that has been successfully employed to achieve a strategic victory at a national level. During World War II, U.S. Navy submarines decimated the Japanese merchant fleet. By 1944, because of the lack of imported raw material, oil, and food, the mighty Japanese industrial machine was grinding to a standstill and defeat was inevitable.

The modern submarine, unlike its close relative the torpedo, is not the creation of a single genius like Robert Whitehead but instead evolved over a long period of time with many distinguished inventors contributing to the design. The sea is a harsh, unforgiving environment, and a large number of less successful inventors forfeited their lives in vain attempts to build submersibles. Unfortunately, the submersibles frequently went to the bottom and took their inventors with them; in these cases, the causes of the failures were unknown. Since mistakes tended to be fatal, the evolution of the submarine was a slow and painful process. Man has always had a desire to return to the sea and, since earliest times, he has experimented with ways to survive for extended periods under water using open diving bells, breathing tubes and other simple devices to provide the air needed for extended dives beneath the surface of the sea.

It is reported that, even before Archimedes discovered the principles of submersion in the third century B.C., Alexander the Great had used some form of submersible vessel during the siege of

Tyre in 322 B.C. However, there is little reliable information about early submersibles, and it was not until the late 16th century that actual details about submersibles began to be recorded. There are numerous documented cases of experiments conducted with submersibles during the 17th and 18th centuries, but these early experiments did not have any significant military potential. Since the technical problems involved in constructing these primitive submersibles far exceeded the available technology, these early vehicles presented more of a risk to their crews than they did to any potential enemy. One of the more successful early inventors was Cornelius van Drebbel, who built several submersible boats between 1620 and 1630 in London, England. It is alleged that he successfully navigated a submerged boat, propelled by 12 rowers, in the Thames and that King James I either witnessed the feat or actually rode in the submersible and encouraged Van Drebbel to continue his experiments.

Early submersibles that had a direct impact on undersea warfare were discussed in chapter 3 as part of the genesis of the torpedo. The *Turtle*, designed by David Bushnell, was the first submersible to conduct an attack on a warship in time of war. In July 1776, the *Turtle* conducted a submerged attack against HMS *Eagle*, a 64-gun ship of the line anchored off Staten Island in New York Harbor. The *Turtle* made a successful undetected submerged approach but could not attach the explosive charge because the screw to hold the explosive charge in place could not penetrate the copper sheeting on the hull of the *Eagle*.

Although the attack failed to actually sink the *Eagle*, it demonstrated the feasibility of a submersible attacking a surface ship, and it did have a tactical impact because it unnerved the British, forcing them to give up their close blockade and move their ships farther out to sea. Similarly, Fulton's early submersibles did not have a major impact on naval warfare, but he did achieve a significant first when his submersible, *Nautilus*, successfully sank a surface ship in an experiment at Brest. This was the first recorded case of a submersible being used to sink a ship.

During the U.S. Civil War, the Confederate Navy built a number of semi-submerged torpedo boats called "Davids." These small steam-powered launches, equipped with spar torpedoes, could not be totally submerged because the air inlets and the funnel had to remain above the surface. However, they did run with their decks awash, and they were difficult to detect at night. The Davids were significant because the spar torpedo provided, for the first time, an offensive underwater weapon that could be used to attack a ship that was underway. The Davids achieved some spectacular successes, but it was a very risky business because the Davids were frequently swamped by their own spar torpedo when it exploded against the side of a ship only a few yards away.

The Confederate submersible *H. L. Hunley*, powered by an eight-man crew turning a crankshaft connected to the propeller, is credited with being the first submersible to sink an enemy warship in time of war. Unfortunately, the *Hunley*, which used a spar torpedo to sink the Union warship *Housatonic* in February 1864, was swamped by the explosion and also sank, thereby paying the supreme price for its achievement. Early submersibles were dangerous for all concerned!

These early submersibles achieved some notable milestones in undersea warfare, but they were isolated successes. The technology to support the development of true submersibles was not yet in hand. The feats were impressive, but wooden hulls, greased leather seals, and hand-powered

propulsion systems did not provide an adequate base for developing an effective submarine. During the second half of the 19th century, as the industrial revolution gained momentum, much new technology became available, which had a significant impact on the development of the submarine. Steel hulls, steam engines, screw propellers, rubber for gaskets and seals, batteries, electric motors, and gasoline engines are some of the emerging technologies that made the modern submarine feasible.

Robert Whitehead's successful development of the automobile torpedo in 1868 provided a demonstration that self-propelled underwater vehicles were feasible, which provided both a technical base and a strong stimulus for the development of manned submersibles. By the 1880s, over 40 different experiments were ongoing, and inventors in almost every seafaring nation were striving to build some sort of a submersible.

There were two schools of thought on how submarines should be designed and how they should be employed. Some thought such a vessel should operate totally and continuously submerged and that stealth was the primary driving requirement. This type of submarine should have a fish-shaped body combined with electric propulsion to optimize underwater performance and permit extended submerged patrols. The other school, basing its thinking on the semi-submersible Civil War Davids, was interested in submerging only during the terminal phase of an attack to provide protection from enemy gunfire. They wanted surface performance equal to or better than a torpedo boat and the capability for submerging for a short period for the final phase of the attack. The British Royal Navy, since it had the most ships to lose if a successful submarine was developed, remained unalterably opposed to all submarine developments and steadfastly refused to support or endorse any submarine-related efforts during the final decades of the 19th century.

In spite of the Royal Navy's objections, British shipbuilders and inventors were interested in establishing a commercial market for submersibles, and much of the pioneering work on submersibles was of British origins. A British clergyman, George William Garrett, developed a submersible with a steam propulsion system in 1879 that used the latent heat from large tanks of hot water stored at high pressure to power the steam engine while submerged. When the high-pressure hot water was released from the tanks, it flashed to steam, providing the energy to drive the steam engine. This type of submersible could operate like a conventional steam launch on the surface and use the energy stored in the water to conduct a submerged attack on a target. Thorsten Nordenfelt, the famous Swedish arms manufacturer, became interested in the commercial potential of Garrett's submersible and, in 1882, provided capital for the development of a larger submersible armed with Whitehead torpedoes. Nordenfelt was the first person to combine the submarine and the Whitehead torpedo to provide the basic elements of a potent new weapons system that would forever change naval warfare.

The *Nordenfelt I*, the first armed submersible, had an external bow-mounted tube with a Whitehead torpedo and a Nordenfelt 1-inch machinegun. The trials held in 1885 were modestly successful. However, there were reliability and depth-keeping problems when operating fully submerged. Since hydrodynamic control theory had not yet been even conceived, these problems had to be solved by trial and error, and this was a slow and dangerous procedure. Air to support human life while submerged was always a critical problem, and an open flame, such as a candle, was

generally used to determine when the oxygen supply was nearly exhausted. When the flame started to flicker and go out, it was time to surface.

The Nordenfelt, with its steam engine, introduced a serious new problem because any leakage from the furnace or smoke box could produce fatal carbon monoxide poisoning. Garrett himself was overcome by carbon monoxide fumes during the trials, and it took him 3 weeks to recover. To warn of the presence of this deadly gas, a cage of mice was carried in the submarine: if they lost consciousness, the submarine immediately surfaced. In addition, the steam power plant generated considerable heat: at times, the internal temperature approached 150° during submerged operations. Despite these problems, Nordenfelt found buyers for his new submarine. The Greek, Turkish, Russian, and German navies all placed orders for Nordenfelt submarines. In the case of the Turks, they could not recruit even the six men required to man one submarine, and their two submarines remained in a dockyard shed unused for decades because they were considered too dangerous to use.

While Nordenfelt was marketing his submarine, inventors in other nations were hard at work. In Russia, an inventor named Drzewiecki designed a number of submarines for the Russian Navy. His designs, which never achieved any notable success, called for the torpedoes to be carried externally in drop collars. External torpedoes became very popular for a time, and the “Drzewiecki drop collar” became the standard method of mounting torpedoes on the external hull of many of the early submarines.

In 1886–1888, a young lieutenant in the Spanish Navy, Isaac Peral, designed and built the *Peral*, a submarine powered by two 30-hp electric motors and 420 batteries. Although Peral had developed the first successful submarine with a true underwater propulsion system, the senior officers in the conservative Spanish Navy killed the effort, and Peral’s electric propulsion system was quickly adopted by most of the other major navies.

The French Navy, influenced by the doctrines of the “Jeune Ecole,” was interested in guerre de course warfare and inexpensive ways to conduct indirect attacks against the mighty British navy. The French Navy was fascinated with submarines as defensive platforms that could be used for coastal defense to prevent the British from imposing a close blockade of French ports in the event of war. During the late 1880s and the 1890s, the French Navy invested heavily in both the technical and tactical development of submarines. Much of the early development of the submarine as a weapon system resulted from these extensive French efforts.

Starting in 1886, the French experimented with a number of submarine designs, including the *Goubet II*, the *Gustave Zede*, and the *Gymnote*. Extensive trials were conducted, and, in spite of technical problems, the French were encouraged in their opinion that the submarine had significant operational potential. In 1896, an open competition was held to design a 200-ton submarine with a range of 100 miles on the surface. Twenty-nine designs were submitted, and the winner was a Frenchman, Maximo Laubeuf, with a remarkable submarine, the *Narval*. The *Narval* was a double-hull design with a flush deck, conning tower, and diving planes. It had an electric propulsion system for submerged operation and an oil-fired steam engine for surface running. The steam engine could also drive a dynamo to recharge the batteries during surface operations, which greatly increased the submarine’s submerged endurance. Although the *Narval* carried its four Whitehead torpedoes in

external drop collars, it bore a strong resemblance to later submarines, and it represented a major step in the evolution of the modern submarine.

In support of their technical developments, the French Navy conducted an aggressive program of trials and fleet exercises to evaluate their submarines and develop tactics. These extensive trials provided valuable hands-on experience and highlighted problems with depth-keeping and stability. During extended fleet operations, problems that could not be addressed theoretically were solved on a trial and error basis. The *Gymnote* was rebuilt three times during its operational life; the depth control problem was not solved until two sets of hydroplanes were added. A conning tower also had to be added to keep it from swamping while operating on the surface.

The French also incorporated foreign developments into their designs, including the Peral electric propulsion system and Drzewiecki's drop collar, and they continuously evaluated such improvements during fleet exercises. The effectiveness of French submarines steadily improved; by 1900, they were demonstrating a consistent ability to successfully attack French battleships, both at anchor and underway, during fleet exercises. These fleet exercises, witnessed by naval observers from the other major naval powers, demonstrated the impressive performance of the French submarines and generated a broad interest in this new weapon system. Unfortunately, the French were hard at work preparing to fight the last war. When the next war came, the British were their allies, and the French ended up on the wrong end of a massive German submarine offensive that was based largely on French developments.

With the development of rapid-fire guns, the U.S. Navy became increasingly concerned about the vulnerability of surface torpedo boats. In 1893, designs were solicited for a submarine torpedo boat. A number of designs were submitted, including proposals by Nordenfelt and the Detroit Dry Dock Company (for a "Baker Boat"), but the two finalists were Simon Lake and John Philip Holland.

After some administrative delays, Mr. Holland's proposal was selected, and, on March 13, 1895, a contract was issued to build the *Plunger*. Holland, an immigrant Irish schoolmaster, was violently anti-British. During the 1880s, he had been secretly supported by the Fenian Brotherhood to build a submarine that could be used by the Irish in their rebellion against British rule. It is ironic that his submarine, which was conceived as a terrorist weapon for the Irish Republican Brotherhood, was to evolve into a weapon system that would nearly destroy the British Empire during two world wars. The *Plunger*, with a dual propulsion system, was to be powered by a steam engine on the surface and by electric propulsion when submerged. Holland and the Navy got into serious disagreements during the construction of the *Plunger*, and he finally got disgusted and withdrew from the venture. He then proceeded to design a new, smaller, 53-foot-long, 75-ton submarine that was powered on the surface by an Otto-cycle type gasoline engine that could also be used to recharge the batteries while underway. Holland then built the submarine, at his own expense, and successfully demonstrated it to the Navy.

The Holland submarine was a major milestone in the evolution of the modern single-hulled submarine, and the U.S. Navy purchased it for \$120,000 on April 11, 1900. It was taken to the Naval Torpedo Station in Newport, Rhode Island, where a "volunteer" crew from the torpedo station, headed by Lieutenant H. H. Caldwell, manned the new submarine and conducted torpedo firings. During the exercises, the *Holland* made an undetected submerged approach to within torpedo firing

range of the battleship *Kearsarge* in Newport harbor. Since Holland had exhausted his resources building the submarine, he was forced to solicit financial backing, and he became affiliated in 1900 with the newly formed Electric Boat Company, which was destined to become the world's best known builder of submarines in the 20th century. It is interesting to note that Holland's early submarines were equipped with E. L. Zalinski's compressed-air dynamite gun to hurl explosive missiles at ships. The U.S. Navy's first submarine came completely equipped with both a torpedo tube and a tube for launching air-delivered missiles!

After failing to get the U.S. Navy submarine contract, Simon Lake sought private funding and pressed on with his submarine efforts. Lake's approach was different from other designers in that he was convinced that submarines should have wheels and travel on the bottom of the sea. This seemed to irritate the Navy, which rejected Lake's submarines for years, even though they incorporated many advanced concepts such as the periscope, simply because he continued to put wheels on them. His later designs resembled conventional submarines except for the small retractable wheels that he continued to incorporate in the design.

Because Lake's submarines were strongly built, smoothly diving boats, the Russian Navy ultimately ordered four of them and the U.S. Navy recommended the purchase of five. By the turn of the century, the submarine's basic feasibility had been demonstrated, and there was an international arms race as the major naval powers started to acquire operational submarines. By 1900, even the British Royal Navy was having second thoughts about submarines as the dynamic Admiral "Jackie" Fisher pressed for the construction of British submarines. In 1901, the British ordered five Holland-designed submarines that were to be built by Vickers and Maxim at Barrow.

The first decade of this century was a turbulent period in the evolution of the submarine as the major naval powers sought to incorporate submarines into their navies. When Dr. Rudolf Diesel perfected a new direct injection internal combustion engine that burned heavier and less explosive fuel oil, it was quickly adopted for submarine use. The first diesel-powered submarine was the French *Aigrette*, launched in January 1904. A quantitative race developed as the French continued to rapidly expand their submarine force and the British demonstrated their seriousness by building over 50 new submarines.

These early submarines, many of which were powered with volatile gasoline engines, had a disturbing tendency to malfunction, catch fire, and explode. One expert calculated that, of the 2,000 men serving in submarines during this period, over 200 lost their lives because of collisions, malfunctions, and gasoline explosions. This 10% casualty rate, more than twice the 4% casualty rate suffered by Union forces during the bloody Civil War, demonstrated that operating early submarines was a high-risk business. In Germany, Grand Admiral von Tirpitz was not very enthusiastic about submarines. It wasn't until 1906 that Krupp got an order from the Imperial German Navy to build an unterseeboot, or undersea boat, that was designated the U-1. The 287-ton boat had a Körting engine fueled by heavy oil (referred to as petroleum, though it was the less volatile paraffin/kerosene type) and was fitted with a single bow torpedo tube with two internal torpedoes for reloads.

The Germans were slow to acquire new submarines, but they had closely watched foreign developments. In a remarkably short time, they developed some superb submarines. By 1911, when

the U-19 was laid down, the Germans were building large, 837-ton (submerged displacement), 210-foot-long, diesel-powered, oceangoing submarines with gyro compasses for underwater navigation, deck guns for surface action, and twin torpedo tubes fore and aft.

The British were also steadily improving their submarine designs. Their large, 500-ton, D-class offensive submarines, laid down in 1906, were the first boats capable of extended independent deployments. These highly successful double-hulled boats with external ballast tanks provided the design base for succeeding British submarines right up through World War II. In one short decade, the submarine had advanced from an experimental curiosity to a capable fighting ship with considerable potential. By the eve of World War I, the submarine had developed to the point where it was ready to go to war.

By the time World War I started in 1914, almost 400 submarines had been built, and 16 different navies had acquired submarines. Even before the war started, French and British fleet exercises had provided some valuable insights concerning the future role of submarines in naval warfare. Naval tacticians had concluded that traditional close blockades by surface warships would be unacceptably risky against a nation employing coastal defense submarines. There were also disturbing indications that submarines, when employed offensively, would pose a significant threat to major warships at sea. The problem was compounded by the fact that there was no way to detect a submarine and no weapons available to attack a submerged submarine.

Before the war was a month old, the threat to surface warships was confirmed when the British submarine E-9 torpedoed the German cruiser *Hela* and the German submarine U-21 torpedoed the British cruiser *Pathfinder*. On September 22, 1914, the U-9 sank three British cruisers—the *Aboukir*, the *Hauge*, and the *Cressy*—in a single attack that brought the new threat into sharp focus. The loss of 36,000 tons of warships and 1,400 men to a single U-boat confirmed that the submarine was a new, deadly instrument of naval warfare that had to be taken seriously. On January 1, 1915, the U-24 sank the battleship HMS *Formidable* in the English Channel, further confirming the magnitude of the submarine threat. When German U-boats were detected trying to penetrate the fleet anchorage, the British became concerned that their precious capital ships were at risk even when in port.

Although these submarine successes did not significantly weaken the mighty Royal Navy, they did have a profound impact at the strategic level and led to some major changes in tactical doctrine that challenged the traditional concepts of naval warfare. The Germans planned to use their submarines to conduct an offensive war of attrition against the Royal Navy to gradually change the balance of power. The British, recognizing this threat, were unwilling to risk any unnecessary exposure of the Grand Fleet. To protect it from submarine attacks, the fleet was moved to remote anchorages in Ireland, and it went to sea only when necessary. First, close blockades, a classic fleet role, had been eliminated; now, the fleet no longer exercised absolute sea control. The mighty Grand Fleet still ruled the seas, but the elusive submarine constantly challenged this rule and made it dangerous for the fleet to use the very seas it ruled.

It was essential that the Royal Navy maintain a numerical superiority over the German High Seas Fleet. The possible loss of precious capital ships was unacceptable, but every time the fleet went to sea, even for training, it was exposed to deadly torpedo attacks from submarines. The submarine

with its torpedoes made fleet admirals very cautious about nonessential fleet deployments, and the destroyer with its torpedoes made them very conservative when conducting fleet engagements. The mighty capital ships still ruled the sea, but the lowly torpedo had demonstrated itself to be a threat that had to be taken seriously. The normally aggressive Royal Navy suddenly became very cautious and conservative. Destroyers became the workhorses that were constantly at sea patrolling while the dreadnoughts were kept in secure protected anchorages where they were, it was hoped, safe from submarine torpedoes.

Contrary to popular belief, prior to World War I, the German Navy had no plans to use their submarines to attack commerce. On October 20, 1914, the U-17, strictly in accordance with prize regulations, stopped, searched, and scuttled the British steamer *Glitra* off Norway. This was the first U-boat attack on a merchant ship, and it opened up the possibility of using submarines against merchant shipping to conduct *guerre de course* warfare. The Germans saw this as a possible way of countering the British blockade and, in February 1915, authorized attacks against merchant ships in accordance with prize regulations. However, neither side would or could adhere to the idealistic prize regulations; within a short time, the U-boats were conducting unrestricted submarine warfare against shipping in the Atlantic approaches to Great Britain.

The German U-boat fleet, still in its infancy, was mostly small coastal submarines, and only about 15 or 16 submarines could be maintained on patrol at any one time. This modest fleet proved to be surprisingly effective: losses to it approached 100,000 tons per month by the summer of 1915. When the British losses exceeded new construction tonnage, it was apparent that the submarine represented a threat that had to be taken very seriously. The British used nets and minefields in attempts to contain them; destroyers were given a reinforced “can opener” bow for ramming submarines on the surface; and specially armed Q-ships were deployed to entrap U-boats. However, there was no way to detect submerged submarines, and there were no weapons available to attack them even if they were detected. Unrestricted submarine warfare represented a watershed in naval warfare as the submarine attempted to exercise sea control by attacking both merchant ships and warships to prevent the enemy from using the sea. For the first time, unarmed men, women, and children were subjected to the terrors of surprise torpedo attacks when traveling in unarmed ships, and most of the civilized nations strenuously objected to these brutal acts.

When, on May 7, 1915, the U-20 torpedoed the British liner *Lusitania*, over 1,000 passengers and crewmen, including a number of U.S. citizens, lost their lives when the great liner sank. Although the *Lusitania* was carrying war materiel and could be considered a valid target, the British vigorously denied it, and the U.S. public was outraged by the act. The British couldn’t defeat the U-boats at sea, but they were also waging a very effective propaganda campaign, particularly in the United States. The German Government called off the Atlantic campaign in September 1915 because of the outcry from outraged neutral nations. The small German Type UB and Type UC boats, operating from Belgian harbors, were quite effective in harassing merchant shipping in the Strait of Dover and near the Thames estuary. These small, 127-ton, 95-foot boats were ideally suited for shallow waters, and the minelaying Type UC boats, built in complete secrecy, gave the British a rude shock by sowing mines in previously safe British channels and harbors.

The submarine also played a significant role in the Mediterranean theater and in the Baltic Sea, where it left no doubt that it had assumed a major role in naval warfare. While the Germans built bigger, longer-range submarines suited for independent *guerre de course* warfare, the British still sought submarines that could operate with the fleet. The large, 2,600-ton, 24-knot, steam-powered K-class submarines, designed in 1913, were intended by the Royal Navy to be large, fast vessels with the endurance and speed to operate with the battle fleet. These cumbersome, disaster-prone vessels were a total failure and were disposed of within a few years. The British also experimented with the M-class submarine, an underwater monitor equipped with a 12-inch gun, but it was never used during the war because the British were afraid the Germans might copy the idea and use it against them. One of the M-class submarines was converted to carry aircraft after the war, but it sank when it flooded through the hangar while submerging. The Germans, experiencing severe shortages due to the British blockade, built a number of large merchant submarines for foreign trade. One of these, the *Deutschland*, made two successful trips to the United States in 1916. They were converted for naval use as long-range U-boats when war with the United States became imminent.

By 1916, the land war on the western front had become stalemated. The Germans, suffering from severe food and raw materials shortages due to the British blockade, were becoming increasingly desperate because they lacked the resources to conduct a long, drawn-out war of attrition. The German Navy was pressing for a resumption of the unrestricted U-boat campaign against merchant shipping, but the government had misgivings about how neutral countries, the United States in particular, would react. Finally, in January 1917, the Germans decided it was worth the risk, and a totally unrestricted submarine campaign to sever Britain's sea arteries was authorized. This was a national-level strategic objective calling for the destruction of all shipping to the British Isles, with the ultimate goal of starving the British into submission.

To accomplish their objective, the Germans had slightly over 100 operational U-boats, of which about half, or 50 U-boats, were at sea at any given time. The campaign was highly successful: 250 ships sunk in February, 330 ships in March, and 430 ships in April. During the first 6 months of the campaign, almost 4 million tons of shipping, or over 600,000 tons per month, had been sunk. However, the Germans' worst fears about this strategy were realized when, in April 1917, the United States declared war on Germany and the massive U.S. industrial machine started mass-producing merchant ships to offset the U-boat losses.

By June 1916, a quarter of the ships sailing from the United Kingdom were sunk before they could complete a round-trip voyage, and neutral shipping, terrorized by the U-boats, fell to a quarter of normal. The British calculated that they would have to arrange a peace by November if the losses continued at the current rate. However, two things occurred that made the pendulum start to swing in the opposite direction. In spite of objections from the Royal Navy, the British started to form convoys to protect slow ships, and the convoys were found to be very effective. By the end of the year, convoys were in widespread use, and the number of sinkings was declining. Losses for the last 6 months of 1917 were down to 2.5 million tons.

This reduction in losses, combined with a massive U.S. shipbuilding program, was enough to bridge the gap. The British were hurting, but enough material were getting through to sustain the war effort. Also, with new U.S. bottoms becoming available in substantial numbers, the Germans were

losing the war of attrition. The U-boat offensive continued in 1918 right to the end of the war: an additional 1,133 ships were sunk during this final phase. Of this total, only 134 were sunk in convoys. The U-boats couldn't find the convoys, and, when they did, the convoy escorts, with their hydrophones and depth charges, made it extremely unhealthy.

During the titanic struggle, the Germans had thrown 373 U-boats into the battle and lost 178 of them, along with 5,000 officers and men. The U-boats had sunk over 5,700 ships, totaling over 11 million tons or a quarter of the world's total tonnage. The U-boats had come perilously close to achieving a major strategic victory. Further, they had not been decisively defeated but had been thwarted by a massive commitment of resources to counter their effectiveness. Over 300 destroyers, 35 submarines, 550 aircraft, 75 airships, and 4,000 auxiliary vessels, manned by 140,000 men and supported by another half a million men, were committed directly to the campaign against the U-boats. In addition, it required an immense national commitment from the United States to replace the staggering shipping losses along with the millions of tons of critically needed war materiel that went to the ocean bottom in the ships.

By the end of World War I, it was clearly evident that the submarine had profoundly altered the course of naval warfare and that, when combined with the torpedo, it had been demonstrated to be the most destructive and decisive naval weapon system ever conceived. At the tactical level, the submarine had severely restricted mighty battle fleets by limiting their ability to control the seas, and every type of major naval combatant, including quite a few battleships, had been sunk by submarine torpedoes. At the strategic level, the submarine, used as a commerce raider, had sunk a quarter of the world's merchant tonnage and had brought Great Britain, an island nation, to the brink of defeat.

Immediately after the war, all German submarines were confiscated by the Allies, and Germany was forbidden to build any more submarines, even for commercial use. At the Washington Naval Armaments Conference in 1921, the British, who had suffered great losses, strongly advocated the abolition of the submarine on the grounds that its use as a commerce raider violated international law. The other naval powers rejected the proposal, and the British lost their bid to legislate the submarine out of existence.

The evolution of the submarine proceeded at a very modest pace in the interwar years. Late in World War I, the U.S. Navy and Royal Navy increased the number of torpedoes carried, and the weapon size grew from the "18-inch" diameter to the "21-inch" diameter torpedo. Starting in 1917, the U.S. Navy S- and R-class submarines were equipped with 21-inch torpedo tubes, and the new Mark 10 torpedo was modified for use in these submarines. Over half a century later, U.S. Navy submarines are still equipped with the same 21-inch torpedo tubes, so there has been no revolutionary growth in the size of submarine torpedoes since World War I.

Many of the early submarines had transverse torpedo tubes mounted on top of the hull that were used for broadside shots similar to those conducted by destroyers. Although, theoretically, these tubes provided additional flexibility when lining up for an attack, they were rarely used, and new designs did away with them and concentrated all of the tubes in the bow and stern. By having four or six tubes in a nest, the submarine could sink large targets by firing a salvo of torpedoes, or it could fire a spread of torpedoes if multiple targets were detected.

In addition to experimenting with numerous conventional patrol submarines, the British were still interested in using submarines to accompany the fleet. In the early 1930s, they built three 2,600-ton Thames-class fleet submarines. These diesel-powered submarines, with a speed of 23 knots, were designed to keep up with the fleet, but they saw limited use as fleet escorts because of further increases in fleet speeds. The French still had great faith in the submarine, and they were fascinated with its use as a commerce raider for *guerre de course* warfare. In 1930, they built the famous *Surcouf*. This submarine cruiser, with a submerged displacement of over 4,000 tons, had twin 8-inch guns in a turret, an airplane in a hangar behind the conning tower, 12 torpedo tubes, and a 12,000-mile cruising range. Only one of these giants was built, and it was lost during World War II while under the command of the Free French forces.

Many of the smaller nations, including Sweden, Holland, Turkey, Norway, Poland, and Finland, became interested in submarines for defensive purposes and built, or had built, small 200- to 400-ton coastal defense submarines. The Soviet Union concentrated on the construction of submarines for their new navy. Between 1928 and 1938, they built over 150 new submarines; most of them were small coastal defense boats, which were split up among their four fleets. Although the Russians had a lot of submarines, their performance left much to be desired when war came. Available World War II statistics indicate that the Russians lost one submarine for every ship sunk by a submarine, or a 1:1 exchange rate. This provided a classic example of how *not* to fight a submarine war.

During the interwar years, the U.S. Navy continued to develop small coastal defense submarines, but they also experimented with some large oceangoing submarines, such as the *Narwhal* and *Barracuda*, that could be used for transpacific patrols. By the late 1930s, when the *Sargo* and *Tambor* classes were being built, the U.S. Navy was well on its way to developing a first-class fleet submarine. These boats provided the design base for the follow-on *Sato* and *Balao* classes that were mass-produced during World War II. These fleet submarines, with a submerged displacement of over 2,400 tons, had 10 torpedo tubes and carried 24 torpedoes. With their long range and high speed, they were ideally suited for use in the vast Pacific Ocean where endurance was a major factor.

Shortly after World War I, Gustav Krupp, the “black baron of the Ruhr,” set up a Dutch holding company to conduct covert submarine design operations for the Germans. This Dutch company, staffed by German naval officers and designers, continued to design submarines clandestinely; in the 1930s, the company began to sell the designs to Spain, Finland, Holland, and Turkey. When these new boats were completed, the unusually exhaustive sea trials, conducted by all-German crews, provided an excellent opportunity for evaluation and training. In 1933, Adolf Hitler came to power and repudiated the Versailles Treaty, and Germany started to build small coastal submarines again.

Captain Karl Dönitz took command of the new German U-boat force in 1935, and, 2 years later, he conducted a series of exercises in the Baltic Sea to evaluate the concept of conducting coordinated submarine operations. Using a centralized shore-based command and control center, he directed massed submarine attacks against a convoy of surface ships and developed the wolfpack tactics that the U-boats employed so effectively in World War II. In this same period, with the World War I Type UB-111 submarine as a design base, Germany developed, a new 500-ton U-boat for use in the Atlantic. These Type VII U-boats became the workhorses of the submarine force. Over 500 of these

boats, which had a submerged displacement of over 800 tons and five torpedo tubes, were built during World War II. A larger Type IX U-boat displacing over 1,000 tons was developed just prior to the war.

Ultimately, over 200 of the Type IX boats, with 22 torpedoes and a range of approximately 10,000 miles, were built for use on long-range patrols to areas like the Indian Ocean and the South Atlantic. When the Germans started to rearm, they initiated a balanced naval program including both surface ships and submarines. As a consequence, the submarine building rate was modest. When World War II started in 1939, the Germans had only 56 submarines, of which most were small training or coastal defense boats. With only 22 U-boats available that were suitable for operations in the Atlantic, the Germans were hardly in a position to mount a major U-boat offensive, given their own calculations indicating that at least 300 U-boats would be needed to defeat the British.

During the interwar years, the British had developed a secret new device called ASDIC for detecting submarines. ASDIC was a ship-mounted active sonar employing active “pings” to locate a submerged submarine and establish its range and bearing. The ASDIC had been installed on most of the British escorts, and, after extensive exercises against Royal Navy submarines, the British were convinced that, in any future war, escorts, equipped with ASDIC and depth charges, would quickly eliminate any U-boat threat.

When, on September 3, 1939, France and Britain declared war on Germany, all available German U-boats were surge deployed, and the “killing time” started again. Since Admiral Dönitz did not have enough submarines to form wolfpacks, conventional tactics were employed during the initial phase of the war at sea. In this initial phase, from September 1939 through March 1940, the U-boats sank 222 ships, or 765,000 tons. In March, 1940, when the U-boats withdrew to support the invasion of Norway, British and German submarines heavily engaged in the invasion demonstrated for a brief period that submarines were key players in major naval actions. By June 1940, the Germans had occupied Norway and France, and the U-boats were being moved to French ports where they would be closer to the Atlantic shipping lanes.

On July 12, 1940, Germany declared a total blockade of the United Kingdom, and the U-boats started an unrestricted campaign against all shipping to the British Isles. By October 1940, the U-boats were sinking 352,000 tons per month. In early 1941, British losses were exceeding new construction by a factor of two to one. Clearly, the British were in serious trouble, and Churchill stated that winning the Battle of the Atlantic was Britain’s number one priority.

During the second half of 1940, as additional escorts and radar-equipped aircraft became available, the losses were reduced somewhat, but the British were still in a crisis due to the loss of critically needed shipping. When the United States entered the war in December 1941, Admiral Dönitz initiated his Paukenschlag (or Operation Drumbeat) offensive against the unprotected shipping along the U.S. east coast. During the first 6 months of 1942, the U-boats sank over 3 million tons of shipping. The U-boat commanders referred to this period as “the happy time,” and they conducted a “turkey shoot” that included a large number of oil tankers, which were in critically short supply. By the summer of 1942, coastal convoys were in use, and the U-boats moved back to the mid-Atlantic shipping lanes to get away from their new deadly enemy—the radar-equipped airplane.

Although the U-boats were meeting with great success, they were starting to encounter serious problems. Land-based aircraft equipped with radar forced the U-boats farther out into the Atlantic to escape detection. Escorts for convoys made attacks on them much more dangerous for the U-boats. Also, although it was a closely held intelligence secret for many years after the war, the British had broken the German codes and could read much of the message traffic between Dönitz and his U-boats. It is impossible to estimate the total impact of this breakthrough, but it had to be the single most dominant factor in the ultimate defeat of the U-boats. Since the information remained classified long after the war was over, the conclusions in most of the histories and analytical studies written after the war are badly distorted by this omission and are actually misleading in some cases. Intelligence data from the “code breakers” were combined with radio direction finding (RDF) equipment to provide the essential information on where the U-boats were and what they were up to. Once the operators learned how to use this intelligence effectively, the fate of the U-boats was sealed.

In the Central Atlantic, the battle resumed with increased fury during the second half of 1942. By the end of the year, the U-boat total for 1942 had reached 7,750,000 tons of shipping destroyed. This was a staggering loss for the Allies, but, with the United States now in the war, a massive ship production program was ongoing; the delivery of 7 million tons of new ships almost completely offset the massive U-boat casualties. By early 1943, there were approximately 100 U-boats at sea, but the exchange ratio was dropping: in February, one U-boat was sunk for every 2½ merchant ships.

Over 500 escorts and 1,100 aircraft were committed to the battle. In April 1943, escort carriers became available to form hunter-killer groups. With these increased resources, the intelligence data on U-boat operations could be fully exploited: the hunter-killer groups using the newly developed acoustic homing torpedoes soon changed the role of the submarine from hunter to hunted. The U-boats were not really submarines but rather submersibles; when the increased air coverage deprived them of their needed high-speed surface mobility, they could no longer converge on the convoys to conduct torpedo attacks.

The U-boats were simply being overwhelmed. By May, the exchange ratio dropped to 1 to 1: for every merchant ship sunk, a U-boat was sunk during convoy attacks. During May, 41 U-boats were lost. Because the loss rate exceeded the building rate, there was no hope that the situation would improve. Admiral Dönitz was forced to call off the campaign and recall the U-boats. The Germans had built 650 U-boats, which had destroyed almost 13 million tons of shipping while losing 250 U-boats during the campaign. The statistics strongly suggest that, if the United States had not entered the war, the probability was high that the British could not have absorbed losses of this magnitude and still continued to fight.

The Germans clearly understood that aircraft and improved radars now made it too dangerous to operate U-boats on the surface, but, without high-speed surface mobility, the U-boats were ineffective because they couldn't close on and attack the convoys. The Germans had been developing a revolutionary high-performance submarine, designed by Dr. H. Walter, that used concentrated hydrogen peroxide, or Ingolin, to provide the necessary oxygen to operate a turbine power plant while submerged. The Walter power plant would provide high submerged performance. However, the concentrated hydrogen peroxide was dangerous to work with, and it was estimated that the system would not be ready for production until 1946.

Admiral Dönitz couldn't wait, so he ordered immediate production of two new conventional submarine classes—the Type XXI and the Type XXIII—that were designed for extended submerged endurance, up to 60 hours at 6 knots, and submerged speeds up to 17 knots. The 1,620-ton Type XXI submarine, equipped with a schnorkel, six torpedo tubes, and 23 torpedoes, was to be capable of conducting fully submerged attacks against convoys. These new submarines were to be equipped with acoustic homing torpedoes for use against escorts and pattern running torpedoes for use against merchant ships. Theoretically, these submarines did not even have to expose their periscopes during an attack because the torpedoes could be fired using only acoustic inputs. These submarines represented an immense advance in submarine technology. If the Germans had gotten them operational earlier, it is conceivable that the Battle of the Atlantic could have shifted again in favor of the Germans. Fortunately, the war ended just as these new submarines were ready to go operational, so their true effectiveness remains a moot question. However, these high-technology submarines started a new era by providing the stimulus for the postwar development of several new submarine classes in Britain, the United States, and the Soviet Union.

While waiting for his new boats, Admiral Dönitz was forced to redeploy his U-boats. In September 1943, they again went to sea to harass Allied shipping. Even though the U-boats were not sinking many ships, they kept the huge Allied ASW forces tied up and forced the Allies to continue using convoys. At the strategic level, these were important considerations. From September 1943 to the end of the war in 1945 was a black period for the German Navy. Over 500 additional U-boats were lost while sinking only 337 ships totaling 1,860,000 tons. In the final year of the war, the U-boats took a terrible beating, but they still continued to aggressively press their attacks right to the end.

When the United States entered the war on December 7, 1941, the Chief of Naval Operations immediately directed that a campaign of unrestricted submarine and air warfare be executed against Japan in retaliation for the surprise attack on Pearl Harbor. During the early months of the war, the U.S. Navy submarines were heavily committed supporting naval actions. As new long-range fleet submarines were delivered to SUBPAC, the number of submarines on patrol steadily increased. In 1942, over 500 attacks were conducted against merchant ships, but only 142 ships, totaling 500,000 tons, were sunk. Part of the problem was training, but defective torpedoes were a major problem; many Japanese ships were escaping because of faulty torpedo exploders and poor depth control.

Thirty-five new fleet boats were delivered during 1942. With the new SJ radar sets, these superb boats were ideally suited to the task of conducting long-range patrols. By January 1943, there were 80 operational submarines in the Pacific, and the submarine campaign began in earnest. In addition, highly secret ULTRA military intelligence, obtained from deciphered Japanese codes, was being sanitized and provided to SUBPAC. The breaking of the maru code for naval signals used by Japanese merchant ships in 1943 provided a valuable source of information on Japanese ship movements, which was put to good use. In 1943, 800 ships, or 1,800,000 tons, of Japanese shipping were sunk by submarines. Since Japanese shipyards could replace only 800,000 tons during the year, the size of their merchant fleet dropped by 1 million tons; this loss caused increasingly serious problems.

By 1944, with 123 submarines operational, the campaign hit full stride, and SUBPAC submarines sent 500 ships totaling 2,500,000 tons to the bottom. Tankers were made priority targets. As the tankers went to the bottom, the Japanese grew so critically short of fuel that some military operations

had to be curtailed, and their industrial machine was slowing down. Food was in very short supply; aircraft and munitions production was falling due to raw materials shortages; and, with iron in short supply, only a quarter of the ships lost could be replaced.

In 1945, the number of sinkings declined simply because the Japanese were running out of ships and there weren't many targets left. The submarines had successfully severed Japan's sea lines of communication, and the island nation was hopelessly defeated. Almost the whole Japanese merchant fleet was on the bottom of the ocean. Japan was cut off from the critical raw materials supplied by its outlying possessions, and her industrial machine ground to a standstill. Even before the atomic bomb fell, Japan's capacity to wage war had been drained away. American submarines in the Pacific achieved a major strategic victory by severing Japan's sea lines of communication. The German U-boats had almost defeated the British in two world wars, but the U.S. submarines demonstrated conclusively that the submarine was capable of achieving this major strategic objective.

The submarines also played a major role in the naval war in the Pacific. They worked closely with the fleet during major sea battles, and SUBPAC submarines destroyed just under a third of the Japanese naval vessels sunk during the war. Considering that they were primarily engaged in a war against merchant shipping, their accomplishments against the Japanese Navy are very impressive. The importance of the Ultra intelligence information in the submarine war cannot be overestimated. Locating targets in the vast ocean expanse is both a difficult and time-consuming process; it was a major problem for the Germans in the Atlantic. With Ultra intelligence, opportunities for attacks increased since the submarines could be vectored into areas where ships were known to be. The fleet submarines were superb fighting machines: once they found a target, they were brutally effective commerce destroyers. In fact, the SUBPAC submarines frequently outfought Japanese escorts during convoy battles, and they sank six escort vessels for every submarine sunk by an escort.

By the end of World War II, there was no longer any doubt about the submarine's role in naval warfare. With a modest maximum force level of 156 submarines, U.S. Navy submarines in the Pacific had decimated the Japanese merchant fleet and accounted for almost a third of the Japanese naval vessels sunk. They demonstrated conclusively that the submarine had a major role both in tactical and strategic naval warfare. The submarine's role is even more impressive when one considers that the 50,000-man submarine force represented only 1.6% of the total naval complement. The submarine force, representing less than 2% of the U.S. Navy, accounted for 55% of Japan's maritime losses.

In the immediate postwar years, the high-performance German Type XXI submarines with schnorkels provided the technology and the stimulus for the development of new submarines in Great Britain, France, Russia, and the United States. The Russians, exploiting both German technology and designers, began a crash program to build a large fleet of modern high-performance submarines. As the cold war intensified and the new Russian submarines were perceived to be a major threat, the United States and Britain invested heavily in ASW development to counter the Russian submarine threat. In the United States, the new *Tench*-class submarines underwent a modernization program to provide Greater Underwater Propulsive Power (GUPPY) by streamlining the hull and increasing the battery power. In addition, the schnorkel, Americanized to a "snorkel," was added to some of these boats. The GUPPY boats, equipped with acoustic ASW torpedoes, were used as test beds for

developing hunter-killer (attack) submarines for ASW warfare as the U.S. Navy concentrated on countering the growing Soviet submarine threat.

In 1946, Ross Gunn and Philip Abelson of the Carnegie Institute proposed the development of a nuclear propulsion system for submarines. The Navy did its best to ignore the proposal, but a dynamic naval officer, Captain Hyman G. Rickover, was fascinated with the concept and enthusiastically supported the development of a nuclear-powered submarine. Captain Rickover was appointed to build a land-based prototype nuclear propulsion system. The construction of the world's first nuclear submarine, USS *Nautilus*, was authorized in 1952. On January 17, 1955, when Commander Eugene Wilkinson, the commanding officer of the *Nautilus*, sent the historic message "Underway on nuclear power," a major milestone in submarine development was accomplished.

The 3,500-ton, nuclear-powered *Nautilus*, with a submerged speed of over 20 knots and essentially unlimited submerged endurance, represented a quantum improvement in performance. For the first time, a submerged submarine had performance equal to, or in some cases superior to, surface ships. There was no doubt that nuclear submarines would revolutionize naval warfare, and, within a short time, they began to demonstrate their potential. The *Nautilus* made a 3,000-mile submerged transit in the Atlantic; it went under the polar ice to the North Pole; and, in 1958, it made a polar transit from Hawaii, in the Pacific, under the ice cap to England. In 1960, another U.S. Navy nuclear submarine, the *Triton*, circumnavigated the globe submerged, dramatically demonstrating that nuclear submarines have the endurance to go anywhere in the world submerged.

Concurrent with the development of the nuclear submarine, in 1953, the U.S. Navy built a conventional submarine to examine the optimum hull shape for submerged operations. The highly successful tear-shaped experimental *Albacore* submarine, with a low hydrodynamic drag and optimized for submerged operation, established the design base for a new generation of high-performance submarines. By the 1960s, with the *Skipjack* class, the *Albacore* hull was combined with a nuclear propulsion system to provide a revolutionary new type of submarine. The follow-on *Permit* and *Sturgeon* classes incorporated noise-reduction techniques and high-performance sonars to improve ASW performance. The U.S. Navy now had the best ASW submarines in the world.

While the U.S. Navy was concentrating on submarines for ASW warfare, the Russians developed their own nuclear propulsion system; starting with the *November*-class nuclear submarines, they proceeded to develop a fleet of nuclear attack submarines. Although the Russian nuclear submarines tended to be noisier, their high speeds made them a significant threat to surface naval forces, which was the primary Russian objective. It is ironic that the major threat to the awesome modern nuclear-powered attack submarine is a quiet ASW submarine with acoustic homing torpedoes. The submarine is a major threat, but the major threat to the submarine is another submarine.

During the 1950s, the U.S. Navy had experimented with using Regulus cruise missiles armed with nuclear warheads from submarines. When intercontinental ballistic missiles (ICBMs) were developed, the Regulus effort was terminated, and the Navy initiated development of the Polaris system. A *Skipjack*-class submarine, then currently under construction, was cut in half, and a 130-foot-long missile section containing 16 Polaris missiles was installed just behind the sail. This first Polaris submarine, the *George Washington*, successfully fired a Polaris missile on July 20, 1960.

The submarine's warfare role was again escalated as it became a key player, at the strategic level, in the nuclear arena.

The large ballistic missile submarines, or "boomers," with their nuclear ICBMs achieved a new threshold of destructive power. A single submarine now had the awesome power to inflict more damage than was unleashed during all of World War II. The Russians were quick to realize the strategic significance of the ballistic missile submarines; by the late 1960s, Soviet *Yankee*-class ballistic missile submarines were operational. The British and the French also built and deployed nuclear-powered ballistic missile submarines. Both the United States and the Soviet Union continue to build new and larger missile submarines with longer-range, multiple-warhead missiles. The current fleet of ballistic missile submarines could totally destroy civilization several times over.

When cruise missiles were developed during the 1970s, they were quickly adapted for submarine use. Some of the U.S. Navy's *Los Angeles*-class attack submarines are now equipped with a mix of cruise missiles and torpedoes. This provides them with a potent capability against surface naval vessels and also the ability to launch missile strikes against land targets.

The submarine has undergone revolutionary advances that make it immensely more effective and destructive than its World War II counterpart. In less than a century, the submarine has transitioned from a naval curiosity to a premier world-class weapon platform. In a sense, the submarine has become the ultimate warship, and its influence is now greater than ever. Yet, little mention is made of the fact that the torpedo is the weapon that made the submarine such a potent threat.

Chapter 13

THE TORPEDO AND AIRCRAFT

Although Robert Whitehead, the father of the torpedo, was a brilliant engineer, he had certain idiosyncrasies, like all geniuses. Whitehead firmly believed everything he read in the newspapers must be the truth, and he was also firmly convinced that heavier-than-air machines would never fly. When it was reported that the Wright brothers had made their first powered flight at Kitty Hawk, North Carolina, on December 17, 1903, thus unlocking the secret of flight, it must have caused Whitehead much consternation to read in the “always truthful” newspapers that a heavier-than-air machine had flown. When Whitehead died in 1905, the airplane was still an experimental curiosity, and there is some doubt as to whether he ever truly believed that man had mastered the secret of heavier-than-air flight. Similarly, as the Wright brothers experimented with their fragile air machine, they could not have visualized that, within a few short years, the airplane would evolve into a major instrument of war.

When the war clouds started to gather over Europe in the early 20th century, military organizations became interested in the airplane, and experiments were conducted to examine potential military applications, including scouting, observation, and bombing. In 1911, two British naval aviators, Commander Murray Sueter and Lieutenant Douglas Hyde-Thomson, proposed to the Admiralty that combining the aircraft and the torpedo could provide a new weapon system with considerable potential. The concept was well received in the Admiralty, and the Sopwith Aviation Company was directed to build a seaplane capable of carrying a torpedo, while Sueter and Hyde-Thomson were assigned the task of designing the drop mechanism.

Sopwith built a seaplane powered with a 200-hp Samson engine, and, in 1913, Lieutenant Arthur Longmore made the first successful flight with an aircraft armed with a torpedo. Since the primitive early aircraft could just about carry the pilot, getting a 14-inch, 800-pound torpedo into the air was a major technical accomplishment. Within a year, the Short brothers built their “folder” seaplane, powered with a 160-hp Gnome engine, and it was promptly fitted with a Sueter and Hyde-Thomson torpedo drop mechanism. On July 28, 1914, just 6 days before the war broke out, the first successful live torpedo drop in history was made by Lieutenant Longmore in the Short seaplane, dropping an obsolete 14-inch, 800-pound Mark X torpedo from the Royal Gun Factory inventory.

Great Britain was not alone in trying to adapt the torpedo for air warfare. In the same timeframe, an Italian, Alessandro Guidons, launched a dummy torpedo from a twin-engine Farman monoplane to demonstrate the aircraft’s carrying capacity. However, the British were serious about using it to wage war. In 1915, a cross-channel packet steamer, the *Ben-My-Chree*, was converted into a seaplane tender, and the Short Company built a new, larger Type 184 seaplane, powered by a 220-hp Sunbeam engine, specifically to carry torpedoes. In May 1915, the *Ben-My-Chree* was dispatched to the Dardanelles, with either two or three of the new Type 184 torpedo-carrying seaplanes, to participate in the Gallipoli campaign. It arrived at Mudros in late June, and the next few weeks were devoted to getting the temperamental Sunbeam engines in the Short Type 184 torpedo planes to operate properly in the hot, dusty climate. When the cantankerous engines were running properly, practice torpedo

drops with the experimental drop mechanisms were made to train the pilots in the art of aircraft torpedo attacks.

The credit for the first successful wartime use of an aircraft-dropped torpedo is difficult to assign precisely. Flight Commander Charles Edmonds, flying one of the Type 184 seaplanes, took off from the Gulf of Xeros on August 12, 1914, and headed toward the Sea of Marmara in search of a target. The Sunbeam engine was in a temperamental mood, and Edmonds had difficulty staying airborne with the heavy torpedo as the engine coughed and sputtered along. As he passed over the Dardanelles, Edmonds spotted a 5,000-ton steamer close inshore. He glided down from 800 feet, leveled off at 15 feet, and, when only 300 yards from the target, dropped his 14-inch Mark X torpedo. The torpedo functioned perfectly, heading right for the center of the target, and there was a large explosion as it hit the ship. Unfortunately, when the elated Edmonds returned to base, he was chagrined to learn that the ship he'd torpedoed was an abandoned hulk that the Turks had beached after it had been torpedoed by a British submarine.

Just 5 days later, on August 17th, Flight Commander Edmonds, accompanied by Flight Lieutenant George B. Dacre in a second Type 184 torpedo plane, was again on the hunt. Edmonds sighted a Turkish supply ship and again executed a flawless attack, scoring a direct hit and setting the ship on fire. However, the small 77-pound warhead in the obsolete Mark X torpedo did not inflict mortal damage, and the ship was later towed back to Constantinople and salvaged. In the meantime, the temperamental engine in Dacre's plane began to act up. With the heavy torpedo aboard, he was forced to make an emergency landing near Galata. Unable to take off with the heavy torpedo attached and unwilling to jettison the weapon, Dacre, under full power, taxied the torpedo plane down the strait looking for a target. He found a small 300-ton tugboat in False Bay on the Asiatic side of the strait, taxied into position, and released the torpedo, which scored a direct hit and sank the tugboat. When the seaplane had been relieved of the torpedo's weight, Dacre managed to take off and return to the *Ben-My-Chree*.

These three successful aircraft-launched torpedo attacks by Short Type 184 seaplanes had clearly demonstrated that torpedoes launched from aircraft were capable of sinking surface ships. However, the proof was not conclusively derived from any single attack. In the first attack by Edmonds, an air-dropped torpedo hit a stationary ship. In his second attack, he hit a moving ship but only damaged it. In the third attack, by Dacre, a ship was sunk by an aircraft torpedo, but the airplane was not airborne when the torpedo was launched. It took three attacks to make the case. Once the basic feasibility was established, the British wanted an aircraft capable of carrying the new, 1,000 pound, 18-inch, Mark IX torpedo, with its much larger, 250-pound warhead.

In 1916, the Short 320 was designed in response to an official requirement for a long-range seaplane capable of carrying the new Mark IX torpedo. In 1917, six Short 320s based in Italy took part in a planned raid against U-boats lying off Cattaro (modern Kotor). Because the aircraft didn't carry enough fuel for the long flight, they were to be towed on rafts to within 50 miles of the target before being launched. When a storm came up, the attack had to be abandoned, and, for some unknown reason, it was never rescheduled. The Short 320 was a very successful airplane, but, as interest in aircraft carriers continued to grow, official preference switched from seaplanes to land-

based torpedo planes that could be used on the Royal Navy's new flat-deck aircraft carrier, HMS *Argus*.

During this same period, the Royal Navy issued a most secret memorandum requesting the Sopwith Aviation Company to investigate the possibility of building a land-based aircraft with a 4-hour endurance that was capable of carrying the Mark IX torpedo. The same memorandum suggested, for the first time, the use of a catapult to help launch the plane from a ship. In response, Sopwith built the T.1 *Cuckoo*, the first plane designed specifically to operate from ships as a torpedo carrier. The prototype folding-wing biplane, which emerged in 1917, did not play a role in World War I, but it did represent the first of a long line of shipborne torpedo planes to be developed by the Royal Navy.

The Germans built the twin-engined Brandenburg aircraft for use as torpedo carriers and conducted some successful torpedo attacks against British ships late in World War I, which demonstrated that land-based torpedo bombers could successfully attack and sink merchant ships. The Germans also explored the possibility of using torpedoes from their huge Zeppelin airships and conducted some trials with torpedo-carrying gliders that were guided toward the target by trailing wires. These weapons were almost ready for service when the war ended. Although the aircraft torpedo did not play any significant role in World War I, the successful employment of aircraft-delivered torpedoes under wartime conditions demonstrated the potential of aircraft torpedoes. The new torpedo aircraft also provided a strong justification for building aircraft carriers. At this point, since the torpedo had been successfully deployed from beneath the surface of the sea, from the sea surface, and from the air, it was established as a universal weapon.

In 1922, a British Air Mission journeyed to Japan to exchange information and to brief the Imperial Japanese Navy on British aircraft torpedo experiences. During the exchange, the Japanese acquired at least one Short 320 torpedo-carrying seaplane and six of the Sopwith T.1 *Cuckoo* torpedo planes that carried Mark 2 torpedoes. Although the war had ended before the *Cuckoo* could make a name for itself by "laying its eggs in other people's nests" like its counterpart in nature, the six *Cuckoos* that "nested" in Japan provided the basis for the development of first-class Japanese carrier-based torpedo planes. In 1922, the Japanese built the *Hosho*, or Phoenix in Flight, the first new carrier built from the keel up. The *Hosho* was the first of many carriers built by the Imperial Japanese Navy. Twenty years later at Pearl Harbor, the Japanese would demonstrate that they had learned well.

Meanwhile, in the United States in 1910, Rear Admiral Bradley A. Fiske proposed using a torpedo-carrying airplane to attack ships. In 1912, Fiske was issued a patent for his invention. Some preliminary experiments were initiated, but the Navy soon lost interest in the concept. When the British and the Germans started their experiments during World War I, the U.S. Navy closely monitored their progress. As soon as the war was over, the U.S. Navy began to experiment with torpedo-carrying aircraft and aircraft carriers. In May 1920, at the Anacostia Naval Air Station (NAS), a modified Curtis biplane, flying 18 feet above the water at 55 knots, successfully launched a Mark 7 torpedo. Although there were problems with both the airplane and the torpedoes during the tests, these experiments were the starting point for U.S. developments.

A new torpedo-carrying airplane, the PT-1, was designed by the Naval Aircraft Factory (NAF) at Philadelphia, Pennsylvania; the first of these was delivered on August 30, 1921. Concurrent with the aircraft development, the Naval Torpedo Station (NTS) at Newport modified and strengthened the 18-inch, 1,600-pound Mark 7 torpedo to withstand the rigors of aircraft launching. The first two PT-1s, equipped with floats, were sent to NTS Newport where an Air Detail was formed to experimentally develop aircraft torpedo drop techniques and tactics. On November 2, 1921, Lieutenant Thomas H. Murphy, head of the NTS Air Detail, made the first successful drop of a Mark 7 torpedo from a PT-1 aircraft. In October 1921, NAF Philadelphia started to deliver the new PT-1 torpedo planes to Torpedo Squadron 1 (VT-1), and the Navy's first operational aircraft torpedo squadron started to take shape. The following year, on March 20, 1922, the U.S. Navy's first aircraft carrier, USS *Langley*, was commissioned. When VT-1 went aboard the *Langley*, the U.S. Navy entered a new era as the aircraft carrier became an operational reality.

Whitehead, who had been upset about the British firing his delicate torpedoes from above-water deck-mounted tubes, must have turned over in his grave when they started dropping torpedoes from aircraft. The torpedo was not designed to absorb the shock of high-speed water entry, so early torpedoes, not being aerodynamically stable, were frequently damaged when they entered the water tail first. Also, since it got very cold at higher altitudes, the delicate torpedo components tended to freeze up; even if the launch was successful, the torpedo frequently malfunctioned because of frozen valves and pipes. To correct this problem, the engine exhaust pipes on early torpedo planes were redesigned to direct the exhaust gases directly onto the exposed torpedo to keep it warm during the flight. The structural strength to withstand high-speed water entry was a serious problem with early aircraft torpedoes. The U.S. Mark 7 torpedo was modified many times over the years to strengthen it for aircraft use. Finally, in 1936, the design of a new aircraft torpedo, the Mark 13, was authorized.

The Air Detachment at the Naval Torpedo Station in Newport had the difficult task of experimentally developing the optimum techniques for successfully dropping the torpedoes from aircraft. The 204-inch-long Mark 7 torpedo had a nasty habit of entering the water nose first and executing a deep dive that frequently resulted in the torpedo getting buried in the mud. Additionally, any minor variations in the plane's speed or altitude resulted in major water entry problems for the unstable torpedoes. A drogue or buoy was attached to the torpedo to hold the nose up during water entry and reduce the magnitude of the initial dive, but for many years the successful launching of torpedoes from aircraft remained a "black magic" art requiring brave pilots with consummate skill. By 1924, when the new Douglas DT torpedo plane became operational, the launch envelope had been extended to plane speeds of 95 knots and a 32-foot altitude, but there were still problems with deep dives and water entry damage to the torpedo.

During the 1930s, as new aircraft carriers joined the U.S., Japanese, and British fleets, work continued on aircraft-launched torpedoes, and slowly but surely their performance and reliability improved. The U.S. Navy concentrated on developing a new 22.5-inch diameter aircraft torpedo, the 161-inch-long Mark 13. With a speed of 33.5 knots and a range of 6,300 yards, this 2,200-pound, turbine-powered weapon had a 600-pound warhead. The Mark 13 was issued to the fleet in 1938, but there were concerns about the very restrictive launch envelope imposed to achieve successful water entry. Many of the pilots were concerned that it would be difficult, if not impossible, to successfully

launch the torpedo under adverse wartime combat conditions. They were also unhappy because the deep initial dive, up to 100 feet deep, meant it couldn't be used against targets in shallow water. Additionally, the torpedo underwent only limited live warshot testing. When war came, it was discovered that the U.S. aircraft torpedo, like its surface ship and submarine counterparts, had exploder problems that drastically reduced its effectiveness.

During the interwar years, the new torpedo planes conducted extensive fleet exercises to develop launching techniques and tactical doctrine. Flying a lumbering torpedo plane, 15 feet above the water, straight and level until less than a 1,000 yards from a warship, with all its guns firing, before releasing the torpedo was a high-risk job requiring considerable skill and courage. The British devised a multi-plane technique in which a flight of planes would simultaneously attack from all points of the compass to saturate the anti-aircraft defenses and prevent the target ship from maneuvering to comb the wakes. The U.S. Navy and the Japanese Navy proceeded to copy this highly successful technique and refined it by including dive bombers in the attack to conduct simultaneous high- and low-level attacks that further overloaded the ship's anti-aircraft defenses.

In some of the fleet exercises, fast carrier task forces were formed, and aircraft attacks were made against a battle fleet while it was still hundreds of miles away. The aircraft far outranged the battleships' big guns, and the fast carriers could evade the slower battleships. Although the battleship admirals wouldn't admit it, there were indications that the battleship was in trouble and that the new aircraft carriers presented a serious challenge. The aircraft carriers were also used for air strikes against land targets. In one exercise, USS *Saratoga*'s planes theoretically destroyed the Panama Canal locks and cut off the Atlantic Fleet, which further demonstrated the potential of aircraft carriers to influence naval tactics.

In addition to the torpedo planes deployed from carriers, there was also an interest in utilizing large land-based torpedo planes and seaplanes, or flying boats, for torpedo attacks. In 1925, the U.S. Navy acquired the twin-engine Douglas T2D torpedo/patrol aircraft, usable on wheels or floats. These planes were deployed from airfields and, with floats, from seaplane tenders to conduct long-range missions. The U.S. Navy did not follow through on this concept because it conflicted with the Army Air Force's coastal defense mission. Most of the world's other major naval powers, including Japan, Britain, Italy, and Germany, proceeded to build multi-engined, land-based aircraft for torpedo warfare. These land-based torpedo planes were used extensively in World War II. The British and the Japanese also built large multi-engine flying boats configured to drop torpedoes, although they saw little wartime action.

When World War II started, the aircraft-launched torpedo was widely deployed from planes on aircraft carriers and from land-based aircraft. However, during the first few months of the war, the aircraft torpedo saw only limited use. When the war started in 1939, the Royal Navy's first-line torpedo plane was the *Fairey Swordfish*, a vintage, fabric-covered, open-cockpit biplane that looked like it came out of a World War I museum. Although the *Swordfish*, also affectionately known as a "Stringbag," was considered obsolete and a replacement, the *Fairey Albacore*, was already in production, the *Swordfish* went on to become one of the most famous and successful aircraft employed in World War II. Its extremely slow speed made it a very difficult target, especially when flying 15 feet above the water, and high-speed fighters frequently stalled or crashed into the water

when trying to attack it. Since it was fabric covered, proximity-fused anti-aircraft shells went right through without exploding, which made it a difficult plane to shoot down. The Stringbags were also rugged and maneuverable; they could take off and land on pitching carrier decks when all other aircraft were grounded. Finally, they were superb torpedo planes and established their reputation with an impressive record of torpedoing ships under extremely difficult conditions.

In June 1940, during the Norwegian campaign, six *Swordfish* torpedo planes attacked the German battleship *Scharnhorst* off the coast of Norway. Two planes were lost in this unsuccessful attack, but the British learned that hitting the highly maneuverable German warships would be a difficult task. A month later on July 12, *Swordfish* torpedo planes from the carrier *Ark Royal* attacked the Vichy French battleship *Dunkerque* at Oran and immobilized it. This attack demonstrated, for the first time, that a fleet using carrier-based torpedo planes could successfully attack enemy ships in protected anchorages. This new capability significantly increased the offensive striking power of a fleet since it could now penetrate the enemy's sanctuaries.

In March 1941, at the battle of Cape Matapan, the Italians sent a fast naval task force into the Eastern Mediterranean to support the German invasion of Greece and to strike at British convoys. The value of an aircraft carrier with torpedo planes accompanying a battle fleet was dramatically demonstrated when Admiral Cunningham's slow battleships could not catch the Italian task force. The Stringbags from the carrier *Formidable* were used to locate the faster Italian ships and conducted torpedo attacks to bring the Italian task force to bay. The Italian battleship *Vittorio Veneto* was damaged by an aircraft torpedo, which allowed the older and slower British ships to close with the Italians and sink three heavy cruisers and two destroyers. Carrier torpedo planes were instrumental in setting the stage for this decisive victory, which gave Britain undisputed control of the Eastern Mediterranean.

Two months later, in the vast Atlantic Ocean, the slower ships of the Royal Navy were trying to hunt down and corner the German battleship *Bismarck* and the heavy cruiser *Prinz Eugen*, which had sortied into the Atlantic on a raiding mission. Again, the British used carrier aircraft to locate the faster German ships, and a Stringbag from the carrier *Victorious* saved the day again with a torpedo hit that jammed the *Bismarck*'s rudders so that she could only go in circles. Once the superior force of the slower British battleships caught up with the *Bismarck*, her fate was sealed. Earlier in this same battle, *Swordfish* torpedo planes from the carrier *Ark Royal* mistook the British cruiser *Sheffield* for the *Bismarck* and attacked it with torpedoes. Fortunately in this case, the torpedoes, armed with influence exploders, exploded prematurely so that the *Sheffield* was not seriously damaged. However, it did demonstrate conclusively to the British that their influence exploders were defective; therefore, contact exploders were used for the attack against the *Bismarck*.

After the successful attack against the Vichy French battleship *Dunkerque* at Oran, the British started to plan a multi-carrier strike against the main Italian fleet anchorage at Taranto in southern Italy. The Italian fleet, anchored in the heavily fortified base at Taranto, posed a major threat to the British in the Central Mediterranean, and Malta was on the verge of being cut off. The aircraft torpedoes were specially modified so that they could be launched in the shallow harbor. Two carriers, the *Illustrious* and the *Eagle*, were designated for the strike. At the last minute, the *Eagle*'s

boilers gave out, so the decision was made to load the *Eagle's Swordfish* planes on the *Illustrious* and conduct the attack with a single carrier.

Late in the evening of November 11, 1940, the *Illustrious* launched 20 *Swordfish* torpedo planes in two waves, in a night attack against one of the world's most heavily protected fleet anchorages. Taranto posed a real challenge because the inner and outer harbors were ringed with anti-aircraft guns, barrage balloons closed off the approaches, and the ships were protected by torpedo nets. Eleven of the Stringbags carried torpedoes, and the rest carried flares and bombs to illuminate the harbor and bomb the oil storage tanks. This audacious attack by a single aircraft carrier was a spectacular success, and it changed the balance of naval power during a critical period when the British were extremely hard pressed. The British sank one battleship, left another sinking, severely damaged a third battleship and three cruisers, and destroyed a seaplane base by fire. Two *Swordfish* aircraft were lost during the attack. This brilliant British raid dramatically demonstrated the devastating destructive power of the torpedo delivered by aircraft and the use of aircraft carriers to deliver surprise attacks against protected anchorages.

The Japanese Navy took a special interest in the Taranto attack. Admiral Yamamoto requested that Japanese naval attachés in Europe gather all available information on the British attack. The Japanese had concluded that, because of the torpedo's initial deep dive when launched from aircraft, it was not possible to successfully launch aircraft torpedoes at ships in a shallow anchorage. They were particularly interested in learning how the British had modified their torpedoes so that they could be launched at ships in water only 50 feet deep. Taranto convinced the Japanese that torpedoes could be used in attacks against sheltered anchorages, and Japanese war plans were modified to include torpedo planes in their planned carrier strike against Pearl Harbor.

On December 7, 1941, six aircraft carriers of the Imperial Japanese Navy, under the command of Admiral Nagumo, conducted a preemptive surprise attack against the U.S. Navy Base at Pearl Harbor. Out of a total of 353 Japanese carrier aircraft that took part in the strike, only 40, or about 12%, were Nakajima B5N (Allied reporting name "Kate") torpedo bombers. Again, the torpedo provided the aircraft carrier's heavyweight punch since the torpedo planes, which were in the minority, inflicted the majority of the damage to the battleships anchored at Pearl Harbor. The battle line of the U.S. Pacific Fleet was a shambles, with all five battleships anchored in the outside row hit by torpedoes. The *Oklahoma*, *Nevada*, *California*, and *West Virginia* were all victims of Japanese aircraft torpedoes. The *Arizona* was also torpedoed, but a bomb hit in a magazine inflicted massive damage topside and over 1,000 men died when the *Arizona* went to the bottom. The Japanese had learned well from the British attack on Taranto. After Pearl Harbor, there was no longer any doubt that the fast carrier task force was a powerful new force in naval warfare. The fleet was at risk even when at anchor in its own well-protected home anchorage.

The British, Japanese, and Germans made extensive use of land-based torpedo aircraft during World War II to attack both naval and merchant ships. Some U.S. land-based B-26 bombers employed torpedoes in the Battle of Midway in 1942, but, in general, the U.S. made little use of land-based torpedo aircraft in World War II. Several million tons of ships were torpedoed by land-based German and British torpedo planes operating from the Arctic Circle all the way down into the Mediterranean Sea during World War II. The Germans conducted large-scale aircraft torpedo attacks

against Allied convoys sailing to Murmansk and against British ships in the Mediterranean. In the Mediterranean, the critical seaborne flow of oil required by Rommel's Africa Korps was effectively cut off by land-based British torpedo bombers. On some occasions, the outcome of a desert tank battle hinged on the ability of the British to torpedo a single oil tanker.

Less than a week after the massive attack on Pearl Harbor, the Japanese again demonstrated their proficiency with aircraft torpedoes when land-based torpedo planes based in Indochina attacked and sank the British battleships *Repulse* and *Prince of Wales*. Even the Japanese were surprised by their success, which clearly indicated that the once mighty battleship was in serious trouble when it didn't have air cover. Earlier in the year, in April 1941, land-based British Bristol Beaufort torpedo bombers, designed by the Bristol Aeroplane Company, had torpedoed the German battleship *Gneisenau* while it was anchored in Brest harbor and laid it up for almost a year. Two months later, Beaufort bombers torpedoed the German pocket battleship *Lutzow* as it was in transit to Norway and sent it back to drydock for 6 months to have its stern rebuilt. Torpedoes delivered by land-based torpedo planes presented a major new threat to enemy capital ships.

Although aircraft torpedoes were brutally effective weapons, they had to be delivered at very close ranges; it took brave, dedicated men to fly directly into the concentrated fire from a capital ship to drop a torpedo. Torpedo planes of all nations experienced very high losses during World War II, and flying torpedo planes was an extremely hazardous occupation. In the attack on Pearl Harbor, the Japanese "Kate" torpedo planes inflicted the most damage, but they also suffered the highest percentage of losses during their attacks on the battleships.

In the Battle of Midway, the U.S. Navy's lumbering Douglas TBD *Devastator* torpedo planes got separated from their fighter cover and the dive bombers on their way to the target. As a consequence, during the air strike against the Japanese carriers, the torpedo planes had to make their attacks without fighter cover to protect them or dive bombers to divert the AA gunners on the ships. Every plane in the carrier *Hornet's* Torpedo Squadron 8 was shot down, and only one man, Ensign George Gay, survived. The *Enterprise's* Torpedo Squadron 6 lost 10 of its 14 planes, and the *Yorktown's* Torpedo Squadron 3, with 12 planes, lost 10 of them. Not a single torpedo hit was scored, and 35 out of the total of 41 planes were shot down either by Zeros or AA fire from the ships. However, these brave suicidal attacks did wear down the Japanese defenses; when the dive bombers finally arrived, they caught the Zero fighters back on deck being rearmed, and the dive bombers had a field day as they bombed the Japanese carriers. The torpedo planes paid a high price, but they constituted a major threat to the Japanese carriers that kept the Zeros totally tied up during a critical period in the battle. This was a major factor in the final outcome of the battle.

In February 1942, the German battleships *Gneisenau* and *Scharnhorst*, along with the cruiser *Prinz Eugen*, made their famous surprise dash from Brest, France, up the English Channel to Germany, and all available British aircraft were ordered to attack the German ships. The six available *Swordfish* (Stringbag) torpedo planes from the British 825 Naval Air Squadron joined in the daylight attack against the heavily protected German force; all six planes were promptly shot down by fighter planes and/or anti-aircraft guns without scoring a hit. The brave torpedo pilots did not hesitate, but they paid the supreme price for their valiant effort. Flying torpedo planes was a dangerous business, and the pilots were prime candidates for posthumous awards.

During the bitterly fought naval campaign in the Pacific, both Japanese and U.S. Navy torpedo planes played a key part in many of the major battles. The torpedo plane was the carrier's heavyweight weapon system, and numerous carriers and battleships, on both sides, were sunk or damaged by aircraft-delivered torpedoes during the great series of sea battles that were fought in the Pacific. In April 1945, the Japanese sent their 72,000-ton super battleship *Yamato* to strike at the U.S. forces invading Okinawa. The *Yamato*, with nine huge 18-inch guns, was the mightiest battleship the world had ever seen, and it represented a significant threat. The *Yamato* presented a rare opportunity for Admiral Mitscher's Fast Carrier Task Force 58 to demonstrate the superiority of carriers over battleships, and a maximum effort was made to intercept the *Yamato* and blow it out of the water with carrier aircraft.

At 1232 on April 7, 1945, the carrier-based dive bombers and TBF Avenger torpedo planes from Task Force 58 struck at the *Yamato*. Less than 2 hours later, it was a pile of junk resting on the bottom of the Pacific Ocean. The *Yamato* took a terrible pounding from the torpedo planes and dive bombers. It took over 10 torpedoes hits to sink the mighty battleship. It had been a long road from the Battle of Midway, but there was no longer any doubt about the effectiveness of U.S. Navy carrier-based torpedo aircraft. With the sinking of the *Yamato*, the fate of the battleship as a major surface combatant was sealed. Everyone was quick to acknowledge that the aircraft carrier was the new ruler of the seas. However, the ship sank because torpedoes made large holes below the waterline that caused it to fill with water. Carrier aircraft delivered the weapons, but the weapon that sank the *Yamato* was the torpedo.

During World War II, aircraft equipped with radar were very effective when used to hunt submarines. They could detect submarines at long ranges, and the submarines were forced to dive every time they were detected, which severely limited their high-speed mobility on the surface. The U-boats moved out into the center of the Atlantic to get away from the aircraft threat, but they could no longer use their high surface speed to converge on convoys as a wolfpack. Unfortunately, once a submarine submerged, it was reasonably safe, because the aircraft could neither detect nor bomb a submerged submarine. Aircraft were a major deterrent, but they lacked the ability to destroy submerged submarines.

During the final phase of the U-boat war in the Atlantic, aircraft took on a new role as the new Mark 24 homing torpedo (mine) was introduced to combat the U-boat threat. The acoustic Mark 24 torpedo, built specifically to hunt submerged submarines, was a homing torpedo designed to home on the radiated noise generated by a submerged submarine. It was the first modern homing missile, and it introduced a new era in naval warfare. The submarine was no longer guaranteed safety from aircraft attacks simply by diving and hiding in the ocean depths. The Mark 24 torpedo, when dropped on the spot where the submarine submerged, would home on the submarine's radiated noise and seek it out and destroy it. The Mark 24 homing torpedo, carried by land-based aircraft and the TBF torpedo bombers on the jeep carriers, represented a revolutionary new ASW weapon. With the introduction of the Mark 24, aircraft assumed a major role in modern ASW warfare.

It was made evident that aircraft equipped with homing torpedoes were an ideal combination for ASW warfare when over 50 U-boats were sunk or damaged by aircraft-dropped Mark 24 homing torpedoes late in the war. During the final months of the war, small, expendable, aircraft-dropped

sonobuoys with radio transmitters were employed by ASW aircraft to search for submerged submarines and pinpoint their locations prior to dropping homing torpedoes. The basic elements of future air ASW systems were in place and had been evaluated under combat conditions.

After the war, additional acoustic and magnetic sensors were added, and specially configured ASW aircraft began to evolve. Initially, these ASW aircraft were modified long-range patrol aircraft; many of the early versions were long-range flying boats. By the 1950s, new aircraft specifically designed for ASW were in existence as the U.S. Navy developed the land-based Lockheed P-2 Neptune aircraft and the carrier-based Grumman S-2 Tracker aircraft. The lowly torpedo, in its ASW homing variant, had spawned yet another major weapon system, and land-based patrol squadrons (VP squadrons) and carrier-based sea control squadrons (VS squadrons) were formed to conduct air ASW missions. Within a short period, specially configured ASW aircraft were built by most of the major naval powers, and, as the Russian submarine threat grew, air ASW became a major naval mission.

The nuclear submarine, with its torpedoes, became a major undersea threat, and the specially configured ASW aircraft, with homing torpedoes, became one of the few viable counters to the nuclear submarine threat. It is ironic that the torpedo, which makes the submarine such a potent threat, is also, in its ASW variant, the only weapon that poses a significant threat to a modern nuclear submarine.

After World War II, since there wasn't any major naval surface ship threat, the role of the aircraft carrier gradually shifted to providing support for the shore-based operations conducted during the Korean and Vietnam conflicts. By the 1950s, the Mark 13 air-delivered anti-ship torpedo was phased out, and, as the mission shifted, the first of the new ASW torpedoes and ASW aircraft joined the fleet. With the advent of nuclear submarines, air ASW became a priority mission. Emphasis was placed on the development of increasingly sophisticated new carrier- and shore-based ASW aircraft, and the aircraft-delivered ASW torpedo became the key weapon in this important new area. The ASW torpedo has become the only type of torpedo used by U.S. Navy aircraft; the World War II anti-ship torpedoes have been replaced by smart bombs and airborne guided missiles. However, a modern anti-ship homing torpedo still remains a viable option for sinking surface ships by making holes in them below the waterline. The combination of airborne missiles and underwater guided missiles (torpedoes) employed to saturate the enemy's close-in defensive systems remains an attractive alternative.

Chapter 14

OTHER APPLICATIONS OF THE TORPEDO

Close naval blockades of enemy ports were routinely employed in the 19th century to prevent the shipment of war materiel. The British used close blockades extensively during the Napoleonic Wars to isolate the French, and the Union Navy blockaded Confederate ports during the U.S. Civil War to keep manufactured goods from being imported. Great sea battles were fought occasionally in some wars, but the routine day-to-day work of navies involved blockades and attacks on ports and shore-based fortifications. Much effort was expended to design weapons and fortifications to defend against such attacks, and most of the major powers were preoccupied with defending themselves against naval attacks and blockades.

The original concept for *Der Kustenbrander*, the coastal fireship, is credited to an unknown Austrian marine artillery officer who conceived it as a harbor defense weapon for use against enemy ships during naval attacks. Fregattenkapitän Giovanni de Luppis built a model of *Der Kustenbrander*—a self-propelled launch filled with explosives and steered by tiller ropes from shore that was intended to attack enemy warships from shore-based defensive positions. He sought the assistance of Robert Whitehead to improve the concept, but it was concluded that the exposed launch's slow speed made it too vulnerable. Although De Luppis's concept proved to be impractical, it provided the stimulus for Whitehead's development of the automobile torpedo.

Ultimately, the automobile torpedo was to have a much wider application, but the concept of the automobile torpedo as a defensive weapon for harbor or coastal defense received a lot of attention in the early years. In the United States, after the Civil War, the U.S. Naval Torpedo Station was founded at Newport, Rhode Island, to develop spar torpedoes, explosives, and, eventually, self-propelled torpedoes for offensive use by the Navy. In the same timeframe, the U.S. Army, which was responsible for coastal defense, became interested in mines and torpedoes for the Army's harbor defense mission. The U.S. Army's Engineer School of Application, or Torpedo School, at Willets Point in the Brooklyn section of New York Harbor was the Army's equivalent of the Naval Torpedo Station at Newport, and there was a fair amount of competition between the two facilities during the 1870s and 1880s as they evaluated various torpedoes for their respective military departments.

The Army's Engineer School of Application, generally referred to as "Willets Point," was headed by a dynamic officer, Lieutenant Colonel Henry Abbot, U.S. Army. Abbot, who had been a brevet brigadier general during the Civil War, was interested in controlled torpedoes that could be used by the Army for coastal defense applications, and he evaluated a number of early torpedoes, including the Lay, Smith, and Sims designs, at the Willets Point facility. In the 1870s, Abbott evaluated an early Lay design and the Smith torpedo. Both of these were semi-submerged, float-type torpedoes that payed out a control wire to a shore-based control station that steered the torpedo to the target ship. The Smith torpedo underwent additional tests in Boston harbor that were considered functionally successful; however, the torpedo's slow speed limited its operational usefulness.

The complex and slow-speed Lay torpedo, which was also undergoing evaluation at the Naval Torpedo Station in Newport, did not impress the Army as a viable harbor defense weapon. Various foreign countries requested demonstrations of improved versions of the Lay torpedoes, and a limited number of them were sold in Europe and South America. The Russians, who loved complex weapons, purchased over a dozen torpedoes from Lay for use as harbor defense weapons. These torpedoes, built by Pratt and Whitney in Hartford, were evaluated by the Russians at St Petersburg between 1879 and 1881. After the trials, the Russians issued a very favorable report praising the torpedoes, and they purchased the rights to manufacture the Lay torpedoes in Russia. In the same timeframe, the Russians were also looking at various other torpedoes, including the German Von Scheliha torpedo.

In the early 1870s, a New Jersey inventor, W. J. Sims, built an electric motor to power pumps and sewing machines. In 1875, Sims began to experiment with a torpedo powered by his electric motor. He collaborated with M. G. Farmer, who supplied the dynamo, and they built a remotely controlled, wire-powered, semi-submerged, locomotive torpedo with a speed of 6 miles per hour. In 1879, the Sims torpedo was evaluated at the Willets Point facility, and Abbot was impressed enough with it to place an Army contract for an improved model with a range of 1 mile and a speed of 9 miles per hour. The improved model, delivered and tested in the summer of 1880, exceeded both its speed and range specifications, and the Army conducted numerous experiments with the Sims torpedo. However, it does not appear that the Army ever got beyond the evaluation stage with their torpedo experiments since there is no mention of any torpedoes actually being installed at any of the coastal defense fortifications.

After witnessing some Australian experiments in 1880, the British invited Louis Brennan, a watchmaker from Melbourne, Australia, to bring his new cable-powered torpedo to England for a series of trials. The Brennan locomotive torpedo was propelled by shore-mounted winches that reeled in 18-gauge piano wire from two drums in the torpedo. Each drum of wire in the torpedo was attached to a propeller shaft; as the wire was pulled off either drum, it and the connected propeller rotated, causing the torpedo to advance through the water. Although the Royal Navy did not consider the Brennan torpedo practical for shipboard applications, the Royal Engineers at Chatham thought that the Brennan torpedo was ideally suited for harbor and coastal defense missions. After a series of trials were conducted in 1885, the Royal Engineers purchased the manufacturing rights for £110,000 and hired Brennan at £1,500 per year to manage the Brennan torpedo works at Gillingham in Kent. Although the Brennan torpedo was tied to the land by its cables, its 20-knot speed and 3,000-yard range made its performance superior to the Whitehead torpedoes that were operational then.

When Brennan was paid the princely sum of £110,000 for his torpedo design, it caused a political furor because, a decade before, the Royal Navy had purchased the manufacturing rights for the Whitehead torpedo for only £15,000. However, all information about the torpedo was classified secret, and the public uproar died away. These torpedoes served as one of the defensive weapons for the Royal Engineers for almost two decades, and Brennan torpedo sites were built at key locations, including harbor entrances and on rivers. In fact, the remains of a Brennan torpedo site were still visible on the banks of the river Thames in England as late as World War II.

The Brennan torpedo was also made available for foreign sales, and it is reported that several European countries adopted the Brennan torpedo for coastal defense. Naturally, most countries were very secretive about their defensive fortifications: information about defensive torpedo sites was seldom revealed. From the limited information available, it appears that defensive shore-mounted torpedoes were widely used at the turn of the century to protect harbors and key coastal locations. In World War I, during the Turkish campaign, the British found themselves facing the wrong end of some Brennan torpedoes that were still in use as part of the harbor defenses at Constantinople.

In 1886, Hudson Maxim, the brother of Hiram Maxim, the famous machine gun designer, obtained a patent for a cable-operated torpedo very similar to the Brennan but requiring only a single drum and cable to power the torpedo. He obtained a contract with the Germans to develop his single-cable version for use as a harbor defense weapon, but details of the German experiments were not revealed. Although the existence of these defensive weapons was a closely held secret, it appears that a number of European countries continued to develop and use shore-mounted defensive torpedoes well into the 20th century.

During World War II, when the Germans invaded Norway, the brand-new German heavy cruiser *Blucher*, a sister ship to the *Prinz Eugen*, was sunk by shore-based torpedoes at the narrowest point in the Oslo Fiord. The fortifications, located below the city of Oslo, consisting of large guns and shore-mounted torpedo tubes, had been built during World War I by Krupp, the famous German armaments company. It is ironic that the *Blucher* was sunk by German-manufactured guns and torpedoes because this delayed the capture of Oslo long enough for the King and other government officials to escape, taking the gold reserves with them.

Late in World War II, the Germans developed the T-10 Spinne, a special wire-guided torpedo for use as a shore-mounted coastal defense weapon. The wire-guided Spinne (Spider) torpedoes were set up along the French coast in 1944 to defend against the expected Allied invasion. Each operator could control up to three torpedoes from observation posts located on high cliffs. The Spinne, with a range of 5,400 yards and a speed of 30 knots, did not play a significant role in the war, but it did provide the pioneering technology for modern wire-guided torpedoes.

As is frequently the case with defensive systems, shore-mounted torpedoes were not extensively used in wartime, but they did achieve their basic purpose by deterring enemy ships from entering or using harbors or narrow waterways that were protected by shore-based torpedo sites. Considerable time, money, and technical effort have been devoted to shore-based defensive torpedo installations. They provided a powerful deterrent and, as the sinking of the *Blucher* demonstrated, they were effective when an enemy ship chose to challenge their role.

Specially armed merchant ships were successfully used as raiders during both World Wars. The Germans had a number of very successful raiders, including the *Emden*, *Mowe*, and *Wolf* in World War I and the *Atlantis*, *Thor*, and *Pinguin* in World War II. Most of the more successful raiders were at sea for extended periods and averaged over 100,000 tons of ships captured or sunk during their cruises. During World War II, most of the German raiders, in addition to their main gun armament, carried aircraft for scouting or bombing enemy ships, and they had either two or three broadside torpedo tubes mounted on each side. The torpedoes were originally provided to quickly sink an

enemy ship after it had been captured and the crew taken off. Accounts of raider actions give a clear indication that German torpedoes in early World War II had serious exploder problems. In some cases, the target was hit with two or three dud torpedoes before one would finally explode and sink the target.

As the war progressed, some of the armed merchant ships began to fight back; to counter this, the raiders began to conduct surprise night torpedo attacks. The raider would sneak up on the ship in the dark and, when it was close enough, launch a torpedo attack. With this technique, the first indication of an attack was when the torpedo exploded against the side of the ship. Some of the later raiders also carried two small, 40-knot, LS (Leicht Schnellboot) boats, each armed with two torpedoes, on deck skids. These small, fast torpedo boats were used to chase down fast ships that could outrun the raider and to conduct surprise torpedo attacks. The torpedo was the raiders' heavyweight weapon, and they frequently used them with ruthless efficiency when an enemy ship failed to heave to and strike its flag.

Near the end of World War I, the Italians began to experiment with midget submarines and manned torpedoes for use in attacking enemy ships in sheltered anchorages. One of these two-man submersibles, a mignatta (leech), was used to attack the Austrian battleship *Viribus Unitis* in the port of Pola in November 1918, just as the war was ending. In the 1930s, the Italians again started working on small submersibles, and two naval engineers, Elios Toschi and Teseo Tesei, designed a manned torpedo. The official Italian name for their craft was Siluro a Lenta Corsa (SLC, or slow-running torpedo), but the Italian operators nicknamed it a "maiale" (pig). The SLC was a modified 21-inch, electric-powered, torpedo with a detachable explosive charge that was to be attached to the target ship or placed under it. Two men, with self-contained breathing gear, rode on top of the torpedo in saddle-like seats to steer the weapon to the target and attach the warhead. During this same timeframe, the Italians also started to build a series of midget submarines, starting with the CA-1 and CA-2, that were also to be used in harbor attacks.

A special human torpedo flotilla, the Decima Flottiglia MAS (for Mezzi d' Assalto), was set up at La Spezia in northern Italy. This self-contained branch of the Italian Navy had complete facilities, with three specially equipped submarines permanently attached. The SLCs were transported to the locale of the proposed attack in waterproof containers mounted on the deck of the submarine. The SLCs were then launched and proceeded into the harbor with their two-man crews at a 2–3 knot speed to attack the anchored ships. The crews were specially trained to penetrate the defensive nets and obstructions used to protect major warships. They attached the warhead to the ship's hull, set a timer to detonate the warhead at a predetermined time, and withdrew from the area on their SLC vehicles.

During the early part of World War II, the Italian SLCs conducted a number of bold raids against the British at Alexandria, Algiers, and Gibraltar, during which they sank or seriously damaged 50,000 tons of merchant shipping and over 60,000 tons of warships. The most spectacular attack occurred on December 18–19, 1941, when three SLC vehicles successfully penetrated the harbor defenses at Alexandria and seriously damaged the British battleships *Valiant* and *Queen Elizabeth*. This audacious attack by six men, riding torpedoes like they were horses, changed the naval balance of power in the eastern Mediterranean. It was a particularly bitter pill for the British to swallow only

a week after losing two other battleships, the *Prince of Wales* and the *Repulse*, to Japanese torpedo planes in the Pacific. It was painfully evident to the British that Whitehead's torpedoes were very versatile weapons, with a suddenly developed affinity for British battleships.

Prime Minister Churchill, very impressed by the bold Italian attack at Alexandria, directed the Royal Navy to immediately undertake a similar effort and to use small submersibles to attack the German capital ships that were threatening British convoys from sheltered anchorages in the fiords of northern Norway. The British had captured some Italian SLC vehicles during an unsuccessful Italian attack on Gibraltar, and they immediately initiated a crash program to produce very similar vehicles, which they called chariots. They also initiated a second program to build midget submarines; these were identified as X-craft.

By the summer of 1942, the British had their first chariots available for training. In October, the charioteers undertook their first mission against the German battleship *Tirpitz*, anchored in a Norwegian fiord. For the trip up Asenfiord to where the *Tirpitz* was moored, two chariots were lashed to the bottom of a disguised fishing boat. During an unexpected severe storm, the chariots broke loose and sank, which caused the mission to be aborted. During the winter months, the cold water along the Norwegian coast made it impossible for the chariots to operate, so the British decided to wait for the new X-craft to attack the *Tirpitz*. The chariots were sent down into the warmer Mediterranean Sea for operations against the Italians.

The British chariots drew their first blood in a successful attack against Italian ships anchored in Palermo harbor on the night of January 2–3, 1943. The chariots sank the brand-new light cruiser *Ulpio Traiano* and severely damaged three submarine chasers and an 8,500-ton troop transport. The chariots also conducted special missions to reconnoiter beaches and proposed landing sites. In June 1944, the charioteers conducted a raid on La Spezia, the home base of the Italian human torpedoes, and sank the heavy cruiser *Bolzano*, thus demonstrating to the Italians that the British charioteers had learned their trade well.

In the spring of 1943, as the new X-craft became available, the British started training for another attack on the *Tirpitz*, which was still anchored in northern Norway. In September 1943, four X-craft penetrated Kaafiord, where the 40,000 ton *Tirpitz* was moored behind an extensive barrier of mines and antisubmarine nets, and successfully attacked the ship. Two charges went off directly under the ship, which ripped a huge hole in its bottom and seriously weakened the hull. It took over a year to get the *Tirpitz*'s power plant back on line, and, with a weakened hull, the ship could operate only at slow speed and in calm seas. The mighty *Tirpitz* was no longer a significant threat after the X-craft raid, but, unfortunately, the British did not learn this fact until after the war was over.

The X-craft also conducted two raids on Bergen, Norway, in April and September of 1944, during which they sank a 7,800-ton ship and a floating drydock. The X-craft were moved to the Pacific theater of operations when the war in Europe ended. In July 1945, the X-craft were used to attack a Japanese heavy cruiser anchored in Johore Strait just above the city of Singapore. The X-craft successfully penetrated the Japanese defenses and placed two charges under the 10,000-ton, 8-inch-gun, heavy cruiser *Takao*. The *Takao* was immobilized for the remaining duration of the war when the charges tore a 30-foot by 60-foot hole in her bottom and put all of her turrets out of action.

The Germans became interested in manned torpedoes and mini-submarines as defensive weapons that could be used to counter the anticipated Allied invasion of fortress Europe. The effort on these defensive weapons was substantially increased in early 1943; by early 1944, the first human torpedoes were operational. The German Neger (Negro) consisted of two torpedo bodies, one mounted on top of the other. The lower unit was a G7e electric torpedo, and the top unit was a modified torpedo used to carry the operator. The upper unit's warhead was removed and replaced by a special cockpit for a human pilot to control the weapon. The operator, protected by a Plexiglas canopy, steered the weapon toward the target and released the torpedo when he was lined up with the target. The Neger did not have any breathing apparatus and had to operate on the surface. The later Marder (Sable) was actually a very small torpedo-carrying submarine that could make submerged attacks.

These anti-invasion weapons were first used in 1944 against the Allied invasion at Anzio in April and then at Normandy in July. These small vehicles could operate only in relatively calm waters; even then, the operators had difficulty navigating and locating targets because the vehicles operated either awash or submerged, which severely limited visibility. Also, they had a very limited range, which reduced their effectiveness because it was often impossible to transport them close enough to the targets to conduct independent attacks. The Germans had some successes with their human torpedoes, including a light cruiser, minesweepers, and some merchant ships, totaling 90,000 tons. However, this amounted to no more than a pinprick against the mightiest invasion fleet the world had ever seen. There was no way that a few hundred human torpedoes could influence the outcome of an invasion by thousands of ships. However, they did demonstrate that a torpedo operated by a single man could successfully attack and sink a warship that was underway in open seas.

The Germans also developed a number of midget submarines, including the *Biber* (beaver), *Molch* (salamander), and *Seehund* (seal) classes, for use against the invasion fleet, but the first of these, the *Biber*, was not available until January 1945. The *Biber*, displacing 6.3 tons, had an internal combustion engine for surface operations and electric propulsion for submerged operations; it was armed with two torpedoes carried in external drop saddles. The *Biber* midget submarines, operating mainly in Dutch and Belgian coastal waters at the very end of the war, saw only limited action, and their effectiveness as a coastal defense weapon was never really evaluated.

In 1936, the Japanese started a secret project at the Kure Naval base to build two-man midget submarines. To maintain security, these small, 46-ton, A-type submarines, assembled from prefabricated subsections, were kept on an isolated island at the Kure Arsenal. It was planned to deploy them from specially equipped surface vessels during open-sea engagements between battle fleets. Early in 1941, a Japanese submarine officer, Lieutenant Naoji Iwasa, proposed that the midget submarines be modified so that they could be carried by fleet submarines and used for raids against enemy fleet anchorages. The proposal was approved, and five fleet submarines were modified on a crash basis to carry midget submarines for use in the planned Pearl Harbor attack.

The five midget submarines employed in the attack on Pearl Harbor were somewhat of a disappointment. Because only one of the midget submarines actually got into the anchorage and was subsequently sunk, the midget submarines did not play a significant role at Pearl Harbor. Later, in May 1942, midget submarines conducted a surprise attack in Sydney Harbor but failed to damage any major ships. A midget submarine attack conducted against the British anchorage at Diego Suarez

in the Indian Ocean damaged yet another British battleship, the *Ramillies*, and sank a large tanker. Midget submarines also sank a troopship and a destroyer during the battle of Guadalcanal. Later in the war, midget submarines were used in the Philippines, with limited success, to defend Surigao Strait and San Bernardino Strait.

Although the Japanese midget submarines were effective, their short range limited their usefulness, and it was logistically ineffective to have valuable fleet submarines tied up ferrying them around to conduct attacks because they carried only two torpedoes. The midget submarines were soon withdrawn to home waters for use as anti-invasion weapons in the last-ditch defense of the Japanese home islands, and the Japanese fleet submarines were given higher priority assignments

In January 1943, the Japanese naval staff began to review designs for a human torpedo. The proposed human torpedoes differed from those of other nations in that the operator stayed with the torpedo during the final attack. In the spirit of the kamikaze pilots, the operators were to steer the torpedo into the side of an enemy ship. The naval staff directed that an escape hatch be added to the design so the operator could bail out during the terminal phase of the attack. However, there are no indications that this option was ever exercised in combat. The Japanese human torpedoes, called Kaitens, were based on the Type 93 (Long Lance) torpedo design. The basic Type 93 propulsion system was repackaged in a larger body—1 meter (39 inch) in diameter and 38 feet long—that had a speed of 30 knots and a range of 12 miles. The Kaitens, being fairly large weapons, carried a huge 3,417-pound warhead that was capable of mortally wounding almost any ship afloat.

A fleet submarine could carry up to four Kaitens to the target area, where they would be released at a range of approximately 8,000 yards for the terminal attack. The first operational deployment took place in November 1944, and they were used with increasing frequency right up to the end of the war. Almost all of the surviving Japanese submarines were converted to carry Kaitens during the final phase of the war. They were generally used to conduct attacks against ships in a sheltered anchorage or harbor. Use of the Kaitens was limited by the severe shortage of submarines to carry them to the target areas where U.S. Navy vessels were located. The Japanese claimed that the Kaitens sank a number of merchant ships and warships, but official U.S. Navy records do not substantiate these claims. The overall results were rather limited. Only about 50 Kaitens were actually used in combat, and the combination of mechanical problems and limited training severely limited their effectiveness. At the end of the war, a large number of Kaitens still existed, and the Japanese had planned to make extensive use of these suicide weapons in their last-ditch defense of their home islands.

On a number of occasions, torpedoes were deployed from conventional platforms for unconventional missions. Several times during World War II, Russian submarines used their torpedoes as underwater artillery to bombard an enemy harbor. The Russian submarines used this tactic against Black Sea ports and also in the north against fiord defenses and ports along the Norwegian coast. The submarine would maneuver into position outside the harbor and conduct a surprise torpedo attack by randomly firing torpedoes into the harbor. The torpedoes were not fired at any specific target but rather fired like artillery shells to inflict random damage, to create confusion, and to keep the enemy off balance. It is also reported that, during the Korean conflict, a U.S. Navy carrier-based torpedo plane destroyed a Korean dam by torpedoing it!

In the Mediterranean, during the invasion of southern France, U.S. Navy PT boats conducted similar “harbor busting” raids in which the PT boats would launch a salvo of torpedoes directly into a busy harbor to disrupt the local shipping. These surprise attacks were quite effective in small, crowded harbors where the Germans were trying to organize their coastal convoys, and it significantly complicated their defensive requirements.

As used in some of these unique applications, the torpedo could well be classified as a terrorist weapon. This would be particularly true in the case of the Kaiten, which was a suicide weapon. Although these torpedo applications did not influence the outcome of the war, the demonstrated threat these applications represented—for example, that relatively inexpensive, shore-based torpedoes could sink a major warship when it attempted to enter a port or that two frogmen riding the back of a 2-ton torpedo could penetrate a heavily defended harbor and severely damage a 30,000 ton battleship with a crew of over 1,000 men—was, in and of itself, a major accomplishment.

Chapter 15

THE TORPEDO BUSINESS

The first torpedo was built by Robert Whitehead with the assistance of his young son and one artisan. From this humble beginning, the torpedo business has grown in the past century into a billion dollar industry that provides a classic case study of the relationships that develop between industry and the military during the typical evolution of a weapon. This unholy alliance, now referred to as “the military-industrial complex,” has been around for a long time, and the relationships between the military and industrial sectors provide some interesting insights into the stresses and strains that occurred as the torpedo industry and the military sought to achieve their diverse goals.

Industry’s primary goal is to make a profit for shareholders, while the military’s primary goal is to maintain a military capability to support or achieve national objectives. Although these goals have a degree of commonality, there are subtle differences that cause considerable push and pull in any weapon acquisition program because of the fundamental differences in goals and loyalties. Whitehead’s objectives were to maintain a proprietary position by protecting the secret aspects of his torpedo and to market and sell torpedoes to any and all buyers for a profit. When, in 1868, the Austrians became the first to purchase Whitehead’s torpedo, they could not afford to purchase the exclusive rights to the weapon, so they merely placed an order for torpedoes. This placed Whitehead in a strong marketing position because he maintained ownership of the design and was free to offer it to other interested buyers. He then purchased the bankrupt STF factory at Fiume and set up his own torpedo business, Silurificio Whitehead, to manufacture torpedoes and sell them on the international arms market.

When the British purchased the Whitehead torpedo in 1871, the Royal Navy also purchased nonexclusive rights to build Whitehead torpedoes in their own factory. Because the British did not want to be totally dependent on a factory located in Austria as the sole source of supply for their torpedoes, they took immediate steps to set up their own production facility in the Royal Laboratory at Woolwich. Since it was mutually beneficial, Whitehead and the Royal Navy signed an exchange agreement calling for an exchange of data and technical improvements. The British wanted access to any design improvements that Whitehead might develop that would make their torpedoes more effective, and Whitehead was equally interested in any Royal Navy improvements that might improve the sales potential of his torpedoes.

The British incorporated some impressive innovations in their torpedoes, including counter-rotating propellers, an improved body shape that significantly reduced drag and provided for a larger warhead, and a new three-cylinder engine designed by Peter Brotherhood. Whitehead exercised his improvement option and incorporated the Royal Navy design improvements into his production torpedoes to improve their sales appeal. However, within a couple of years, he modified the valve design on the Brotherhood engine and identified it as a new Whitehead design so that he would no longer have to pay the British a royalty on every Brotherhood engine he sold in a Whitehead torpedo. Whitehead’s goal was to maximize profits, and the engine redesign to eliminate the British royalty was generally considered to be an ethical routine business transaction. Two decades later, when

Whitehead's son introduced the gyro-controlled steering system, the situation was reversed and the Royal Navy had to pay Whitehead a royalty of £25 for every torpedo in its inventory that was modernized to incorporate gyro steering. The British had an inventory of several thousand torpedoes, and Whitehead, the hardheaded businessman, made sure that, regardless of any design changes, he got his royalty for every single unit that was modified. The Royal Navy got a more effective torpedo, but "business was business." Whitehead made a small fortune on the royalties from this single modification.

The torpedo is generally defined as a "warehouse" type of weapon, and each buyer had to purchase a substantial quantity of them to accumulate an inventory of weapons sufficient to support military requirements. Further, because the torpedo was continuously exercised during peacetime training exercises, there was a continuing need for spare parts and expendables to support the training cycle and to maintain the weapons. During the early years, Whitehead, as the sole source of torpedoes, did a handsome business as country after country signed up to purchase his torpedoes. His factory was working at full production, and his order books were full. However, he would not patent his torpedo, and he sold it only to countries that pledged to keep the secret of his depth control mechanism. This placed him in a somewhat vulnerable position: if even one of his customers had chosen to break the pledge of secrecy and to disclose the design details, he would have had no legal recourse since the design was not patented.

Paradoxically, the many governments that purchased torpedoes appear to have been quite ethical about maintaining Whitehead's secret, and the naval officers entrusted with the secret were both honest and discreet. When the United States was offered the "secret" by a disgruntled employee, it refused the offer as unethical. Later, when the Turkish government captured a Russian Whitehead torpedo, they did not disclose the secret; instead, they negotiated with Whitehead, who purchased the weapon from them. Whitehead lost his monopoly as the sole source when Louis Schwartzkopff's Berliner Maschinenbau started to market an almost identical torpedo made out of phosphor bronze. A year earlier, Schwartzkopff had been Whitehead's houseguest, and, during the visit, someone had broken into the laboratory and stolen a complete set of torpedo plans. Whitehead and his son-in-law, Georg Hoyos, had suspected a foreign government (the United States was a prime suspect) of stealing the plans, and much was said about the unethical act of stealing the design.

When Schwartzkopff suddenly became a competitor, he was not directly confronted about the theft. It seemed that this type of activity was acceptable if done by an industrialist, but it was unethical if a government did it. Clearly, there were double standards, and industrial concerns were not bound by the same rigid code of ethics that governments were expected to maintain. Industry was in business to make money, and anything done to make a profit could be rationalized as ethical. Schwartzkopff's Berliner Maschinenbau AG sold torpedoes to various foreign countries, including China, Japan, Spain, England, and the United States. For a number of years the Schwartzkopff torpedoes actually outsold Whitehead torpedoes in the international arms market. The company remained Whitehead's major competitor for over a half century until it went out of business shortly after World War I.

In spite of the competition, Whitehead continued to sell large numbers of torpedoes all over the world in the last three decades of the 19th century, and he became a very wealthy man. Silurificio

Whitehead had a standard catalog with all of the torpedo models and their prices listed. The first torpedoes sold for about £300, and standard production torpedoes listed in the catalog varied in cost from £280 for a 14-inch steel torpedo up to £380 for a 15-inch bronze model. The competing phosphor bronze Schwartzkopff torpedo, selling for £450, was the highest-priced torpedo available. It appears that, in some cases, Whitehead was willing to take old torpedoes in trade when a customer wanted to purchase a newer model. These trade-ins were refurbished and sold to smaller nations that could not afford the new, higher-priced models. By the end of the century, all of the major powers had Whitehead torpedoes in their inventories, and Whitehead was firmly established as the leader in the torpedo business.

By the 1880s, the other major European naval powers, including France, Germany, and Italy, had also become concerned about the availability of Whitehead's Austrian-made torpedoes in the event of war. These governments purchased nonexclusive rights to manufacture their own Whitehead torpedoes and set up government factories to manufacture them. Since Whitehead's plant was located in Austria, his business dealings were strongly influenced by the political whims of the Austrian government. On numerous occasions, the Austrians refused to approve torpedo sales to unfriendly foreign powers. Whitehead maintained excellent relations with the Austrian government and generally managed to resolve most of these political problems. However, Austria could not allow him to sell torpedoes to any country that Austria was at war with, and he did suffer the loss of some sales because of these government restrictions. In 1890, Whitehead decided to expand his options by opening a second plant in Weymouth, England, so that he would not be totally dependent on the goodwill of the Austrian government.

Since the Royal Navy was a major customer, the new plant in England assured continued sales to the British in the event of political differences between Austria and Great Britain, and it also gave Whitehead additional flexibility in selling his torpedoes on the international market. In this same period, Whitehead had been developing a new 18-inch torpedo at the Fiume plant and was pressing hard to get the Royal Navy to purchase this larger weapon. Captain Arthur Wilson, Chairman of the Royal Navy Torpedo Design Committee, had some reservations about the new weapon, but Whitehead got Captain Edwin Gallwey, the Royal Navy's leading torpedo expert, to endorse the new design and convince the Admiralty that they should place an immediate order. Shortly after the order was placed, Captain Gallwey retired from the Royal Navy and was hired by Whitehead to manage the plant at Weymouth, which would produce the new torpedo that he had been instrumental in ordering. It appears that the concept of a defense contractor offering employment to a military officer during a negotiation to obtain a contract is not purely a 20th-century phenomenon.

In 1893, the Royal Navy built a new torpedo plant at the Royal Gun Factory (RGF) and started making all its own 18-inch torpedoes. The Germans, Whitehead's other big customer, also decided to build all their torpedoes at their imperial arsenal, so Whitehead lost his two biggest customers. At the time, Fiume was producing 900 torpedoes per year, and, in spite of the loss of these customers, the Weymouth plant was also working at full capacity within a short time. Whitehead completely rebuilt the Fiume plant by installing modern production lines to further increase production. The torpedo had become a major weapon in the naval arsenal, and there was a phenomenal worldwide demand for them. Whitehead was determined to supply the demand with Whitehead torpedoes. All

of the major naval powers were using Whitehead torpedoes, and, as the war clouds gathered, the orders just kept rolling in.

In 1902, Whitehead's eldest son, John, the manager of the Fiume operations, died unexpectedly. Since Robert Whitehead was already semiretired and in poor health, the total management burden for the family business had to be taken over by Georg Hoyos, his son-in-law. The heavy workload weakened Hoyos's health, and he died in 1904. The following year, in 1905, the father of the torpedo, Robert Whitehead, died, and the family business dynasty ended because there was no member of the immediate family qualified to take over Silurificio Whitehead. The management of the Whitehead family business was taken over by Edwin Gallwey, the manager of the English Whitehead plant, but Gallwey died in 1906. Within a period of 4 years, the essential creative forces behind the Whitehead torpedo had been wiped out, and there was serious concern about the future of the lucrative but leaderless family business. With the international arms race starting to accelerate, Silurificio Whitehead, with full order books and two modern plants, was a golden goose. Several of the great European arms conglomerates were interested in acquiring the Whitehead family business.

Because the British government was concerned about the Whitehead torpedo business falling into unfriendly hands, the Admiralty became involved in a little bit of intrigue. Some of the Royal Navy's major contractors were forewarned that a portion of the family shares were going to be sold, and it was suggested that they consider purchasing them to ensure that the Whitehead facilities remained in friendly hands. Two of the contractors, Vickers and Armstrong Whitworth, responded to this subtle pressure by teaming up. Each company purchased 184 shares, for a total of 368 shares to gain a controlling interest in Whitehead. The Whitehead family retained the remaining 367 shares in the torpedo business. In 1907, Vickers and Armstrong registered the Weymouth factory as a separate English company, and, as the war clouds got darker, they began an expansion program to become a major multinational torpedo conglomerate. By 1910, they had formed two additional companies, La Societe de Torpilles Whitehead at St Tropez, France, and La Societe Anonima Italiana Whitehead in Naples, Italy, to increase their production capacity and to sell torpedoes directly to the French and Italian navies. On the eve of World War I, they were also negotiating with a Russian firm, A. Lesser and Co., to establish a Russian plant at Feodosia on the Crimean peninsula, but the war started before the deal could be finalized.

With all of the major powers engaged in a massive arms race, Vickers and Armstrong had every reason to be pleased with the lucrative Whitehead torpedo business that they had purchased. It is also interesting to note that the other great arms merchants in Europe became interested in the torpedo as World War I approached. Ultimately, Krupp in Germany, Schneider in France, and Orlando in Italy all became involved in the torpedo business. Whitehead's torpedo joined the major league when Europe's great arms conglomerates added the torpedo to their catalog of war machines offered for sale.

Meanwhile, the U.S. Navy had finally developed an interest in Whitehead's torpedo. In 1891, the E. W. Bliss Company of Brooklyn, New York, purchased nonexclusive rights to manufacture Whitehead torpedoes in the United States for the U.S. Navy. Although the U.S. Navy had a torpedo station at Newport that did experimental torpedo work, there were no Government-owned facilities available for the manufacture of torpedoes. Pratt and Whitney had built the few Lay torpedoes that

the Navy had, and Hotchkiss Ordnance had built the operational Mark 1 Howell torpedoes. When the U.S. Navy became interested in the Whitehead torpedo, they again sought a private contractor to manufacture them in the United States. During the 1890s, E. W. Bliss manufactured a series of 17.7-inch-diameter (45-cm) Whitehead torpedoes designated Marks 1, 2, and 3 for the U.S. Navy. Some of these early “cold-running” torpedoes remained in service until 1922.

The E. W. Bliss Company was interested in increasing their torpedo profits and eliminating the royalties they had to pay Whitehead, so Frank McDowell Leavitt, an engineer and part owner of E. W. Bliss, designed a new turbine-powered torpedo and offered it to the U.S. Navy. The first version had a single-stage Curtis turbine; the final design had a two-stage turbine with a gearbox that powered counter-rotating propellers. A very talented engineer, Leavitt made a number of major design improvements that dramatically improved both the performance and endurance of early torpedoes, including the turbine power plant that was used by the U.S. Navy for the next half century. He was the first person to increase the thermodynamic efficiency of the torpedo by burning alcohol to heat the air, and the Bliss-Leavitt Mark 1 torpedo, developed in 1904, was the first 21-inch-diameter weapon. He was also instrumental in introducing the Uhlan gear, which repackaged the depth control mechanism and course control gyro into a single compact unit that could be tested and calibrated on a special test stand and then plugged directly into the bottom of the afterbody.

The E. W. Bliss Company was also interested in increasing their profits by selling their new turbine-powered torpedoes on the international arms market, but the U.S. Navy objected to public disclosure of the performance and design details of the new weapons that it was purchasing from Bliss. The Government sued Bliss to keep the information secret but lost the case. Representatives of the Japanese Navy visited the Bliss plant to examine the new Bliss-Leavitt torpedoes. This was a typical case of the push and pull that exists between industry and the military when profits and national security seem to conflict. Bliss wanted to sell the new torpedoes on the open market to make a profit, but the U.S. Navy wanted the design kept secret for military reasons. The Navy got so upset about the alleged breach of security that it decided to set up its own torpedo production facilities at the Naval Torpedo Station in Newport.

Since relations with Bliss were badly strained by the foreign sales issue, the U.S. Navy purchased nonexclusive rights to build Whitehead torpedoes. In 1906, Congress appropriated \$150,000 for a U.S. Navy torpedo factory at Newport. In 1908, the new factory began manufacturing Whitehead Mark 5 “hot-running” torpedoes powered by a four-cylinder radial engine for the U.S. Navy. However, the new Bliss-Leavitt Mark 7 steam torpedo was clearly superior. By 1911, the Navy had reconciled its differences with Bliss, and the Newport torpedo plant switched over to produce the new turbine-powered Bliss-Leavitt Marks 7 and 8 torpedoes. The 45-cm Mark 7 and the 21-inch Mark 8 torpedoes both had long active service lives: the Mark 8 torpedo was still in use on older destroyers and PT boats during World War II.

As World War I drew closer, even some of the smaller nations began to worry about the availability of commercially manufactured torpedoes during wartime. In 1908, the Swedish Navy started to build a factory at Karlskrona; in 1910, they began to manufacture a 45-cm, cold-running Whitehead torpedo. The Swedish planned to also sell their torpedoes to Norway and Denmark in

order to boost their production to a reasonable level. By the eve of World War I, both government arsenals and private contractors were working at full capacity to produce torpedoes.

When World War I started in 1914, the Whitehead torpedo empire was split up: the Austrian plant supplied torpedoes for the Germans, and the other three plants, in England, France, and Italy, produced for the Allies. In England, the Admiralty, Vickers, and Armstrong set up the Caton Engineering Company Ltd in 1915 to build additional torpedoes at the Caton works near Lancaster. To provide additional torpedo production capacity in the United States, a huge new torpedo factory was built at Alexandria, Virginia; torpedo production facilities were installed at the Naval Gun Factory in Washington, District of Columbia; and a second Naval Torpedo Station was opened at Keyport, Washington. Although all of the naval powers worried about their torpedo inventories during the war, the German U-boats accounted for most of the torpedoes used during World War I. This demand placed a severe strain on the German torpedo producers, including the imperial arsenal, Schwartzkopff, and Whitehead's Austrian plant. The Austrian plant had been evacuated from Fiume to St. Polten some 40 miles south of Vienna to protect it from the Italians.

When World War I ended in 1918, the arms market dried up overnight. The major naval powers elected to use the very limited funding available to keep their own government-owned torpedo factories operating. With empty order books and no cash flow to keep the factories operating, a worldwide collapse of the commercial torpedo industry soon followed. By 1919, the Caton works in England had closed; by 1921, the Whitehead factory at Weymouth was forced into voluntary receivership. In Germany, Schwartzkopff went out of business; in the United States, Bliss-Leavitt stopped making torpedoes. Vickers and Armstrong also sold their French and Italian Whitehead plants to syndicates. The international commercial torpedo business essentially ceased to exist. When Fiume was ceded to Italy under the terms of the peace treaty, the original Whitehead complex came under the control of the Italian Orlando industrial group that was allegedly backed by the Italian fascists.

The Italian Whitehead group completed the development of a new two-cylinder, double-acting, horizontal engine that had been designed by Tell Jones and the Fiume design group just prior to World War I. This new engine, which was rugged, quiet, and extremely reliable, provided the basis for a new Italian Whitehead torpedo that was marketed to Russia, Japan, and other smaller nations that did not have their own capability to develop and build torpedoes. The Italian torpedo was a Whitehead in name only, but it was, nevertheless, an excellent torpedo that provided the technological base for both the Russian and Japanese torpedoes used in World War II. With most of the commercial torpedo companies out of business, the development of new torpedoes became more of a national affair, with each of the major navies developing its own torpedoes in government facilities.

Information about new torpedoes was generally classified, and, since each country wanted to keep its torpedo efforts secret, there was little exchange of technical information. Perhaps because of the secrecy and/or the lack of incentive to sell new torpedoes on the international arms market, there was surprisingly little new technology incorporated into torpedoes during the period between the two World Wars. For some reason, once governments took over the torpedo business, creativity seemed to be stifled, and innovative concepts gave way to incremental improvements on old, proven designs.

In the United States after World War I, the E. W. Bliss Company was forced out of the torpedo business; the new government torpedo plant at Alexandria was closed; and the torpedo production facilities at the Naval Gun Factory in Washington were shut down. The Naval Torpedo Station at Newport again became the Navy's only active torpedo production facility and the sole source for the development of new torpedoes. A new family of submarine, surface ship, and aircraft torpedoes was developed by the Naval Torpedo Station during the 1930s, but the new Marks 13, 14, and 15 torpedoes were basically improved variants of the Bliss-Leavitt Mark 8 torpedo developed prior to World War I. During this austere period, the annual research and development budget for torpedoes was only \$30,000 to \$40,000 per year, so the scope of development was limited to the key components required to increase speed and/or warhead size.

The torpedo basically remained a handmade, artisan weapon. The dynamic control of torpedoes remained a trial-and-error, "black magic" art that defied theory and was accomplished only by extensive in-water testing. With the limited funding available, it was not possible to conduct extensive trials to evaluate the in-water performance of the three new torpedoes under realistic conditions, and significant changes in the dynamic performance of the warshot-configured torpedoes went unnoticed. Some experimental work was also done on an electric torpedo, but, with the austere budgets and conservative military management, technological innovations were few and far between. Since the new torpedoes developed at Newport were essentially improved versions of the earlier Bliss-Leavitt torpedoes, they were not exhaustively tested by the fleet in live warshot evaluations. When the United States entered World War II, it was found that the unrealistic peacetime focus on firing exercise torpedoes had masked some serious design deficiencies.

The British had also lost their commercial torpedo suppliers—Caton and Whitehead; all British torpedo expertise was now resident at the Royal Torpedo Factory at Greenock. The British improved their basic Whitehead torpedo with a semi-internal combustion, or "burner-cycle," engine that significantly reduced the expendables consumption rate, but the new British Mark VIII torpedo was still basically an improved Whitehead torpedo similar to those used in World War I. The British experimented with liquid hydrogen peroxide as an oxidant and with some turbine power plants, but these new technologies got little support from the conservative "old guard" naval officers. Thus, most of this innovative work was never incorporated into new torpedoes because of the risks involved and the cost of new developments.

An exception to this general trend occurred in Japan in 1926 when Rear Admiral Kaneji Kishimoto and Captain Toshihide Asakuma developed a new torpedo propulsion system that used pure compressed oxygen in place of compressed air. The British had experimented with using pure oxygen, and the Japanese had observed the British experiments. The British had concluded that pure oxygen was too dangerous to use in torpedoes because it had a nasty habit of exploding if there was the slightest bit of oil or dirt in the system. Working at the Kure Torpedo Institute, the thorough and meticulous Japanese covertly perfected an oxygen propulsion system, and the Kure Arsenal secretly modified operational weapons to incorporate the new oxygen system. When World War II started, the existence of these wakeless, high-performance, oxygen-powered torpedoes came as a complete surprise.

At the end of World War I, when they were disarmed, the Germans destroyed all their newly developed electric torpedoes so that they would not fall into Allied hands. Although the Germans were forbidden to develop new torpedoes, German engineers, working in other countries, continued to work on new torpedoes. During the 1920s, development of the German electric torpedo continued at Karlskrona, the Swedish torpedo factory. After successful trials in 1929, the design was frozen to await full-scale production in Germany at a later date as the famous German G7e electric torpedo, the premier U-boat weapon of World War II. In 1934, the Germans purchased a new aircraft torpedo developed at the Horten factory in Norway, and, in 1936, the Schwartzkopff Company again became active in the torpedo business and began to build copies of the Horten torpedo for the German government. Because the Horten torpedo did not meet operational expectations, the Germans started to negotiate with the Italian Whitehead factory at Fiume for a new aircraft torpedo just before the war.

In Italy, the old Whitehead factory at Fiume, controlled by the fascist Orlando group, continued to produce torpedoes, and the Vickers-Whitehead plant at Naples had become the State Torpedo Factory. Italian World War II torpedoes with a “W” prefix were manufactured at Fiume; an “SI” prefix denoted manufacture at the Naples plant. French torpedoes were developed and produced at the French Navy Facility at Toulon. Wartime production was augmented by utilizing the Whitehead plant at St Tropez, which was renamed “Establishment de la Marine” and controlled by the Schneider syndicate, to manufacture torpedoes based on the Toulon designs. During the war, the Toulon facilities were heavily damaged. In 1945, torpedo production was centralized at St Tropez.

During the 1930s, the United States, Great Britain, and Germany were all involved in top secret programs to develop an influence, or standoff, exploder to increase the effectiveness of torpedo warheads. Theoretically, a warhead inflicted greater damage if it exploded under a target or just before it contacted the target, and an influence exploder would substantially increase the kill effectiveness of a torpedo. All three countries conducted independent but highly secret developments to build magnetic influence exploders, and all three countries had major problems when they tried to transfer influence exploders, developed under laboratory conditions, into their fleets where they had to operate under real-world conditions.

In the period before World War II, the existence of torpedo influence exploders was a closely held secret. Fleet use was prohibited to avoid losing one or accidentally disclosing their existence. Consequently, testing was done on secure test ranges under controlled conditions. When war came and the influence exploders were issued to the operational forces, it was a horror story. The magnetic influence exploders were sensitive to variations in the earth’s magnetic field, so performance varied radically with changes in geographic position. The Germans had problems in Norway, the U.S. Navy had problems in the Pacific, and the British had problems in the Atlantic, as influence exploders prematured and malfunctioned at an alarming rate. In hindsight, it is clearly evident that exotic new secret technology, such as the torpedo influence exploder, developed under laboratory conditions should be exhaustively evaluated by operational forces under real-world conditions before it is approved for combat use. The development of the torpedo influence exploder was a classic case of attempting to transfer secret new technology directly from the laboratory to the battlefield: the transfer was a dismal, multinational failure.

When war fever started to build again in the late 1930s, the need for additional torpedo production capacity was evident, and industrial support was solicited to mass produce torpedoes. There were only a few hundred modern torpedoes in the U.S. inventory, and only 50 to 60 torpedoes per month were being produced by the NTS factory at Newport. Clearly, action was needed to increase torpedo production and build up the inventory. The response to the torpedo crisis provides a typical example of “the American way of war” as the government waited until the last possible moment and then initiated a massive program to increase production. The NTS factory at Newport was retooled for three-shift, around-the-clock production; the government torpedo plant at Alexandria was reactivated; and the NTS at Keyport was tooled up to build torpedoes. The government also built a Naval Ordnance Plant at Forest Park, Illinois (NOPF), to be operated by the American Can Company as a government-owned, contractor-operated facility.

Still concerned about production, the U.S. Navy contracted with American Can to operate a second NOPF in St Louis, Missouri, and placed additional contracts with International Harvester and the Pontiac Division of General Motors. Also, E. W. Bliss Company and the Precision Manufacturing Company received contracts to build torpedoes for the British navy. In 1942, the U.S. Navy placed a production contract with Westinghouse Company to mass produce the new electric Mark 18 torpedo. In addition, as the secret new homing torpedoes were perfected, the General Electric Company, Western Electric Company, and Westinghouse received contracts to produce the new Marks 24, 27, and 28 acoustic homing torpedoes.

The torpedo shortage would be solved several times over once all these new facilities were on line, but new problems appeared as all these new vendors learned to mass produce torpedoes that had always been handcrafted by highly skilled artisans. Because of unrealistic testing, the Marks 13, 14, and 15 torpedoes developed by NTS Newport still had serious deficiencies when released to the fleet. The process of identifying and correcting the design defects was complicated by the problems related to mass production. As the system became contaminated with improperly made torpedoes and parts, it became increasingly difficult to isolate basic design deficiencies, and it took a massive effort to identify, sort out, and correct all of the production problems. The Bureau of Ordnance established a Central Torpedo Office at Newport to standardize the documentation base and get the production problems straightened out. Ironically, with the production delays, it was 1943 before the new facilities hit their stride. The result was a massive overproduction of torpedoes late in the war when actual torpedo usage was on the decline.

During World War II, the United States spent almost \$700 million on torpedoes and torpedo production facilities, and, during the period from January 1, 1939, to June 1, 1946, an impressive total of 57,653 conventional torpedoes were produced:

NTS Newport produced	18,751
NTF Alexandria produced	9,920
NOPF Forest Park produced	8,391
NOPF St Louis produced	6,257
Westinghouse produced	8,250
Pontiac/International Harvester produced	5,289
NTS Keyport produced	795

Since the U.S. Navy used only approximately 15,000 torpedoes during World War II and NTS Newport produced over 18,000 during the war, the data suggest that the original Newport plant by itself would have been sufficient to meet the U.S. Navy's World War II torpedo requirements. Instead, the U.S. Navy, in the typical American response to a military production problem, built a host of additional production facilities and built enough torpedoes for three world wars. In addition, Western Electric and General Electric produced over 6,100 of the new Marks 24, 27, and 28 acoustic homing torpedoes during World War II. After the war, most of the huge torpedo inventory was declared surplus; thousands of new torpedoes were sold for junk just to get rid of them.

In Great Britain, at the start of World War II, the production rate was about 80 torpedoes per month, which was just about balanced by the expenditure rate. The Royal Torpedo Factory at Greenock was the source of all British torpedo development and the main producer of torpedoes before the war. When the war started, the Whitehead plant at Weymouth, owned by Vickers-Armstrong Ltd, and the Caton Engineering Company plant were reopened to provide additional torpedo production facilities. Production increased rapidly; by the end of 1942, it reached a rate of 440 torpedoes per month. Up to that time, 2,308 torpedoes had been used, so the increased production quickly made up the initial shortage, and the inventory started to grow.

Through September 1944, the Royal Navy expended a total of 6,447 torpedoes of all types to meet wartime requirements. By far, the greatest expenditures were of the 21-inch Mark VIII submarine torpedoes and the 18-inch Mark XII aircraft torpedoes. Because the Royal Navy had a very unusual mix of ships that included World War I destroyers from the United States, Polish and Dutch submarines, and Free French warships, providing the diverse mix of torpedoes needed to keep these one-of-a-kind platforms operational was a logistical challenge that kept the British busy during the early days of the war.

The German Navy fired over 10,000 torpedoes up to the end of January 1945, of which the vast majority were fired from U-boats. The most popular weapon was the electric G7e torpedo; over 7,000 of them were expended. The G-7a thermal-powered torpedo was next in demand; 2,300 of them were used during the war. Because the Germans had severe shortages of critical materials, extensive redesign efforts were undertaken to reduce the amount of critical material and scarce labor required to build torpedoes.

In the case of the thermal G-7a torpedo, the amount of nickel, which was very scarce, was reduced from 46 to 2 kilograms per torpedo. The amounts of copper and tin used were substantially reduced. The cost and labor hours were cut in half. These modifications simplified the torpedo significantly, so that a torpedo with only a minor loss in performance could be mass produced under austere wartime conditions when skilled labor and raw materials were in critically short supply. In 1939, it took 3,730 man-hours of labor to produce a G-7a torpedo; by 1943, the labor had been reduced to 1,707 man-hours per torpedo. By 1943, the labor required to produce the electric G7e had been reduced to 1,255 man-hours per torpedo, and the Germans had the production capacity to produce 1,000 torpedoes per month.

Late in the war, both the United States and Germany introduced acoustic homing torpedoes, and the manufacture of these new weapons with their sensitive acoustic homing systems radically

changed both the design of torpedoes and the methods used in their manufacture. The new homing torpedoes required a quiet propulsion system so that the noise of the torpedo power plant would not acoustically mask targets; the body had to be specially designed to minimize flow noise for the same reason; and the torpedo speed had to be kept low, generally under 20 knots, because, at higher speeds, the acoustic homing system was blinded by the self-noise of the torpedo. As a consequence, the homing torpedoes were a new breed that had to be specially designed to be compatible with their acoustic homing systems.

Because of the inherent noise of thermal power plants, all of the early homing torpedoes were powered by electric propulsion systems to minimize machinery noise. In the United States, most of these early homing torpedoes were made by companies such as General Electric and Western Electric who had been pioneers in the development of acoustic homing systems but had never built conventional torpedoes. These early homing torpedoes were the forerunners of a new generation of modern underwater guided missiles. In the postwar years, most of the new torpedo development effort concentrated on establishing the technology to support a new generation of high-performance acoustic homing torpedoes.

In the United States, a very high national priority was assigned during the war to the development of an acoustic homing torpedo, and the best technical minds were applied to the task. The prestigious Bell Laboratories, General Electric, the Harvard Underwater Sound Laboratory, and Western Electric all participated in the development of the new acoustic homing torpedoes. When the war was over, the demand for torpedoes went to zero, and the brilliant technical team was reassigned to more pressing postwar problems, such as developing new consumer-oriented products and reestablishing their companies' competitive position in the marketplace. Harvard University also decided to get out of the defense business after the war, and their Sound Laboratory was split up. The ship-related effort was consolidated with the Columbia University program in underwater sound in New London, Connecticut, as a new Navy laboratory (called the Navy Underwater Sound Laboratory), and the torpedo expertise was transferred to the newly formed Ordnance Research Laboratory at Pennsylvania State University.

The U.S. Navy also started building up its laboratories at Newport, Rhode Island, at China Lake, California, and at the Naval Ordnance Laboratory in Silver Springs, Maryland. The corporate expertise for the new acoustic homing torpedoes was absorbed into the Navy laboratory system. In the postwar years, the Navy laboratories became the major source of torpedo-related technical expertise. They functioned as the Navy's corporate memory in torpedoes and assumed the leadership role in developing new torpedoes.

In the torpedo production business, the private contractors dismantled their torpedo facilities as soon as the war was over and returned to their peacetime roles. The newly formed U.S. Department of Defense decreed that the government should get out of the manufacturing business and leave it to private industry, but the Navy argued that the torpedo was a special case that required a government-operated torpedo factory. The Navy shut down the government factories at Newport, Alexandria, and St Louis, but the Naval Ordnance Plant at Forest Park (NOPF) was retained to provide an in-house source of torpedo manufacturing expertise. The NOPF at Forest Park continued to modify existing weapons and manufacture new torpedoes in the postwar period, but it became increasingly difficult

to compete with the private sector given the rapid advances in technology. When the second generation of postwar acoustic torpedoes started to appear in the 1960s, the NOPF was phased out as private industry began to compete directly for torpedo production contracts.

The U.S. Navy no longer maintains any torpedo production facilities, and all Navy torpedoes are now produced by private contractors. The Navy does maintain the resident technical expertise to conduct basic torpedo research and development, but private industry conducts the engineering development and production of new weapons on a competitive basis. There is little incentive for private industry to invest in the torpedo business because torpedoes are developed infrequently and only limited numbers are produced. Private industry is in business to make money for stockholders, and, historically, building torpedoes has not been a big moneymaker for U.S. industry.

The torpedo procurement problem is also compounded by rapid changes in technology, particularly in electronics, that can make a new torpedo obsolete before it is fully operational in the fleet. For example, vacuum tubes were in use in the 1950s, transistors came into use in the 1960s, integrated circuits were used in the 1970s, and large-scale integrated circuits were in common use by the early 1980s. Within a decade of vacuum tubes becoming obsolete technology (and increasingly expensive), it became difficult to maintain an inventory of torpedoes requiring vacuum tubes no longer being mass produced by private industry. Traditionally, torpedoes had a shelf life of 30 years or more, and the cost of the warehouse inventory, or war-ready stockpile, was amortized over the operational life of the weapon.

The torpedo, as conceived by Whitehead, was a masterpiece of artisan genius. Torpedoes were built by hand by skilled craftsmen; the individual parts were finished and fitted by hand. Each torpedo underwent individual in-water testing (generally referred to as “proofing”) to make the necessary final adjustments to meet the performance specification. Since the theory to support the design of control systems and servo controls did not exist, extensive experimentation was required to get the temperamental systems to function. Frequently, no one really understood what the problem was or how it had been fixed. In a typical torpedo shop, all of the senior craftsmen had private little notebooks with all their “secret” information about the critical adjustments required to make a temperamental torpedo operate properly. The “black magic,” experimental approach to problem solving was the rule, and there was little scientific information to support the solutions.

The torpedo remained an experimentally designed, artisan weapon right up through World War II. Most of the problems encountered early in the war were not even recognized until the weapons were used in a warshot configuration, and most of the solutions were found by conducting additional tests with warshot torpedoes and without ever really identifying or understanding the basic problem. There were many “torpedo experts,” but no one had a sound scientific understanding of the torpedo’s dynamic behavior. The torpedo designers were smart, talented individuals, but it took considerable skill to master the complexities of a deadly self-propelled guided missile in an era when the scientific theory to support the design evolution did not exist. Their ingenuity and persistence deserve high praise. Since the torpedo was treated as a “black box,” each major modification was treated as a new torpedo design. As a result, by the end of World War II, the U.S. Navy had over two dozen different torpedoes either in development or in production.

In the postwar period, major advances in scientific theory, combined with rapidly emerging new technologies, started evolutionary changes in the torpedo business. During the 1950s and 1960s, the explosion in technical information provided the base for the scientific design of torpedo components at the subsystem level. Technology programs were initiated in naval laboratories to scientifically develop torpedo propulsion systems, homing systems, new hydrodynamic shapes, and warheads on a subsystem basis. By the 1970s, with the advent of large-scale computers and simulation models, it was possible to scientifically design a complete torpedo and analytically predict its performance before it went in the water. The torpedo had completed the transition from an experimental artisan weapon to a modern guided missile, and the scientific tools to design it and analytically predict its performance were in hand. It was no longer necessary to proof each and every torpedo to verify its performance because a limited number of tests would verify the accuracy of the analytical predictions of performance and reliability.

These evolutionary changes also had a profound impact on the torpedo's life cycle. The high cost of developing and producing new torpedoes led to a dramatic reduction in the number of types employed. From the two dozen weapons in the cycle at the end of World War II, the number of operational weapons has steadily shrunk to the point at which the U.S. Navy, by the 1990s, will have essentially two torpedo types—a large multi-mission submarine torpedo and a lightweight multi-platform ASW torpedo. Given the rapid changes in threat performance and new technology, it is no longer feasible to treat torpedoes like iron cannon balls, to be manufactured and then stored in a warehouse for decades. The rapid changes in technology and threat performance have dramatically increased the rate of obsolescence. Since the capability exists to modify torpedoes at the subsystem level, it has become common practice to periodically modify torpedoes to maintain their operational effectiveness.

The static warehouse concept of building a stable inventory of torpedoes to be stored for wartime use is gone. Modern torpedoes have been forced into a dynamic life-cycle mode to protect the huge procurement investment and to extend the operational life of the inventory. It is not uncommon for a modern torpedo to be kept operationally effective by making five or more major modifications to it during its life cycle because of threat improvements or technological initiatives. This dynamic life cycle has also changed the classic concepts of torpedo management because the technical community is now directly involved in the modernization of operational fleet weapons on a routine basis throughout their life cycle.

During its first 100 years, the torpedo's design remained remarkably stable and similar to the original weapon conceived by Robert Whitehead in 1866. There were evolutionary changes and improvements, but, through World War II, most of the torpedoes were based on Whitehead's designs. He would have had no problem assembling or running one. During the past quarter of a century, the torpedo has undergone revolutionary changes as modern space-age technology has been incorporated into the original guided missile. A modern torpedo with its triaxial autopilot and software-based computer systems is very similar to modern airborne guided missiles. Robert Whitehead would be at a loss to even comprehend how they function or to understand the sophisticated technology employed. The torpedo, and the torpedo business, is in the process of

revolutionary changes. As the new generation of high-technology torpedoes enters the fleet, there is no doubt that the torpedo will remain a key naval weapon well into the 21st century.

Since World War II, as new sensors and fire control systems were developed, the combat system has become increasingly complex. With the advent of digital technology and minicomputers, the combat system became extremely sophisticated, and the torpedo became part of a larger information system that makes extensive use of automated information to control the decision process. As the sophisticated new systems evolved, the role of the naval laboratories changed; by the 1970s, they were being called “systems centers” and tasked with the technical management of the evolving computer-based combat control systems. The torpedo is no longer a stand-alone weapon: it has become a key part of the complex computer-based combat control systems required to conduct modern naval warfare.

The torpedo business has evolved from a simple weapon that Robert Whitehead and one artisan could build and operate into complex underwater guided missile systems incorporating advanced digital computer technology, sophisticated sensor systems, wire guidance, and numerous other advanced technologies. The modern torpedo and the combat system that supports it are dramatically different from even their World War II counterparts, and the industrial base required to produce these modern high-performance weapon systems is closely related to those required to build modern airborne guided missiles.

Chapter 16

20th-CENTURY EVOLUTION OF THE TORPEDO

During the last decade of the 19th century and the first decade of the 20th century, a series of major torpedo design improvements were initiated that resulted in significant increases in torpedo performance and effectiveness. With the addition of gyroscopic steering to control the torpedo's course, it became the first guided missile. The gyro provided a dramatic increase in accuracy that increased the torpedo's effectiveness and made longer firing ranges feasible. The addition of fuel and a combustion system to heat the air, combined with the addition of cooling water to increase the mass of the gases, substantially increased the thermodynamic efficiency of the propulsion system and increased both the speed and range of new thermal-powered torpedoes.

New forged-steel air flasks allowed air pressures to be increased from 1,000 psi to over 2,000 psi. New three- and four-bladed propellers increased performance. New blunter nose shapes reduced drag and increased available warhead volume. Also, the size of new torpedoes steadily increased: torpedoes were built with diameters of 18 inches, then 19 inches, and, finally, 21 inches. As World War I drew near, the major powers eagerly sought the new generation of high-performance torpedoes being offered by the commercial torpedo suppliers—Whitehead, Schwartzkopff, and Bliss.

By the eve of World War I, torpedo ranges exceeding 10,000 yards had been demonstrated, speeds in excess of 40 knots had been achieved, and warhead weights were approaching 500 pounds. The technological feasibility of high-performance, thermal-powered torpedoes had been demonstrated: the stage was set for the introduction of these new weapons in World War I. Torpedo performance increased rapidly as major technical improvements were introduced in quick succession. This was truly the golden age of torpedo development.

In 1906, the German Navy introduced a new 500-mm (19.7-inch) torpedo, designated the G series, that incorporated all of the improvements. The 500-mm-diameter torpedo, powered by a four-cylinder radial engine, had a 440-pound warhead, a range of 11,000 yards, and a speed of 28 knots. The G series torpedo became the standard German navy torpedo and remained in use, with minor improvements, through both World Wars. Over 5,000 of them were fired during World War I. The German G type torpedo was undoubtedly the outstanding torpedo in use during World War I. Its effectiveness was dramatically demonstrated when the U-boats sank over 11 million tons of shipping during their campaign against Allied shipping.

During World War I, the Germans also developed a 500-mm-diameter, 28-knot, electric torpedo with a 2,000-yard range, but the war ended just as the new electric torpedo was being released for use by U-boats. The Germans destroyed all of their new electric torpedoes so that they would not fall into Allied hands after the war. The Germans, concerned about the Royal Navy's new, larger-sized, 21-inch-diameter destroyer torpedoes, had also initiated development of a 600-mm (23.6-inch) torpedo with a 550-pound warhead for use on surface vessels. A few of these "king-sized" torpedoes were installed on major combatants, such as the *Lutzow*, but the German destroyers were still equipped with 500-mm torpedoes when the war ended. Late in the war, the Germans also developed

a new 18-inch aircraft torpedo with a 350-pound warhead and a speed of 35 knots for use by their twin-engine Brandenburg aircraft and Zeppelin airships.

The Germans had developed an influence exploder to increase the effectiveness of their mines, and, late in the war, they began to experiment with an influence exploder for torpedoes. The war ended before their torpedo influence exploder was fully operational, so, like their electric torpedo, this technology was quietly hidden away for later use.

Prior to World War I, newer British submarines had standardized on 18-inch torpedo tubes, so the 18-inch-diameter RNTF Mark VIII torpedo became the major submarine weapon. A few of the older submarines still used the 14-inch-diameter RGF Marks VI and VII torpedoes. When the war started, British submarines discovered that the 18-inch Mark VIII torpedoes were defective, and a number of German ships escaped from British submarine attacks because of the faulty torpedoes. The First Sea Lord, Admiral Fisher, was enraged and wrote to Admiral Jellicoe,

“Our torpedoes seem to be filled with sawdust!!! There’s a heavy reckoning coming to everyone connected with *Vernon* [HMS *Vernon* was the Royal Navy’s senior torpedo establishment] during the last four years ... I hope to get a good many officers disgraced for it!”

A major investigation was undertaken, in which it was found that the heavier warshot torpedoes ran considerably deeper than the positively buoyant torpedoes that were fired in peacetime exercises. Torpedo performance improved dramatically once the problem was identified and the depth settings were corrected. The U.S. Navy experienced the exact same problem again in World War II with their heavier warshot-configured torpedoes. Apparently, the U.S. torpedo experts did not learn this important lesson from the bitter experiences of their British cousins in World War I. Unfortunately, since the U.S. Navy did not get involved in any torpedo warfare during World War I, it was not until World War II that the effectiveness of U.S. torpedoes was tested in actual combat and it was found they were not actually combat ready.

The British placed the major emphasis on torpedoes for surface ship warfare. Just prior to World War I, they increased the size of their destroyer torpedoes to a 21-inch diameter with the introduction of a Mark II destroyer torpedo with a 10,000-yard range and a 225-pound warhead. Later in the war, a 21-inch RNTF Mark IV torpedo with a 515-pound warhead was developed. In 1916, the steam-powered submarine *Swordfish* was equipped with two 21-inch torpedo tubes in addition to four of the conventional 18-inch submarine torpedo tubes. By the end of the war, all new British submarines were being fitted with 21-inch torpedo tubes, and the 21-inch torpedo became the primary surface ship and submarine torpedo. British torpedoes, like the German G series, were powered by four-cylinder radial engines designed by the Brotherhood Company. Variations of these four-cylinder radial engines remained the standard British torpedo power plant until after World War II.

When the British decided to experiment with the use of torpedo-equipped aircraft to attack ships, the 1897-vintage RGF 14-inch Mark X cold-running torpedo was modified for use from aircraft. In 1915, during the Gallipoli campaign, Short seaplanes made successful aircraft torpedo attacks against Turkish ships, but the RGF Mark X’s modest performance and small, 77-pound warhead limited its effectiveness against larger ships. Consequently, the British initiated development of a larger, 18-inch

torpedo designed specifically for use from aircraft. The war was almost over before the 18-inch RNTF Mark IX aircraft torpedo was completed, and there is no information indicating that they were used in combat during World War I.

In the United States, when the Bliss-Leavitt Company initiated development of their new turbine-powered torpedoes in 1904, they increased the diameter of their new Mark 1 torpedo to 21 inches, and this new, larger torpedo soon became the standard for use by U.S. Navy battleships. It was closely followed by improved versions with counter-rotating turbines (Marks 2 and 3), also designed for use by battleships. In 1908, a 45-cm (17.7-inch), turbine-powered, Bliss-Leavitt torpedo designated the Mark 4 was developed specifically for use by submarines.

In the 1900s, Bliss-Leavitt and the Naval Torpedo Station (NTS) Newport initiated development of two new destroyer torpedoes for the U.S. Navy. The 45-cm (17.7-inch) Mark 6 torpedo had a new horizontal turbine. The 45-cm Mark 7 turbine-powered torpedo was the first to use diluent water in the combustion pot to cool the gases and increase the mass of the gas. The Mark 7, a very successful torpedo that was still in use during early World War II, was also deployed from both submarines and aircraft. During World War I, the Mark 8 torpedo, the first 21-inch-diameter by 21-foot-long weapon, was developed for use on the new U.S. Navy *Wickes* and *Clemson*-class destroyers. These torpedoes also remained in the inventory and were used during World War II. The U.S. Navy issued approximately 600 Mark 8 torpedoes to Great Britain early in World War II for use with the 50 destroyers turned over to the Royal Navy under the lend-lease act.

The U.S. Navy decided to increase the size of the submarine torpedo tubes in the new R and S class submarines from 17.7 inches to 21 inches late in World War I. The 21-inch Mark 9 torpedo, originally designed for use on battleships, was modified for submarine use; in 1915, the development of a new Mark 10 torpedo, for use on the R and S class submarines, was initiated. With a 497-pound warhead, the Mark 10 torpedo had the largest payload of any torpedo built up to that time. The Mark 10 torpedo continued in use as the primary submarine torpedo until it was replaced by the Mark 14 torpedo early in World War II.

Although the U.S. Navy conducted an aggressive torpedo development program prior to World War I, the Navy did not see much action in the shooting war, so there was no opportunity to evaluate these new weapons in the ultimate crucible of combat. The Germans and the British had the opportunity to work the bugs out of their torpedoes during World War I, but the U.S. Navy had to wait until World War II to find out that its torpedoes were not combat ready.

With the demise of the highly competitive commercial torpedo companies after World War I, torpedoes started to assume national characteristics as new torpedoes were designed and developed in government facilities under closely controlled conditions. There was a considerable amount of innovative torpedo-related research and development conducted during the interwar years, but surprisingly little of this new technology was actually incorporated into new torpedo designs. Perhaps it was because much of the information was classified, which stifled the normal competitive development of new weapons, or perhaps tight budgets and conservative military management discouraged any risk-taking to develop new concepts.

In the interwar years, Britain, Germany, Japan, and the United States all experimented with either concentrated hydrogen peroxide or oxygen-enriched air systems to replace the compressed air used in conventional torpedoes. Since air contains approximately 77% nitrogen, which does not support combustion, and only 23% oxygen that burns with the fuel, any method to reduce the volume of inert nitrogen gas carried in the torpedo would lead to significant increases in performance. It would also reduce the torpedo's wake because the insoluble nitrogen gases were the reason for the torpedo's highly visible wake. In the mid-1920s, the Royal Navy developed a high-performance oxygen-enriched torpedo, the Mark VII, for use on the *London*-class cruisers. The Mark VII torpedo, with a speed of 33 knots and a range of 16,000 yards, entered the fleet in 1928, but the corrosive oxygen introduced severe maintenance problems. The system was converted to use conventional high-pressure air shortly after it entered the fleet.

After World War I, the Japanese began developing their own torpedoes and torpedo production facilities at the Kure Naval Arsenal. When they experienced difficulties fabricating reliable high-pressure air flasks for their torpedoes, they negotiated with the British to purchase air flasks and manufacturing technology. When the Japanese became aware of the successful British development of an oxygen-enriched air torpedo, they initiated a secret program at the Kure Torpedo Institute to develop a torpedo that would use pure oxygen. In spite of the difficult technical problems, the Japanese successfully developed a pure compressed-oxygen propulsion system in total secrecy and produced a family of oxygen torpedoes that came as a complete surprise in World War II. This was one of the outstanding torpedo developments during the interwar period. To ensure the success of their new torpedoes, the meticulous Japanese secretly conducted extensive warshot evaluations in which large numbers of old ships were actually sunk under combat conditions to ensure that the new oxygen torpedoes were combat ready.

The extremely reliable and trouble-free operation that Japanese torpedoes demonstrated during World War II bore out the wisdom of the thorough Japanese evaluation program. Japanese torpedoes were identified by the last two digits of the Japanese year that they were developed. For example, the standard World War II 18-inch aircraft torpedo, with a speed of 45 knots and a 338-pound warhead, was designated a Type 91 torpedo since it was developed in the Japanese year 2591. The Type 93 torpedo was developed in the Japanese year 2593. (It was nicknamed "Long Lance" after the war by Samuel Eliot Morison.) The giant, 24-inch-diameter, 30-foot-long Type 93 torpedo weighed over 3 tons, had a 1,000-pound warhead, and could travel over 20,000 yards at 49 knots or 40,000 yards at 36 knots. The wakeless, oxygen-powered, Long Lance torpedo was, without a doubt, the outstanding destroyer torpedo in use during World War II.

The Japanese also developed a scaled-down, 21-inch-diameter version of the oxygen-fueled torpedo for use by submarines, which was identified as a Type 95 torpedo. There are also references to other Japanese torpedoes, including a Type 96, a Type 98, and an electric-powered Type 92 torpedo. During World War II, the Germans supplied their Japanese allies with some U-boats, torpedoes, and technical information to assist them in developing new capabilities. The use of this German technology in some of the Japanese wartime torpedo development efforts is evident.

In the early 1920s, the British also started to experiment with using concentrated hydrogen peroxide instead of air as the oxidant in their torpedoes. The liquid hydrogen peroxide provided

greater energy density, but it was an unstable liquid requiring special materials and handling to keep it from decomposing. Therefore, the British terminated their experiments and concentrated their limited resources on their oxygen-enriched Mark VII torpedo. Later, both Germany and the United States began to experiment with hydrogen peroxide. Both countries conducted extensive development efforts during the 1930s and early 1940s, to develop torpedoes that used concentrated hydrogen peroxide as the oxidant. In the United States, the Naval Research Laboratory did the early experimental work and developed Navol, a concentrated hydrogen peroxide for use in torpedoes.

In 1937, a Mark 10 torpedo, modified to use Navol, was tested at NTS Newport and demonstrated a 275% increase in range (from 3,500 yards with air to 9,500 yards with Navol). The Navy began a program to develop a new destroyer torpedo with a Navol propulsion system. In 1940, the U.S. Navy authorized the development of a 50-knot destroyer torpedo with a 16,500 yard range designated the Mark 17. When the attack on Pearl Harbor occurred, the highest priority was placed on volume production of existing operational torpedoes. The Mark 17 development was postponed, since there was not enough Navol production capacity available in the United States to support an operational torpedo utilizing hydrogen peroxide. In 1943, work resumed on the Mark 17 torpedo and on a submarine version of the hydrogen peroxide torpedo designated the Mark 16. These weapons were not used in combat during World War II, but they were issued to the fleet in limited numbers just as the war ended. The Mark 16 torpedo remained in limited use on selected U.S. Navy submarines, as an anti-ship weapon, for almost three decades until it was withdrawn from service use in 1975.

During the 1930s, the Germans conducted covert experimental programs to develop a more efficient oxygen carrier for use in their new torpedoes. The goal of this research was to develop a long-range torpedo that could be fired into a convoy of ships to run a programmed pattern until it hit one of the ships and exploded. They experimented with a number of high-energy oxygen carriers, including hydrogen and oxygen, ammonia and oxygen, magnesium and oxygen, and hydrogen peroxide. During early World War II, the Germans initiated the development of a new turbine-driven torpedo powered by concentrated hydrogen peroxide (Ingolin). The Steinwal's complex and sophisticated four-fluid, pump-operated, propulsion system experienced numerous development delays, and the Steinwal torpedo was still in development when the war ended.

During the interwar years, most of the major naval powers experimented with new prime movers for their torpedoes. The British, French, Germans, and Swedish all experimented with turbine power plants for torpedoes, but none of these units ever reached operational status. The U.S. Navy remained the only major power that continued to develop new turbine-powered torpedoes. The British experimented with direct fuel injection to increase the efficiency of their four-cylinder radial engine and developed the "burner-cycle" (B-cycle) engine that was actually a semi-internal combustion two-stroke cycle engine. The redesigned B-cycle four-cylinder radial engine, made for use in both the 21-inch Mark VIII submarine torpedo and the 18-inch Mark XII aircraft torpedo, was the most efficient power plant used in any torpedo up to that time.

When the Italians took over the old Austrian Whitehead facilities after World War I, they completed the development of a large, two-cylinder, horizontal expander engine that had been designed prior to World War I but never developed for use in an operational torpedo. This quiet, double-acting engine was a rugged, reliable design, and these Italian Whitehead torpedoes were the

first operational torpedoes to achieve a speed of 45 knots. The Italian Navy used these trouble-free torpedoes extensively during World War II, and a number of foreign countries, including Russia, also purchased these torpedoes from the Italians. The Italian Whitehead torpedo, which saw considerable service in World War II, was generally rated as a very dependable and effective torpedo.

During World War I, the Germans became convinced that the torpedo's wake was being used to determine the location of the attacking U-boat, so they initiated a program to develop a wakeless electric torpedo to protect the U-boats from counterattacks by surface escorts. After the war, most of the major naval powers became interested in the German efforts and undertook programs to develop electric propulsion systems for torpedoes. The Germans, by virtue of their World War I electric torpedo development program, had an obvious advantage. When World War II started, the German G7e torpedo, which had been secretly developed at the Swedish torpedo plant at Karlskrona during the 1920s, was the only operational electric torpedo available.

The other naval powers, reluctant to accept the reduction in torpedo performance that resulted when a wakeless electric propulsion system was employed, decided to concentrate on developing higher-performance thermal propulsion systems to power their new torpedoes. Although the wakeless German G7e electric torpedo, with a 30-knot speed, was 14 knots slower than its thermal-powered twin, the G-7a torpedo, the slower wakeless electric torpedo was the odds-on favorite of the U-boat commanders when they were used in combat in World War II. Later in World War II, the U.S. Navy introduced the electric-powered Mark 18 torpedo, based on a captured G7e torpedo, for submarine use. By the end of the war, the slower, wakeless Mark 18 was the preferred weapon for the majority of the U.S. Navy submarine attacks. Evidently, the armchair tacticians preferred high-speed torpedoes, but, given the choice, operational submarine commanders preferred wakeless torpedoes that did not disclose their firing position. They were willing to sacrifice performance to gain security.

Early torpedoes used warheads filled with either dynamite or wet gun cotton. During the Russo-Japanese war, a Russian destroyer was sunk when one of its torpedoes exploded when hit by a Japanese shell. This clearly demonstrated the need for stable warhead compounds that did not endanger the firing vessel. At the turn of the century, considerable research was done to develop stable warhead compounds. The Germans developed a TNT-based explosive, Hexanite, for torpedo use that was very stable. In World War I, a British torpedo scored a direct hit on the German battleship *Moltke's* torpedo magazine, but there were no sympathetic explosions from the stable Hexanite warheads in the magazine.

Since sailors had to sleep on top of torpedoes in submarines and the torpedoes were exposed on the decks of surface ships, the concern for warhead stability and safety continued during the interwar years as new explosive compounds were developed. Most of the warhead compounds continued to have a TNT base with various additives to increase effectiveness. During World War II, a TNT-based compound with powdered aluminum, called Torpex, was developed and widely used in torpedo warheads. During the war, Torpex's stability was dramatically demonstrated when a severe battery fire in an electric torpedo on the submarine *USS Flying Fish* caused the Torpex warhead to melt and run out of the torpedo without exploding.

In spite of the many torpedo developments undertaken during the interwar years, most of the torpedoes that inflicted such immense damage during the early years of World War II were basically updated variants of the original Whitehead torpedo that existed at the turn of the century. Although the Germans had installed an electric propulsion system in their G7e torpedo and the Japanese had developed their oxygen propulsion system, the torpedo design was still an experimental artisan art. The performance of each individual torpedo was still experimentally verified by proofing, or testing, in the water on a test range before issuing it to the fleet. As mentioned earlier, the Germans, British, and the United States had secretly developed torpedo influence exploders to increase warhead effectiveness, but these new devices had not been extensively tested in fleet exercises.

On the eve of World War II, the U.S. Navy had torpedoes of six designs in its inventory. The Marks 7 and 8 destroyer torpedoes and the Marks 9 and 10 submarine torpedoes were World War I vintage. The Marks 11 and 12 multispeed destroyer torpedoes were developed in the 1920s. During World War I, the U.S. Navy had initiated a program to develop an electric torpedo, but the effort was grossly underfunded and little real progress was made during the interwar years. NTS Newport built and tested a Mark 1 electric torpedo during the 1920s, but there were no funds for battery development and frequently only one engineer working on the project on a part-time basis. The Navy sporadically conducted electric torpedo developments over 25 years on the Marks 1 and 2, and, at the start of World War II, on a Mark 20 electric torpedo. In the interwar period, the Navy also conducted extensive experiments with the Hammond radio-controlled torpedo. The world's most powerful radio transmitter was built adjacent to the NTS in Newport, and radio signals were used to successfully control an experimental torpedo operating on the torpedo range. The Navy purchased the Hammond patents, but, because the huge power requirements for the transmitter made it impractical for shipboard use, the concept never got beyond the demonstration stage.

During the 1930s, the U.S. Navy initiated development of a new family of modern, turbine-powered torpedoes with large warheads. The 22.5-inch-diameter, 2200-pound Mark 13 torpedo with a 600-pound warhead was authorized by the Navy in 1930 to provide a new torpedo designed specifically for use by aircraft. This was followed by the 21-inch by 246-inch-long Mark 14 torpedo with a 643-pound warhead for use by submarines. Finally, the Navy authorized a 21-inch-diameter, 288-inch-long torpedo with an 825-pound warhead, designated the Mark 15, for use on destroyers. All three of these new torpedoes, developed by NTS Newport, shared the same basic technology developed by Bliss-Leavitt prior to World War I, and they were considered to be improved versions of proven, reliable designs that had been in operational use for decades. Although the concurrent development of the Marks 13, 14, and 15 torpedoes was a major undertaking, the research and development funding to support the efforts averaged only \$30,000 to \$40,000 per year, so the scope of the developments was severely constrained by fiscal reality. The three developments were finally completed just before World War II started, but, because of inventory problems and fiscal constraints, very few warshot tests were conducted. The U.S. Navy did not have any combat experience with warshot torpedoes. When World War II started, it soon became painfully evident when they were used in combat operations that there were serious problems with the warshot torpedoes.

The new torpedoes had been rushed into production with only a bare minimum of actual warshot testing, and all three new torpedoes were experiencing operational problems. The naval combat

forces in the Pacific vigorously complained that the new warshot torpedoes were malfunctioning, but the Bureau of Ordnance and the Naval Torpedo Station responded by claiming that the exercise versions of these same torpedoes performed satisfactorily during proofing and exercise runs. It took almost 2 years and a major bureaucratic battle to establish that there were subtle differences between exercise and warshot torpedoes and that the combat malfunctions resulted from design deficiencies that were not checked during the proofing and exercise runs at the torpedo station.

Exercise torpedoes were tested in a positively buoyant end-of-run configuration to facilitate their recovery. The new torpedoes, with their larger warheads, were several hundred pounds negatively buoyant in their warshot configuration, which caused them to run at an increased angle of attack to compensate for the extra weight. The increase in the angle of attack in turn introduced a depth sensing error that caused the warshot torpedoes to run considerably deeper than the exercise configuration. The torpedo depth mechanisms, tested and calibrated in positively buoyant exercise torpedoes fired on test ranges, were causing the warshot torpedoes to run deeper than the preset depth, so that the torpedoes frequently passed under the target. Identification of the depth error problem in warshot torpedoes was complicated by the fact that the influence and contact exploders were also faulty, and exploder malfunctions were also frequently causing dud shots.

Since the warhead was replaced with a lighter exercise head for proofing and exercise runs, the exploders were not routinely tested by the torpedo station, so the exploder problems remained hidden until the shooting war started. SUBPAC, the submarine force in the Pacific, was extremely upset about the poor performance of the new Mark 14 torpedo, and the torpedo problem became a major crisis during the early part of the war as SUBPAC, the Bureau of Ordnance, and the torpedo station became engaged in a bitter bureaucratic battle over warshot torpedo performance.

The British navy had experienced exactly the same problem during World War I, but the U.S. Navy had to learn the hard way in early World War II that concentrating on exercise torpedo performance in peacetime does not necessarily guarantee good warshot performance in wartime. By 1943, the problems had been corrected, and the Mark 14 torpedo established an outstanding record by sinking over 4 million tons of Japanese shipping during the war. The U.S. Navy had learned a painful, but important, lesson concerning the need to evaluate new torpedoes under realistic combat conditions during peacetime to verify warshot performance.

The Mark 13 aircraft torpedo required that launchings be made from aircraft flying straight and level at an altitude of 50 feet and a speed of 110 knots. When 37 out of 41 torpedo bombers were shot down during the Battle of Midway without making a single hit, the naval aviators protested that the Mark 13's stringent launch envelope was suicidal and requested the development of a new, rugged torpedo designed for high-speed, high-altitude launching. A Mark 13 improvement program was initiated immediately, and, in 1943, the Navy authorized a new high-performance Mark 25 aircraft torpedo to be developed by the Columbia University War Research Division. The new Mark 25 aircraft torpedo was entering pilot production just as the war ended.

Drag rings and stabilizers were added to the Mark 13 torpedo, and these modifications significantly improved its launch characteristics. By the end of the war, when carrier torpedo planes sank the giant Japanese battleship *Yamato*, launch altitudes of 2,400 feet and launch speeds of 410 knots had

been achieved. Carrier-based torpedo planes conducted 1,287 torpedo attacks during World War II and scored 514 hits to achieve a very respectable 40% hit average. U.S. Navy torpedoes received an awful lot of bad publicity during early World War II, and there is no doubt that much of it was justified since the weapons were not ready for war. However, a look at the bottom line shows that these same weapons did an immense amount of damage and played a major role in winning the war at sea, although little is ever said to acknowledge this contribution. When there was a problem, the torpedo always bore the brunt of the criticism, but, when things went well, the launching platform got all the praise and the torpedo was ignored.

The U.S. Navy initiated a number of new conventional torpedo developments during the war, including the Marks 18, 19, and 20 torpedoes, but few of these new torpedoes were completed in time to use them during the war. The exception was the electric-powered Mark 18 torpedo, a copy of a captured German G7e torpedo that was built by the Westinghouse Corporation and released to the fleet in 1943. The Mark 18 was used by SUBPAC submarines to sink over 1 million tons of Japanese shipping during the latter part of the war.

In the early part of the war, the Royal Navy, faced with a torpedo shortage, had to use older, obsolete torpedoes, but once production increased, the 21-inch-diameter Mark VIII torpedo became their standard submarine weapon. The 21-inch-diameter Mark IX torpedo was used on surface ships, and the 18-inch-diameter Mark XII torpedo was used by aircraft. These three torpedoes were the workhorses of the British wartime efforts. These reliable weapons, all powered by B-cycle, four-cylinder, radial engines, sank several million tons of shipping during the war.

In the late 1930s, the Germans began to investigate the feasibility of developing an acoustic homing system for a torpedo. The early work, involving noise measurements to determine the noise of various ships and weapons, indicated that a useful acoustic homing system could be built using a quiet electric torpedo running at speeds below 25 knots. The goal of the German effort was to build an anti-escort acoustic homing torpedo that could be fired at escort vessels from a fully submerged submarine. Some G7e electric torpedoes, modified for slow-speed operation, were used as test beds, and extensive tests were conducted to evaluate various transducer concepts and acoustic system designs. The first acoustic homing torpedoes were issued to the U-boats, in very limited numbers, in January 1943.

The tactical advantage that these new weapons offered was largely offset by a countermeasure produced to reduce their effectiveness before they were even employed because Allied intelligence had learned about their existence before they were operational. The 20-knot T-4, or Falcon, was the first homing torpedo employed by the Germans. Only about 20 of these were used in combat before the more advanced 25-knot T-5, or Wren, torpedoes were introduced. The T-5, known to the Allies as the GNAT (German Naval Acoustic Torpedo), became the major German homing torpedo during World War II, and over 600 of them were used against escorts in the last 2 years of the war. The Germans continued to conduct a very active acoustic torpedo development program during the last 2 years of the war and experimented with a number of new concepts, including an active acoustic torpedo and a wire-guided operator-controlled passive acoustic homing torpedo. Fortunately, these advanced weapons were never mass produced or used in combat. The wire-guided T-10 Spinne, or Spider, torpedo was developed by the Germans late in the war as a shore-based coastal defense

weapon to defend against the anticipated Allied invasion. The Spinne employed new wire technology, and it was the first 20th-century torpedo to employ wire guidance. After the war, most of the major powers began to experiment with wire guidance systems for torpedoes.

The GNAT, with its 25-knot speed, was designed for use against ASW escort ships operating at speeds between 12 and 19 knots. The 12-knot speed was established as the lowest speed at which the ship's radiated noise level would still activate the torpedo's passive homing system. Although the Allies had the Foxer countermeasure available to neutralize the GNAT torpedo, the U-boats sank a number of escort vessels with these primitive weapons, thus demonstrating that a submerged submarine with a homing torpedo was a dangerous adversary. With the introduction of the GNAT homing torpedo, the hard-pressed U-boats managed to again make some successful attacks on convoys, but, during this same timeframe, another event was taking place that would significantly alter the role of the torpedo in naval warfare and dramatically change the way future ASW warfare was to be conducted.

In 1940, the U.S. Navy advised the prestigious National Defense Research Committee (NDRC) of an urgent need for acoustic torpedoes to counter the growing submarine threat. The NDRC, under James Conant, initiated a crash program that applied the best available talent from industry (Western Electric, Bell Labs, General Electric, etc.), universities (the Harvard Underwater Sound Laboratory, Columbia University, Massachusetts Institute of Technology, etc.), and government (Bureau of Ordnance, David Taylor Model Basin, etc.) to establish the feasibility of developing acoustic torpedoes. In addition, the British provided the results of their initial research work on acoustic torpedoes to the U.S. scientists. For security reasons, the new acoustic torpedoes were identified as mines, and parallel programs were initiated to develop a Mark 24 mine (torpedo) and a Mark 30 mine (torpedo), both to be launched from aircraft. Less than 3 weeks after the attack on Pearl Harbor, Western Electric proposed the development of an aircraft-launched acoustic homing torpedo for use against submerged submarines. General Electric and Bell Labs were given the task of developing and producing a new acoustic homing torpedo (codenamed "Fido" or "Proctor") that was officially designated as the Mark 24 mine (torpedo).

The new weapon was developed, built, and released to the fleet in less than 18 months. The first attacks using the Mark 24 against U-boats were made in May 1943; the Mark 24 sank its first U-boat, U-160, in July 1943. With the introduction of Fido, both the Germans and the Allies were employing acoustic homing torpedoes, or homing missiles, in the Battle of the Atlantic. The use, by both sides, of homing missiles in combat operations to sink both submarines and surface ships represented a significant new achievement in the history of warfare. The torpedo had the dubious honor of being the first of a new generation of homing weapons to be used in combat. The torpedo's escalation from a guided weapon to a homing weapon would significantly expand the role of the torpedo in modern naval warfare.

The air-dropped Mark 24 was a primitive weapon developed on a crash basis. It had a speed of only 12 knots and a modest, 92-pound warhead, but, for the first time, aircraft had a weapon that could be used to attack a fully submerged submarine. About 360 of these new weapons were used during World War II to conduct 204 attacks against U-boats. The Mark 24 acoustic torpedo sank 37 U-boats and seriously damaged an additional 18 U-boats in these attacks. With the introduction of

the Mark 24, a U-boat could no longer simply submerge and wait until the airplane went away because, when the airplane launched the Mark 24 at a potential target, the acoustic torpedo could track down and sink the submarine even when it was submerged. The Mark 24 torpedo more than doubled the effectiveness of aircraft attacks as the airplane became the U-boat's deadly adversary, not only during surface transits but also when the submarine was fully submerged.

Once the successful attacks against U-boats in the Atlantic had established the effectiveness of the new acoustic homing torpedoes, a modified version, designated the Mark 27 mine, was developed for use by U.S. submarines in the Pacific to attack Japanese escorts. About 106 of the Mark 27 Mod 0 torpedoes, introduced in late 1944, were fired during the final year of the war, with 33 hits (31%) resulting in 24 ships sunk and 9 ships damaged. When used against escorts, a single Mark 27 had about the same effectiveness as a salvo of conventional straight-running torpedoes, which clearly indicated that homing torpedoes were a step in the right direction. Late in the war, the Mark 28, a full-sized, 21-inch-diameter, 246-inch-long, homing torpedo with a 585-pound warhead, was developed, but the war ended just as this new weapon was being introduced. Only about 14 of them were fired by SUBPAC submarines.

The passive acoustic torpedoes used in World War II listened for noise from the target and then homed on the noise source. If the target was very quiet (for example, a submarine sitting on the bottom), the passive homing system was ineffective. To correct this shortcoming, the NDRC was also investigating active torpedo homing systems that operated much like the ASDIC gear that British destroyers used to locate submarines by transmitting active acoustic "pings" that bounced off the target's hull and disclosed its location. By mid-1944, a prototype torpedo with an active homing system had been successfully tested, and production of the Mark 32 Mod 0 torpedo was authorized. About 10 units had been completed when World War II ended. The program was then deactivated until 1951 when the Philco Company started volume production of the Mark 32 Mod 2 torpedo for use from aircraft and surface ships.

The existence and use of acoustic homing torpedoes was a closely held secret during the war, and the role of homing torpedoes in defeating the submarine threat is not mentioned or discussed by many naval historians because much of the information remained classified long after the war was over. This lack of information on the topic in published naval histories is unfortunate because few people appreciate the fact that substantial numbers of homing torpedoes were used during the war, by both sides. The lessons learned from experience with these weapons during the war provided a firm basis for postwar acoustic homing torpedo developments and the evolution of modern ASW systems.

Most of the conventional torpedoes used to sink millions of tons of shipping during World War II were direct descendants of the original Whitehead designs. These torpedoes, with very careful assembly, handling, and deployment, caused immense destruction. Since their dynamic performance could not be theoretically predicted, almost all of the major navies experienced serious problems getting their warshot torpedoes to perform effectively, and torpedoes were generally acknowledged to be "temperamental." These artisan torpedoes were brutally effective weapons, but the operational forces were unhappy with them because reliable operation could be achieved only under closely controlled conditions that sometimes severely constrained operational flexibility. The problem was

uniquely severe with aircraft-launched torpedoes because pilots were required to maintain a launch speed and altitude that exposed them to murderous anti-aircraft fire in order to launch a torpedo.

During World War II, immense amounts of money and technical effort were devoted to the development of new torpedoes. Both the Germans and the Americans succeeded in developing a new breed of acoustic homing torpedo and employed them operationally to sink enemy ships and submarines. This intense wartime effort to develop new and better torpedoes was conducted in a manner that still treated the torpedo as a monolith: that is, each new modification was treated as a new torpedo design since nobody could predict theoretically the impact that the modification would have on the torpedo's performance. For example, when a decision was made to simplify the U.S. Navy's Mark 14 torpedo from a multispeed torpedo to a single-speed weapon, the new version was designated a Mark 23 torpedo although it was just a simplified Mark 14 torpedo. When an electric control system was proposed to replace the pneumatic control system in the electric Mark 18 torpedo, the modified torpedo was redesignated as a Mark 19 torpedo.

As a consequence, the number of torpedo types under development or in production increased dramatically. By the end of the war, the U.S. Navy had about two dozen different torpedo types in the pipeline. Much of the technical effort focused on the development of new subsystems. The work on homing systems, propulsion systems, and control systems produced a generation of technical experts dedicated to the scientific design of torpedo subsystems. This technical specialization in torpedo subsystems, combined with new scientific facilities including water tunnels, wind tunnels, propulsion dynamometers, reaction stands, and tow tanks, was changing the way torpedoes were designed and developed. The era of the classic artisan torpedo designed by a single individual was drawing to a close, and the theoretical base and specialized facilities to support the scientific design of torpedoes was beginning to evolve.

It would take another decade for the transition to gain momentum, but the sophisticated new homing torpedoes required a mix of specialized talents to develop the various subsystems required. It was increasingly evident that the old Whitehead concept of monolithic torpedo designs created by single individuals was out of date and that future torpedo developments would require teams of engineers with specialized subsystem expertise and extensive facilities to support the design evolution.

The use of aircraft-dropped Mark 24 homing mines (torpedoes) against U-boats during World War II also provided early indications that the new homing torpedoes would lead to sophisticated ASW combat systems to counter the submarine threat. The aircraft were effective when they caught a submarine on the surface and therefore had a datum for dropping the torpedo when the submarine submerged. If the submarine was already submerged, the aircraft had no sensors capable of detecting its presence, so the submarine was relatively safe from aircraft attacks.

Then, the expendable sonobuoy with a radio link was developed so that the aircraft could listen for submerged submarines, and magnetic anomaly detection (MAD) gear was experimented with to detect submerged submarines. These primitive systems were the forerunners of follow-on developments that were to lead to increasingly sophisticated ASW systems employed by aircraft, submarines, and surface ships to conduct ASW warfare. The acoustic homing torpedo represented

the cutting edge of the new ASW systems, but increasingly sophisticated systems began to evolve to exploit the effectiveness of acoustic homing torpedoes in this new mission area.

By the end of World War II, there were clear indications that the era of the experimentally conceived and handcrafted artisan torpedo was drawing to a close, that future torpedo designs would be based on scientifically designed subsystems, and that the new homing torpedoes would become an integral part of the new ASW systems that were under development. The classic role for the anti-ship torpedo still existed, but employment of the new acoustic homing torpedo in ASW warfare was opening a new era.

Chapter 17

THE MODERN TORPEDO

At the end of World War II, the torpedo's transition from an experimental, artisan-built weapon to a scientifically designed weapon accelerated as the technology to support the analytic design of torpedoes became available. The first step of the transition occurred shortly after the war when the U.S. Department of Defense decreed that government arsenals would be phased out and new military hardware would be produced by private industry. The bureaucrats and politicians fought the decision, but, one by one, the various government-owned torpedo factories were shut down. In the 1960s, the U.S. Navy completed phasing out its torpedo manufacturing business by closing the Naval Ordnance Plant Forest Park, and all new torpedoes were produced by private industry.

The large inventory of torpedoes left over from the massive wartime production programs far exceeded inventory requirements, and there was little justification for the large-scale production of additional torpedoes in the immediate postwar period. Because there was no major naval surface fleet threat to counter, the fleet's mission shifted from surface warfare to a projection role, and conventional aircraft and surface ship torpedoes were removed from the inventory. Development efforts on conventional aircraft and surface ship torpedoes, such as the Marks 17, 25, and 31, were also phased out since there was no longer a fleet requirement for new conventional weapons to support these traditional missions.

The U.S. Navy continued the development of the submarine-launched Mark 16 anti-ship torpedo utilizing concentrated hydrogen peroxide (Navol) as an oxidant. The Navy built and issued to the fleet a limited number of these new wakeless, long-range torpedoes. However, the unstable hydrogen peroxide required continuous surveillance while the weapon was stored onboard the submarine, and the fleet was less than enthusiastic about the "tender loving care" that the Mark 16 torpedo required. The Mark 16 torpedo never received wide acceptance by the fleet, and the combat-proven Mark 14 torpedo remained the favored submarine-launched anti-ship torpedo for another two decades. Development efforts continued at a modest level on some of the other conventional submarine-launched anti-ship torpedoes, including the Marks 26, 36, and 42 torpedoes. As the cold war intensified, the emphasis shifted: homing torpedoes designed for ASW warfare received priority attention to counter the rapidly growing Russian submarine force.

To provide the submarine force with an interim ASW weapon, the submarine-launched Mark 27 Mod 0 passive homing torpedoes, which were successfully employed against Japanese escorts late in the war, were converted to the Mark 27 Mod 4 torpedo. The Mark 27 Mod 4 provided the submarine force with its first ASW homing torpedo as the submarine force became increasingly involved in the new ASW mission to counter the growing Soviet submarine force. Development of new homing torpedoes using active homing systems had been initiated just as World War II was ending, and a limited number of Mark 32 torpedoes had been built for surface ship use. The Ordnance Research Laboratory, working with General Electric, developed an improved Mark 32 Mod 2 active torpedo for use by aircraft and surface ships, and this torpedo went into volume production in 1950 at Philco Corporation in Philadelphia and at the Naval Ordnance Plant Forest Park. Just as the war was ending,

the U.S. Navy had initiated a torpedo development program with General Electric to develop the Mark 35 ASW torpedo that was to provide a universal torpedo for deployment from all platforms (submarines, surface ships, and aircraft). After the Mark 35 development started, it became evident that the size and weight restrictions for the aircraft mission were overly restrictive, so the Navy initiated a second, separate development, using the same technology, to develop a shortened version, designated the Mark 41 torpedo, for aircraft use.

During the immediate postwar period, Westinghouse, working with the Ordnance Research Laboratory Project 4 active/passive homing system, was developing the Mark 37 torpedo for use from submarines and surface ships. Since both the Mark 35 and the Mark 37 were new active homing torpedoes that would provide major advances in capabilities, the final selection of the weapon for fleet issue was a drawn-out, competitive process that included an extensive fleet evaluation to compare the performance of the two torpedoes under operational conditions. When the Navy selected the Mark 37 torpedo for fleet issue in the early 1950s, the submarine force got its first torpedo designed specifically for the new ASW mission.

Shortly after the Mark 37 torpedo entered the fleet, the Navy decided that the firing submarine should have the capability to control the torpedo during its run to the target, so a mid-course guidance system was needed. The Vitro Corporation modified a limited number of Mark 27 Mod 4 torpedoes to incorporate a mid-course wire guidance system employing the wire guidance technology developed by the Germans during World War II for their T-10 Spinne (Spider) torpedoes. These experimental units, redesignated as the Mark 39 torpedo, underwent fleet testing to evaluate the effectiveness of mid-course wire guidance. The task of developing a Mark 37 Mod 1 torpedo incorporating a mid-course command guidance system was assigned to the Naval Underwater Ordnance Station (NUOS) at Newport, formerly the Naval Torpedo Station, Newport. The improved wire-guided Mark 37 Mod 1 torpedo entered the fleet during the early 1960s. The Mark 37 Mod 1 torpedo contained a spool of single-conductor wire that paid out as the torpedo went through the water. The system added very little drag to the torpedo since the wire essentially stood still in the water. To allow the submarine to continue maneuvering after the torpedo was fired, a similar spool of wire was installed on the submarine to provide a link for transmitting guidance commands for course corrections to the torpedo after firing. The British, Swedish, Italian, and Germans also incorporated command wire guidance systems into their postwar torpedo designs.

The helicopter, introduced late in the war, showed considerable potential as an ASW platform because of its unique ability to hover. The U.S. Navy established a requirement for a new, small, lightweight ASW torpedo for use by helicopters and aircraft because early helicopters could not lift much weight. Responsibility for developing the new Mark 43 lightweight torpedo was assigned to the Naval Ordnance Test Station (NOTS) in California. The Mark 43 torpedo employed some of the technology developed in the Brush Corporation's work on a 10-inch-diameter, 265-pound, Mark 30 mine (torpedo) during early World War II. Mark 43 torpedoes were developed by the Brush Corporation and General Electric, and, after a technical evaluation, the 10-inch-diameter Brush torpedo was selected for volume production. The Mark 43, deployed from helicopters, fixed-wing aircraft, and surface ships and as a rocket-thrown standoff weapon was the Navy's first lightweight multiplatform ASW torpedo. The Mark 43 torpedo filled a real need for a lightweight ASW torpedo,

but there was concern about its modest 21-knot speed and its small warhead size. The Navy issued a requirement for a new higher-performance lightweight torpedo designated the EX-2 shortly after the Mark 43 torpedo entered the fleet. The EX-2 program included a competitive evaluation of two configurations and led to a second and higher-performance lightweight torpedo, powered by a seawater battery, that was designated the Mark 44. The U.S. Navy employed the Mark 44 torpedo from surface ships and aircraft for over a decade, and it is still used by a number of foreign navies.

During the 1950s, the U.S. Navy generated a requirement for a submarine-launched torpedo with a nuclear warhead and assigned technical direction of the program to develop the nuclear-warhead Mark 45 torpedo to the Applied Physics Laboratory (APL) at the University of Washington in Seattle, Washington. The torpedo development, conducted by the Westinghouse Corporation, produced a 19-inch-diameter, 225-inch-long, seawater battery-powered electric torpedo with wire guidance capability and a nuclear warhead. The Mark 45 nuclear anti-ship anti-submarine torpedo, which went into production at Westinghouse in 1959, was restricted to use by the U.S. Navy only.

The torpedo's transition from an artisan weapon to a scientific weapon was accelerated when the U.S. Navy initiated a program to develop undersea weapon subsystem technologies in the naval laboratories in the immediate postwar period. The Navy directed the various naval laboratories to conduct exploratory development programs in their areas of technical excellence (for example, warheads and exploders at the Naval Ordnance Laboratory, propulsion at the Naval Torpedo Station, and homing systems at the Ordnance Research Laboratory) to scientifically demonstrate the feasibility of new subsystem concepts. With the technical focus at the subsystem level, a detailed understanding of the various subsystem technologies began to evolve.

To support the scientific design of torpedoes and subsystems, the various naval laboratories built specialized facilities: towing tanks, water tunnels, and wind tunnels to study hydrodynamic drag, propulsor designs, and control system theory; propulsion facilities and reaction stands for research in new propulsion systems and propellants; and acoustic tanks for use in noise studies and transducer developments. To formulate the theoretical base required to support scientific designs, a close working relationship developed between the naval laboratories and major universities. During the 1950s, one by one, the "black magic" arts of torpedo design succumbed to basic scientific theory as the research efforts in hydrodynamics, propulsion, and control systems began to produce a firm foundation for the scientific design of torpedo subsystems.

During the 1960s, as computer simulations came into widespread use, the techniques required to theoretically predict component-level performance began to evolve; it was no longer necessary to conduct in-water tests in a complete torpedo to evaluate every new concept. Computer programs were developed to predict the performance of thermodynamic cycles, to design propellers and body shapes, and to predict control system dynamics and hydrodynamic responses. By the mid-1970s, with the advent of large mainframe computers and the massive digital computer programs developed for guided missiles and space vehicles, the technology existed to combine the various torpedo subsystems programs into larger, vehicle-level programs capable of predicting the performance of a complete torpedo running in the water. This new technology allowed engineers to design a complete torpedo and use computer modeling to accurately predict its in-water performance without building the torpedo or conducting a range run. The new large computers also provided the capability to

combine hardware and computer simulations in hybrid facilities (combining both digital and analog computers) that evaluated the in-water performance of actual subsystem hardware in a simulated computer environment. In addition, large-scale computer simulations provided scientists with the means to investigate the performance of new torpedoes in various tactical scenarios, to evaluate proposed design changes, and to predict the results of in-water evaluations.

Although the operational torpedoes were still products of the old artisan, experimental concept that required extensive in-water testing to verify performance, by the mid-1970s, the technology was in hand to design torpedoes scientifically and to predict their performance theoretically before they were ever put in the water. The era of the artisan-built experimental torpedoes was over; the torpedo, like guided missiles and space vehicles, had evolved into a modern, scientifically designed weapon. The specialized facilities, scientific theory, computer programs, and technical expertise to support the design of modern torpedoes were in place: the torpedo had completed its transition. Since the torpedo does not have any commercial applications, most of this expertise resides in naval laboratories. Further, since most of the work is highly classified, there has been little public discussion of the fact that the modern torpedo is vastly different from its World War II counterpart.

When the nuclear submarine became an operational reality in the 1950s, its high-performance and essentially unlimited submerged endurance posed a major challenge to torpedo designers. The modest performance of existing acoustic homing torpedoes severely limited their effectiveness against the emerging high-performance nuclear submarines; there was an urgent need for new high-performance ASW torpedoes to counter the emerging nuclear submarine threat.

To demonstrate the feasibility of high-performance ASW torpedoes, the U.S. Navy initiated a crash program in the mid-1950s to selectively employ the new subsystem technologies being developed in the naval laboratories to configure Research TORpedo Configuration (RETORC) test vehicles. The RETORC I program, conducted by the Naval Ordnance Test Station (NOTS) in Pasadena, California, concentrated on a feasibility demonstration of a new high-performance, multi-platform, lightweight ASW torpedo to replace the operational Mark 44 lightweight torpedo. The RETORC II program, conducted by the Ordnance Research Laboratory at Pennsylvania State University (ORL/PSU) and assisted by NUOS, Newport, for propulsion system development, mobile targets, and fire control systems, focused on a full-sized, submarine-launched torpedo to replace the currently operational Mark 37 Mod 1 submarine-launched ASW torpedo. During the RETORC program, the naval laboratories built experimental test vehicles to demonstrate that the high performance required to effectively counter the nuclear submarine threat could be achieved with the new torpedo technology under development.

For the RETORC I program, NOTS, with the assistance of the Bendix Corporation, rushed to completion their new REVEL homing system, which was then mated with a new solid-propellant combustion system driving a piston engine. The RETORC I torpedo development started in 1958, the configuration was selected in 1961, and, on completing fleet evaluation, full-scale production was initiated in 1966. The Aerojet General Corporation in California initially manufactured the new torpedo, designated the Mark 46 Mod 0. A new high-energy liquid monopropellant called Otto Fuel became available shortly after the Mark 46 Mod 0 entered production, so a new propulsion system was developed for the Mark 46 to incorporate this new monopropellant. The new configuration,

designated the Mark 46 Mod 1, was approved for fleet use in 1967. A competitive production contract was won by Minneapolis Honeywell, and thousands of these lightweight torpedoes were produced for the fleet. The Mark 46 Mod 1, an excellent ASW torpedo, was designed to effectively counter the first-generation nuclear submarine threat. It was widely used on U.S. Navy and Coast Guard surface ships equipped with multi-barrel Mark 32 torpedo tubes as a payload for the Antisubmarine Rocket (ASROC) surface ship ASW standoff weapon, as well as on land- and carrier-based ASW aircraft, and on ASW helicopters. The Mark 46 Mod 1 torpedo was also approved for foreign military sales (FMS) and was purchased by a number of foreign countries.

The RETORC II test vehicles, built by ORL/PSU with the assistance of NUOS, Newport, utilized the sophisticated new ORL Project 20 active/passive homing system, a wire-guided mid-course guidance system, a high-concentration Navol (hydrogen peroxide) combustion system driving a turbine-powered prime mover, and a pumpjet propulsor. The high-technology test vehicles, which demonstrated dramatic increases in both torpedo performance and homing system performance, provided the base for initiating a competitive development/production contract from private industry. In the final phase of the RETORC II program, the test vehicle propulsion systems were converted to use the newly developed monopropellant, Otto Fuel. The design goals for the RETORC II ASW submarine torpedo were established in 1956, laboratory construction of test vehicles was initiated in 1957, and in-water test vehicle tests demonstrating the concept feasibility were completed and the concept was firmed up by 1963. Just as the competitive development specification went out to bid, the Department of Defense changed its policy on procuring military hardware by directing that the Navy not dictate the weapon design but rather specify the desired performance and let the contractor propose how to design a weapon to provide the specified performance.

In spite of the freedom that the contractors had under the new ground rules, most of the contractors' proposals submitted to the Navy made maximum use of the technology that the Navy laboratories had developed and demonstrated. The Westinghouse Corporation won the development contract, and, in 1964, the Navy initiated development of the new torpedo, originally designated the EX 10 but redesignated as the Mark 48 Mod 0. Since the Mark 48 Mod 0 ASW torpedo's weight approached 2 tons, there were valid concerns that, even in an exercise configuration without a warhead, the high-speed Mark 48 could seriously damage or sink a submerged submarine if it hit it during an exercise run. To provide a means of evaluating the new torpedo's close-in homing performance, a concurrent program was initiated to develop a Mark 27 mobile target to simulate a submarine for close-in homing system runs. The new high-performance, wire-guided Mark 48 torpedo also required major modifications to the submarine to provide the extensive shipboard interfaces required to preset and wire guide the sophisticated new weapon. The Navy directed that a new submarine fire control system be developed as a separate development effort directed by NUOS.

Just as prototype Mark 48 Mod 0 torpedoes were released for production, an improved version of the Project 20 homing system with significantly improved countermeasure resistance became available. The Navy directed the Naval Ordnance Laboratory (NOL) in Silver Springs to conduct a separate, offline evaluation of the new homing panel. To evaluate the new Project 20-C homing system, NOL had test vehicles built by the Clevite Corporation. These test vehicles used the new Otto Fuel monopropellant to drive a swashplate piston engine similar to those used in the Mark 46

torpedoes. The new test vehicles indicated that gains in performance and packaging density would allow a significant increase in warhead size. In 1968, the Navy initiated a second engineering development for a Mark 48 Mod 1 torpedo based on the NOL/Clevite test vehicles. At the same time, the Navy decided that the Mark 48 torpedo should be a dual-purpose weapon that could be used against both submarines and surface ships. This new surface ship requirement generated a need for homing system modifications and a bigger warhead to sink large surface ships. To provide the desired dual-purpose capability, the Navy redirected the Mark 48 Mod 0 program with Westinghouse to provide an improved dual-purpose torpedo designated the Mark 48 Mod 2.

In 1970, the U.S. Navy conducted a “shoot out” in which operational submarines conducted an evaluation of the Mark 48 Mod 1 and Mark 48 Mod 2 torpedoes under realistic conditions. This side-by-side evaluation resulted in the selection of the Mark 48 Mod 1 torpedo, and the Gould Corporation (Clevite had been purchased by Gould) received a production contract. The Mark 48 Mod 1 torpedo became operational on U.S. Navy submarines in February 1972. When the Mark 46 Mod 1 lightweight and Mark 48 Mod 1 heavyweight torpedoes became operational, the U.S. Navy had effective ASW torpedoes to counter the Russian nuclear submarine threat.

After World War II, the British began to develop a submarine torpedo that utilized unstable high-concentration hydrogen peroxide as an oxidant. The torpedo, codenamed “Fancy,” incorporated a new high-test hydrogen peroxide propellant system in a modified World War II torpedo to provide greater range and speed. The Royal Navy completed the development during the mid-1950s. On June 16, 1955, a Fancy torpedo loaded in a tube on the submarine HMS *Sidon* in Portland Harbor exploded. The propellant system explosion sank the submarine and killed 13 crew members and injured 7. This disaster soured the Royal Navy on high-energy-density thermal propulsion systems for torpedoes; for the next two decades, the British favored less energetic, but quieter, electric propulsion systems for their new torpedo developments.

During World War II, the British developed the Mark XI, an electric torpedo based on a captured German G7e torpedo. The Mark XI torpedo never went into volume production, but, after the war, when the British started to develop a new ASW homing torpedo, the British selected the electric propulsion system for further development since it was inherently quieter. The performance of torpedo homing systems is degraded by the torpedo’s self-noise, so the quiet, but less energetic, electric propulsion system was a logical choice. The first new British homing torpedo developed, initiated in 1950, was the electric-powered Mark 20 torpedo designated as a submarine weapon for ASW missions. The Mark 20 torpedo, developed by the Admiralty Underwater Weapons Establishment (AUWE) in Portland, had passive homing, a speed of 20 knots, and a range of 12,000 yards. While the Mark 20 torpedo was still in development, the Royal Navy staff issued a requirement for an improved Mark 23 torpedo, which was basically a Mark 20 torpedo with a mid-course wire guidance capability added.

The British faced an urgent need for higher-performance ASW torpedoes as nuclear submarines became an operational reality in the late 1950s. The Royal Navy staff issued a requirement in 1959, based on AUWE developmental efforts, for a new weapon concept codenamed “Ongar.” This effort provided the technology base for generating a follow-on requirement for a new higher-performance Mark 24 submarine-launched ASW torpedo. The wire-guided Mark 23 torpedo was then redesignated

an interim weapon to be used for training the fleet in the use of wire guidance. The Mark 24 torpedo was to be a wire-guided, electric-powered torpedo with an active/passive homing system. A number of problems caused serious delays in the development program, and, in 1969, Parliament directed that the program be transferred from AUWE to industry. The Royal Navy then assigned responsibility for completing the Mark 24 torpedo development to Marconi Space and Electronics Ltd. By 1974, the first Mark 24 production prototypes were going to sea. To stimulate export sales of the weapon, the British renamed the Mark 24 torpedo, calling it the Tigerfish. The British did sell some Tigerfish torpedoes to the Brazilian Navy, but because of the long delays experienced during the development phase, the technology was out of date by the time it entered the fleet. To counter the second-generation nuclear submarine threat, the British faced the need for yet another submarine ASW torpedo.

Right after World War II, the British also addressed the need for new aircraft torpedoes. The Zonal flying torpedo was under development until 1949 when the British decided to cancel the Zonal program and concentrate their resources on the development of a new aircraft-delivered ASW homing torpedo. The Royal Navy issued a staff requirement in March 1950 for a new lightweight ASW torpedo, 18 inches in diameter by 8 feet long with a weight of 630 pounds. The new Mark 30 torpedo, initially codenamed "Dealer B," was electrically powered, had a passive homing system, and had a 25-knot speed with a 2,500-yard range. The development experienced a number of delays; by the time the Mark 30 was ready for fleet issue; it was approaching obsolescence. The Mark 30's modest performance limited its operational effectiveness; when the nuclear submarine made its appearance, the Mark 30's fate was sealed. The Mark 30 lightweight torpedo program was canceled in 1956, and the British purchased U.S. Navy Mark 43 and Mark 44 torpedoes for use with their new "Match" ASW helicopter. In an effort to reduce their export expenditures, the British decided to build an anglicized version of the U.S. Navy Mark 44 torpedo and designated it the RN Mark 31 torpedo. This joint effort, conducted by the Royal Navy Torpedo Factory and Plessy Ltd, experienced unanticipated delays during the conversion program; by the time the Mark 31 torpedo entered the fleet, it was outperformed by the newer nuclear submarines. As a stopgap measure, the British purchased U.S. Navy Mark 46 torpedoes.

The French also had access to the German torpedo homing technology developed during World War II, and they initiated development of acoustic homing torpedoes after the war. The French acoustic torpedo programs evolved along a path similar to that of the U.S. and British programs. The early French homing torpedoes utilized electric propulsion systems, to reduce the torpedo self-noise, and passive homing systems. They also developed larger (heavyweight) torpedoes for use on submarines and surface ships and smaller (lightweight) torpedoes for use by aircraft and helicopters. As the French continued to develop their own acoustic torpedo technology, they built improved models that incorporated active homing systems, wire guidance, thermal propulsion systems, and lightweight structures. The E-14 and E-15 torpedoes were 550 mm (21 inches) in diameter, full-sized, 25-knot torpedoes with passive acoustic homing systems. They were designed for use by submarines against surface ships and submarines. The French also built a series of L torpedoes utilizing lightweight materials; the L-3 and L-4 were 550-mm-diameter torpedoes with active homing systems, but they were shorter and considerably lighter than the E series torpedoes. The French Navy also developed a smaller 400-mm (16-inch)-diameter lightweight acoustic torpedo with an

active homing system. The French authorized the sale of some of these torpedoes as part of the weapons suite for the submarines, surface ships, and aircraft that the French offered for sale in the world foreign military sales (FMS) market.

In the immediate postwar period, the Germans, Japanese, and Italians were prohibited from developing new torpedoes, but, by the late 1950s, as these nations began to rearm, they also started developing new acoustic homing ASW torpedoes. The Japanese initially purchased some Mark 44 lightweight torpedoes from the U.S. to use in their ASW-equipped flying boats, but they also began to develop their own torpedoes. Since the Japanese have not indicated an interest in selling their new torpedoes in the international FMS market, there has been very little public information or publicity about post-World War II torpedo developments in Japan. The Italians have also been active in developing new acoustic torpedoes; it is reported that their newer ASW torpedoes include active homing systems and mid-course wire guidance systems. The Whitehead torpedo plant in Naples, Italy, purchased by an Italian arms conglomerate after World War I, still bears the name *Silurificio Whitehead* and has been periodically involved in developing new torpedoes for sales to foreign countries. This FMS effort provides an occasional public view of Italian torpedo technology, but, since Italy, like all of the other nations developing modern acoustic ASW torpedoes, treats the performance of new torpedoes as a highly classified topic, there is little information in the public domain about specific performance details of their new homing torpedoes.

The Germans became involved in the manufacture of small coastal U-boats with conventional diesel-electric propulsion systems for foreign military sales, and they developed a family of modern acoustic torpedoes that are offered on the FMS market for use in these submarines. In 1958, the German corporation AEG Telefunken resumed research and development on new modern acoustic homing torpedoes for the Federal Republic of Germany. This effort resulted in the Seal anti-ship torpedo and the Seeschlange ASW torpedo. These new torpedoes, which were offered for foreign military sales, included an active/passive homing system, mid-course wire guidance, and an electric propulsion system. In the late 1960s, an improved Special Surface Target torpedo (SST-4) for anti-ship use and a Surface and Underwater Target (SUT) torpedo for use against both surface and submarine targets were introduced. The Germans reported that, by 1979, over 55 submarines and 70 surface ships of various nations were using these new torpedoes and that over 700 of them had been produced.

By the mid-1970s, it was evident that the Soviets had made a massive national commitment to develop a large family of modern high-performance nuclear submarines. The torpedo community faced a severe challenge because new higher-performance ASW torpedoes were urgently required to counter the rapid emergence of new higher-performance Soviet nuclear submarines. It soon became clear that the classic warehouse concept—developing a new torpedo and building up a large static inventory of warehoused weapons for wartime use—was dead. To counter the rapidly emerging new threat submarines, the technical community had to initiate frequent updates of in-service torpedoes to maintain their operational effectiveness against the new higher-performance threat submarines as they became operational. In the evolving dynamic environment, the technical community became closely coupled to the operational forces, and fast-reaction weapon updates became commonplace. By the end of the 1970s, there were five modifications of the Mark 46 torpedo and four modifications

of the Mark 48 torpedo in the pipeline. The rapid technological advance in nuclear submarine designs was forcing the structured torpedo development cycle into a dynamic mode that required the frequent infusion of new technology into operational torpedoes to ensure their continued effectiveness. The rapid obsolescence of new technologies was also a problem. The replacement of vacuum tubes by transistors, transistors by integrated circuits, and integrated circuits by large-scale integrated circuits and microprocessor chips is just one example of a succession of new technologies that required a dynamic torpedo development cycle. The acceleration of modern technological change resulted in the establishment of new working relationships between the technical community and the operating forces as the scientists and engineers became directly involved in working with the fleet to extend the operational life of the billion-dollar operational torpedo inventories when new threat submarines suddenly became operational.

In the early 1980s, the torpedo designers faced a massive challenge when the new Soviet titanium-hulled *Alfa*-class submarine demonstrated speeds in excess of 40 knots and the Soviets launched the new *Typhoon*-class ballistic submarine, the world's largest submarine, with a displacement greater than World War I battleships. The need to counter the threat posed by the almost simultaneous introduction of the world's fastest and largest submarines generated an urgent requirement for major improvements in ASW torpedo performance. The British responded to the rapidly expanding Soviet threat with a major initiative in 1979 directing Marconi Ltd to develop a high-performance lightweight torpedo capable of countering the new Soviet submarines. The new seawater battery-powered Stingray torpedo trials were highly successful, demonstrating a major increase in performance, and the Stingray was rushed into production. The Stingray was the first modern torpedo to extensively employ microcomputers and software control, and it is the first of a new generation of computer-controlled torpedoes that will further increase the pressure for direct hands-on working relationships between the scientists and the fleet to exploit the full operational potential of software-controlled torpedoes.

The British also generated a new requirement—Naval Staff Requirement 7525—for a new heavyweight torpedo to succeed the Tigerfish torpedo. After an extended evaluation of both the Gould-manufactured Mark 48 torpedo used by the U.S. Navy and the concept proposed by Marconi that utilized the Stingray computer-based technology, the British decided to go with the Marconi design since it had more growth potential. The new heavyweight torpedo, designated Spearfish, has been under development since the early 1980s. It is a 21-inch diameter by 232-inch-long, wire-guided weapon that bears a strong physical similarity to the Tigerfish torpedo that it will replace. However, the new Spearfish will have a sophisticated computer-based homing system based on the Stingray technology, and the experimental vehicles have utilized Otto Fuel-powered, turbine-driven, thermal propulsion systems. It was reported that one of the experimental Spearfish torpedoes achieved a speed of 70 knots during a trial. Although specific performance information about the Spearfish is classified, it is evident that the British have a new heavyweight torpedo in development that will seriously challenge the newer Soviet submarines.

The U.S. Navy recognized that major initiatives were required to counter the emerging threat, in addition to the ongoing programs to modernize the Marks 46 and 48 torpedoes to extend their operational lives. In the early 1980s, the Navy initiated the development of an Advanced Light

Weight Torpedo (ALWT) to replace the Mark 46 torpedo and to provide the dramatic increases in performance required to counter the next-generation threat submarines. The Mark 48 torpedo, which had good dynamic performance (speed, range, and depth) against threat submarines, was scheduled for a new ADvanced CAPability (ADCAP) guidance and control system with a totally new computer-based, software-controlled homing and guidance system. The ALWT torpedo, which was redesignated the Mark 50 torpedo in the development phase, employs the latest high-technology subsystems; it is the first of a new generation of scientifically designed torpedoes. It will have a depth-insensitive, closed-cycle, thermal propulsion system, a new high-energy warhead design, and a computer-based, software-controlled, active/passive homing and guidance system. Although specific performance information is highly classified, it is reported that the Mark 50 will provide a dramatic increase in effectiveness over the currently operational Mark 46.

The new digital ADCAP homing and guidance system being developed for the Mark 48 torpedo shares the same basic microcomputer technology as the Mark 50 torpedo, but, since the Mark 48 torpedo is a larger submarine torpedo, the ADCAP will be a more sophisticated system employing a two-way wire guidance system that will share information about the target with the submarine during its run to the target. New computer-driven submarine Combat Control Systems (CCS), utilizing software based microprocessors, are also under development to automatically preset these new digital torpedoes and to provide pertinent real-time target information. The modern submarine torpedo has become an integral part of a sophisticated computer-based submarine weapon system in which the development of the shipboard CCS and the torpedo must be coordinated as one weapon system because, in the operational environment, they must share and exchange large amounts of computer information in a real-time combat environment. The ADCAP variant of the Mark 48 and the new CCS systems, which should be operational before 1990, offer a major increase in submarine combat effectiveness, but it will require a close working relationship between the scientific community and the operational forces to exploit the full potential of these new software-controlled, computer-based systems in the real-world operational environment.

Since World War II, the torpedo has made a major transition from an experimental, handmade, artisanal weapon into a sophisticated, scientifically designed, underwater guided missile under computer control that interfaces with equally sophisticated computer-driven combat control systems that can automatically preset and control the torpedo. The torpedo's demonstrated ability to sink ships by filling them with water remains unchanged, but how it accomplishes this mission is changing radically as it joins the front ranks of a new generation of high-technology, computer-controlled guided missiles. By the end of this century, the old artisanal torpedoes will all be replaced by the new generation of scientifically designed torpedoes that are currently under development. Robert Whitehead might be able to identify a modern torpedo from its external shape, but he would be at a complete loss if he opened one up and saw the maze of high-technology subsystems that a modern torpedo contains.

Chapter 18

IN SUMMARY

The decision to write this book examining the role of the torpedo in naval warfare was not motivated by any desire to glorify a weapon that has caused immense destruction and suffering. However, both the torpedo's significance as a tactical weapon and the considerable impact of torpedo warfare on naval and national strategies have been largely ignored by contemporary naval experts and historians, and it is not reasonable for a weapon that has caused such immense destruction to be treated as a nonfactor that doesn't warrant even a footnote mention in modern naval history. This book assumes an advocacy posture concerning the significance of the role of the torpedo in naval warfare, describes the evolution of the torpedo and its adaptation to multiple launching platforms, and documents the major effect this freakish new weapon has had on modern warfare. This has been undertaken as a "bottom up" examination that traces the invention of a radical new weapon of war and examines the impact that this new weapon had on naval theoreticians, on the design of warships, and on the evolution of new classes of warships specifically designed to exploit the torpedo's potential. The changes that torpedo warfare fostered in fleet doctrine, fleet composition, and tactical doctrine have also been traced to identify the torpedo's major influence on the evolution of modern navies and their employment. Finally, a review of the torpedo's role in two major wars demonstrates that the torpedo had a significant impact on tactical and strategic doctrine not only in the naval arena but also at the level of global conflict.

The torpedo is the first of a major new class of weapons called guided missiles. A weapon-oriented, bottom-up evaluation of the considerable evidence that has accumulated during the past century strongly suggests that Mr. Whitehead's automobile torpedo has in fact had a major impact on how modern wars are conducted and that it will continue to be a major player in any future conflict. When Whitehead developed the concept of a self-propelled underwater projectile, he created a new type of weapon. Wars had traditionally been fought by conducting pitched battles in which the objective was to kill the enemy and gain the advantage by destroying his ability to wage war. In support of this classic strategy, most weapon designs concentrated on killing individuals and ultimately winning the war by attrition. Whitehead's torpedo was not designed as a killing machine but as a weapon to destroy ships. This new weapon escalated the conflict to a new level since its objective was not to kill specific individuals but rather the destruction of complete warships and all those on-board.

The torpedo was awesomely effective in carrying out its ship destruction mission, and tens of thousands of people died because they were on ships—warships, passenger ships, merchant ships—destroyed by torpedoes. By the beginning of the 20th century, when the gyroscope was installed in the torpedo to control its course, the torpedo became the first of a new class of weapons that would become known as guided missiles. The tens of millions of tons of ships sunk in two world wars by torpedoes were in reality the victims of the first operational guided missiles used on a large scale in modern warfare. The fact that the torpedo was an underwater guided missile specifically designed to

destroy ships has been glossed over by most analysts and historians, and there is a distinct possibility that, by ignoring this basic fact, some significant lessons may have been overlooked.

The available evidence indicates that the torpedo, as the first operational guided missile, is the most destructive naval weapon ever conceived and that, over the past century, it has changed the whole concept of naval warfare. If the first simple guided missile employed in modern warfare could uproot the classic Mahanian concepts of sea control that formed the keystone of the British Empire and could have a major influence on how two major world wars were conducted, there may be important lessons to be learned. The torpedo's role in modern warfare may provide clues about the ongoing proliferation of guided missiles and their impact on future conflicts. When the immense destruction of ships, war materiel, and maritime personnel wrought by the world's first underwater guided missile in two world wars is added to the staggering losses of expensive high-technology aircraft and tanks to guided missiles during the 1973 Israeli-Egyptian war, the result is a disturbing indicator that the basic concept of conventional conflict may be in transition. Everyone is obsessed by the catastrophic results of a nuclear war, but there are also grim indications that any global conflict employing the widespread use of conventional (nonnuclear) guided missiles could also have a catastrophic impact that could drive modern civilization to the brink of extinction. If a simple guided missile like the torpedo could obliterate the Japanese merchant fleet and sink a major portion of the Japanese Imperial Fleet during World War II, it is difficult to comprehend the magnitude of the destruction that would result if modern guided missiles were used on a global scale in a major conflict between super powers.

Although the torpedo clearly ranks as the most destructive naval weapon ever conceived, it is difficult to quantify precisely the total destruction. Most statistical information about ship sinkings identify the ships or platforms involved in the action but frequently omit specific details about the weapons employed, which makes it difficult to quantify the total number of ships destroyed by torpedoes. The torpedo, employed by submarines, by carrier- and land-based aircraft, and by numerous surface ships types (ranging from PT boats to battleships), sank just about every conceivable type of ship from mighty battleships down to rusty fishing boats. Since most of the major naval powers used torpedoes extensively, this broad multiplatform, multinational usage further complicates the problem of accurately establishing the total damage wrought by the torpedo. Also, it is often difficult to credit the torpedo with a specific sinking because many ships were sunk by a combination of bombs, gunfire, and torpedoes. Additionally, when numbers are available, as in the case of submarine operations, there are frequently wide variations in the numbers reported, and it is impossible to know which claim is accurate.

For example, SUBPAC claimed that U.S. Navy submarines in the Pacific sank almost 10 million tons of Japanese ships during World War II, but, after the war, the Joint Army Navy Assessment Committee (JANAC) reduced this number to under 6 million tons. The actual tonnage sunk is somewhere between these two values, and it is not possible to resolve the discrepancy at this late date. There are similar discrepancies in the estimates of the total tonnage sunk by German U-boats during World Wars I and II. A conservative estimate of the total tonnage sunk by U-boat torpedoes exceeds 30 million tons, but the total approaches 50 million tons when the sinkings resulting from torpedo attacks launched from aircraft and surface ships are factored in. The total magnitude of this

destruction is difficult to comprehend because ships destroyed by torpedoes end up on the ocean bottom, and the opaque ocean depths effectively mask the total scope of the torpedo's awesome record. In the cases of the island nations of Great Britain and Japan that were critically dependent on shipping, the ship tonnage sunk by enemy torpedoes during World War II significantly exceeded the tonnage of their respective merchant fleets at the beginning of the war, and such massive losses had a major impact at the strategic level.

The torpedo is credited with destroying a grand total of over 10,000 ships. These ships, rotting on the ocean bottom, contained the industrial output, raw materials, and food of many nations, and it is impossible to estimate how many billions of dollars these losses represented or to define the total impact of these losses on World Wars I and II. Few people realize that the torpedo, although it was a uniquely naval weapon that operated only underwater, destroyed an impressive array of military hardware, including substantial numbers of tanks, trucks, and aircraft. The sinking of a single ship loaded with tanks or aircraft frequently resulted in greater war materiel losses than those suffered in major land battles and air raids. Who would believe that a single guided missile could destroy a squadron of airplanes? A single torpedo hit on a ship loaded with aircraft could wipe out a whole squadron before it ever got to the combat zone. The thousands of ships that the torpedoes sank contained millions of tons of valuable military hardware and raw materials. The loss of these immense quantities of materials had a profound impact on the war on both sides and the impact was felt both at the tactical and strategic levels.

At the tactical level, the torpedo had a major impact on naval warfare. It was a major factor in the demise of the battleship. Torpedo aircraft made the aircraft carrier a heavyweight capital ship. During World War II, the torpedo even played a role at the tactical level in land battles in North Africa and at Guadalcanal in the Pacific. In the Mediterranean, British and German submarines and aircraft made extensive use of torpedoes to interdict the supply lines to North Africa. The torpedoing of ships loaded with tanks and fuel often strongly influenced the results of the seesaw desert battles between Montgomery and Rommel. The torpedoing of a single Italian tanker loaded with fuel for Rommel's Africa Korps brought the German offensive to a standstill and permitted the British to go on the offensive. Similar tactics were used in the Pacific during the island-hopping campaign, as the Japanese and Americans conducted night torpedo attacks to interdict supplies urgently needed to conduct island campaigns such as Guadalcanal. In battles where seaborne supplies were essential, the torpedo frequently had a direct impact on land battles at the tactical level because it could be used so effectively to interdict such supplies and to isolate forward-deployed troops that required them.

The torpedo had its greatest impact at the strategic level when it was used by submarines to interdict seaborne supplies. In both World Wars I and II, German U-boats employing torpedo, warfare against merchant shipping came perilously close to completely severing all seaborne lifelines to Great Britain—merchant ships carrying the food, fuel, and raw materials that were critical to that island nation's ability to wage war. Conducting unrestricted torpedo attacks against unarmed merchant shipping might be considered barbaric, but the U-boats demonstrated dramatically the torpedo's brutal effectiveness as a weapon to destroy merchant ships. The large-scale loss of ships and their cargos had a devastating impact on Great Britain's war effort at the national level and actually influenced the conduct of the war at the strategic level. It took a massive multinational

effort to counter the U-boat threat during both World Wars. This effort required the dedicated commitment of resources many times greater than the number of German U-boat forces conducting the attacks. It also required a massive industrial commitment to replace the millions of tons of shipping sunk and to replace the valuable cargos.

When the Japanese attacked Pearl Harbor, the U.S. Navy initiated a campaign of unrestricted submarine warfare against the Japanese, and U.S. Navy Submarines in the Pacific (SUBPAC) ultimately achieved the goal that had eluded the Germans in the Atlantic in both World Wars. The Japanese started the war against the United States with approximately 6 million tons of merchant shipping, but, by 1945, the SUBPAC submarines had decimated the Japanese merchant fleet. The Japanese failed to make the massive commitment required to protect and replace their merchant ship losses; by 1944, their mighty war machine was grinding to a standstill because there were not enough bottoms available to import the raw materials and oil to keep the industrial machine operating.

Japan, as an island empire, was totally dependent on imported oil and raw materials to continue the conflict. As the SUBPAC submarine sinkings grew into millions of tons, severe shortages developed. By late 1944, the Japanese were facing a strategic defeat as their once mighty war machine started to collapse because of shortages of critically needed imported raw materials.

Although the atomic bomb is generally credited as the weapon that ended the war, it is well documented that the Japanese war machine was already in a state of collapse because of the loss of its merchant shipping capacity. The 6 million tons of Japanese shipping destroyed by SUBPAC submarines represented the equivalent of the Japanese merchant fleet before Pearl Harbor. When Japan was isolated from its overseas sources of raw materials, the stage was set for a strategic victory. Although torpedo warfare sank the ships and brought the enemy war machine to a standstill, the atomic bomb is credited as the weapon that ended the war, and most military historians still ignore the significance of the torpedo as a strategic weapon.

The torpedo is a weapon specifically designed to sink ships, regardless of ownership or contents. Torpedo warfare that did not discriminate between naval combatants and noncombatants gave the torpedo a reputation as a terrible weapon. It came to be hated and despised by almost all seafaring men. For example, in 1914, when the U-20 commanded by Kapitänleutnant Schwieger sank the passenger liner RMS *Lusitania* with a single torpedo, 1,198 people lost their lives. It is mind boggling to think that a single torpedo could kill over a thousand people, but this is exactly what happened. Since the casualties were noncombatants, including women and children, it is easy to understand how the torpedo became both a hated and feared weapon. Large numbers of innocent people lost their lives in unrestricted torpedo attacks against passenger and cargo ships, and these losses firmly established the torpedo's reputation as a terror weapon.

Even when it was used strictly against military targets, the immense destructive power of the torpedo made it a much feared weapon. The sinking of a single troopship could result in more casualties than a major land battle; the torpedoing of a hospital ship could cause the death of defenseless wounded soldiers and the nurses caring for them. On more than one occasion, the attacking submarine crew discovered belatedly that the torpedoed ship was carrying prisoners of war, who died when the ship sank. The torpedo, a brutally effective weapon for destroying ships, caused

the deaths of untold thousands of innocent people unfortunate enough to be aboard torpedoed ships. So, it is easy to understand how the torpedo became one of history's most despised weapons and the feared enemy of all seafaring men as it was employed with ruthless efficiency to sink ships of all types and sizes. The emotion is understandable, but it should not mask the basic fact that this immense suffering and destruction was caused by the first underwater guided missile specifically designed to destroy ships.

Even those naval professionals who employed the torpedo had a natural dislike for the weapon. Because the torpedo was a weapon designed to be used at relatively close ranges, making torpedo attacks against enemy ships was a high-risk operation, and life expectancy for the attackers was short in combat operations. Further, since it was a close-in weapon, the platforms that delivered the torpedoes took a terrible beating while prosecuting torpedo attacks. The high losses suffered by the air, surface, and submarine platforms delivering torpedoes did not endear the torpedo to naval professionals serving on these platforms.

Destroyers and PT boats took a fearful pounding when they closed to deliver torpedo attacks against major warships. Destroyers were exposed to murderous close-range fire from battleship main batteries while conducting torpedo attacks against the battle line. Frequently, the "thin-skinned" destroyers suffered massive damage or sank during massed torpedo attacks, but, time after time, the torpedo attacks caused the battle line to break off engagements. Ultimately, the role of the battleship as a major combatant was questioned. However, the destroyers and their crews paid a high price to deliver the torpedoes since both the ships and crews were considered expendable when the order was given to attack the battle line.

The same was true with the fragile high-speed torpedo boats. Their torpedoes could inflict massive damage, and their attacks were much feared. Still, for a crew in a thin-skinned wooden torpedo boat loaded with high-octane gasoline, it was a suicidal task to conduct a close-in torpedo attack against an alerted major combatant. The small, fast, torpedo-carrying surface combatants, such as the DDs, DEs and PTs, sealed the fate of the mighty battleships and changed both tactical and strategic naval doctrine. However, these small ships and the brave men who operated them paid a high price to deliver their torpedoes. It is easy to understand how they could come to despise the torpedo given that they had to be willing to sacrifice their lives every time they conducted a torpedo attack.

Much the same situation existed with aircraft-delivered torpedoes. They were immensely effective, but conducting aircraft torpedo attacks was a very high-risk occupation that required brave men with iron nerves. The aircraft-delivered torpedo had a major effect on the outcome of many battles in World War II. Further, it was a key factor in establishing the aircraft carrier as a major combatant since the aircraft-delivered torpedo provided the heavyweight punch needed to counter the battleship in fleet engagements. The attacks at Pearl Harbor and Taranto, along with the sinking of the battleships *Yamato*, *Bismarck*, *Repulse*, and *Prince of Wales*, demonstrated dramatically that aircraft-delivered torpedoes were a major new weapon.

However, the casualty lists also made it all too evident that pilots of combat torpedo planes had a short life expectancy. In the Battle of Midway, Torpedo Squadron 8 lost every single plane while

attacking the Japanese carriers, and only one man from the squadron, Ensign George Gay, survived the attack. Japanese torpedo planes suffered the highest casualties at Pearl Harbor; British *Swordfish* torpedo planes were cut to ribbons by German fighter planes and ship anti-aircraft guns during the German warships' famous dash up the English Channel; and torpedo planes of all nations experienced heavy casualties to achieve successful attacks.

It took brave and dedicated men to fly the slow, cumbersome torpedo planes straight and level against murderous anti-aircraft fire to release a torpedo at point-blank range. As demonstrated at Pearl Harbor, aircraft-delivered torpedoes could inflict staggering damage, but, to execute such attacks successfully, a near-suicidal dedication was required of the pilots to press home the attacks. Flying torpedo planes was a very risky service assignment, and the pilots had little affection for the temperamental torpedo that required them to put their lives at risk each time one was employed.

A torpedo fired from a submarine inflicted the greatest damage of all, but, to achieve this success, the submariners had to pay the highest price in terms of casualties. The personnel in the U.S. Navy submarine force in World War II (including staff and support personnel) consisted of approximately 50,000 officers and men, or about 1.6% of the total Navy complement. However, the submarine force accounted for over 55% of Japan's maritime losses, a truly remarkable feat for such a small force. To accomplish this, 52 submarines were lost, and, of the 16,000 men who participated in war patrols, approximately 3,500, or almost 22%, lost their lives. This casualty rate of 22%, the highest experienced by any branch of the U.S. military services, again clearly demonstrated that delivering torpedoes was a high-risk business. However, the Japanese merchant marine, which began the war with 122,000 personnel, suffered 116,000 casualties during the war, including 27,000 men killed in action. The majority of these casualties were caused by torpedoes fired from submarines

In World War I, German U-boats sank 5,000 ships totaling over 11 million tons, and an estimated 25,000 noncombatants lost their lives during these attacks. The Germans lost 178 submarines and about 5,000 officers and men. In World War II, the U-boats sank over 2,600 merchant ships, for a total of 14 million tons, plus 175 men-of-war. The cost was high: the Germans lost 783 submarines and 32,000 officers and men out of a seagoing strength of 39,000. This 80% casualty rate surely has to be the highest ever experienced by a major branch of any armed force; it is a tribute to the U-boat sailors that the 7,000 survivors continued to function as an effective combat force right to the bitter end. These men demonstrated their ability to use torpedoes to cause destruction on a grand scale, and they also demonstrated a near-suicidal willingness to sacrifice their lives to get the job done.

The high losses suffered by the platforms that employed torpedoes in combat operations should not be ignored, but it should also be recognized that these same platforms caused destruction far out of proportion to their numbers. At Pearl Harbor, the Japanese torpedo planes were the fewest in number and suffered the highest losses, but their torpedoes caused by far the greatest damage. Although the U.S. Navy submarine force, representing less than 2% of the naval forces, suffered the highest casualty rate of any U.S. military organization in World War II, the SUBPAC submarines inflicted by far the greatest amount of damage. In fact, when the number of casualties is considered relative to the damage done, it is quite low. The data suggest that, regardless of the platform employed, torpedo warfare, employing the torpedo as the first guided missile, inflicted immense damage. At bottom, the issue is the torpedo's major impact on naval warfare.

The torpedo is a guided, or homing, missile, that is designed to sink ships, and it has been proven to be immensely effective. In the process of destroying over 10,000 ships, the torpedo, a completely merciless destroyer of ships, was also responsible for untold death and suffering. There was little chance of surviving a winter sinking in the frigid North Atlantic, and many innocent people suffered terrible deaths during torpedo attacks. Since large troop transports and naval capital ships carried several thousand people, the number of casualties sometimes numbered in the thousands when a major ship was torpedoed. For example, in a single 6-week period late in World War II, SUBPAC submarines conducting torpedo attacks against Japanese shipping accidentally killed or drowned over 4,000 Allied POWs being transported on Japanese ships.

In fact, the torpedo knows no loyalty: once fired, it poses a danger to all ships within its range. There are numerous cases in which malfunctioning exercise torpedoes circled back and hit the vessel from which they were fired. The U.S. Navy identified the *Tullibee* and *Tang*, both SUBPAC submarines, as being sunk by their own torpedoes during World War II. The *Tang* was sunk by a Mark 18 electric torpedo fired from one of its stern tubes. Evidently, the torpedo's delicate steering motor jammed, causing the torpedo to circle back and hit the *Tang* in the stern and causing it to sink. It is understandable that the brave men who served aboard ships exposed to torpedo attacks would come to despise the torpedo; even those who employed torpedoes disliked them. Few naval professionals have had much to say about torpedoes, and what has been written generally consists of critical comments about the torpedo's poor performance or the need for bigger warheads, higher speeds, longer ranges, or better reliability.

It seems that everybody hates the torpedo, and it is common practice to blame all the problems in torpedo warfare on the torpedo itself. Aircraft, submarines, destroyers, destroyer escorts, PT boats, and their crews got the commendations and medals for sinking ships, but torpedoes got all the "gigs" when there were problems. When reading contemporary naval histories, one might wonder how the unreliable, temperamental torpedo with its major deficiencies ever got to be the most destructive naval weapon of all time: it is somewhat of a mystery.

Torpedoes were the first guided weapons to be extensively used in naval combat and they were complex, temperamental, artisan-built weapons that were plagued with problems. Most senior naval professionals, both military and civilian, tend to be self-professed torpedo experts. When the temperamental torpedoes malfunctioned, the designers and builders of early torpedoes were subjected to some vicious investigations by these alleged experts. During World War I, when British submarine torpedoes malfunctioned, the First Sea Lord Admiral Sir "Jackie" Fisher was incensed and threatened to have the senior torpedo officers hung or shot. During the Norwegian campaign in early World War II, a sharp increase in German torpedo malfunctions caused Admiral Dönitz, head of the German U-boat force, to initiate a major investigation of the German torpedo industry. In the Pacific, SUBPAC submarines experienced difficulties with their Mark 14 torpedoes early in the war, which resulted in a prolonged bitter exchange between SUBPAC, the Bureau of Ordnance, and the Naval Torpedo Station in Newport about correcting the deficiencies. The Mark 14 torpedo debacle is covered in great detail in most comprehensive histories of U.S. Navy operations in World War II and provides a classic case of "torpedo experts" in action.

The torpedoes used in World War II were direct descendants of Whitehead's early hand-built experimental torpedoes. Although they were primitive by today's standards, these torpedoes were designed and built primarily by extremely talented artisans. At that time, there was scant scientific information to support the torpedo's design evolution, so design improvements required extensive experimentation and testing (proofing). Since no one was sure why the torpedo acted the way it did and no one could theoretically predict the results of design changes, the torpedo was considered to be both temperamental and unreliable. During the interwar years, the average budget for torpedo research at the U.S. Navy's only torpedo activity, NTS Newport, was approximately \$40,000 per year, and this pittance was totally inadequate to support the level of technical effort necessary to develop the hydrodynamic and control system theory required to design torpedoes scientifically. There was essentially no sound theoretical base to support the experimental, empirical data, so the dynamic performance of the torpedoes was established by extensive range testing and proofing of exercise torpedoes. There were all kinds of problems and alleged experts to solve them. Because the problems had to be solved experimentally, the lack of a sound scientific basis for analyzing these problems made resolving them a nightmare.

If World War II had been fought on the Naval Torpedo Station torpedo range at Newport with exercise torpedoes, the torpedoes would have performed magnificently. However, the war was fought in the Pacific Ocean with heavier warshot torpedoes that had untested exploders, which provided the ingredients for disaster. The NTS artisans were absolutely convinced that their (exercise) torpedoes met the specifications, and the SUBPAC submariners were equally positive that their (warshot) torpedoes were malfunctioning. The U.S. Navy paid dearly in World War II for the false economy of not conducting live warshot tests during the low-budget prewar years to verify the performance of warshot-configured torpedoes. Because the performance variations could not be theoretically predicted or verified, many important targets escaped because of faulty torpedoes. Submarines were put at risk unnecessarily, and much ill will was generated between the operating forces and the technical community. Not even the so-called "experts" recognized clearly that the artisan-built torpedo's performance, verified by experimental data obtained by in-water (proof) testing of each individual torpedo in a positively buoyant exercise configuration, provided no firm theoretical basis for predicting performance variations that would result when the torpedoes were fired in a heavier warshot configuration.

It was not until World War II that technical efforts were initiated to investigate theoretically the technologies of the subsystems required to build a torpedo. The massive, high-priority effort initiated by the National Defense Research Council during World War II to develop an acoustic homing torpedo applied the best academic and industrial research talents to the development of torpedoes. A scientific approach was applied to the design of torpedoes. It took another 25 years to complete the development of the theoretical basis for all of the torpedo subsystem technologies. By the 1970s, torpedo technology had progressed to the point at which, with the aid of computers, it was possible to design a torpedo analytically and to predict its dynamic performance accurately.

The modern torpedo has evolved into a scientifically designed, guided homing weapon that is equivalent in every way to the host of airborne guided weapons developed since World War II. In its first century of existence, this primitive, artisan-built weapon, deployed from all types of naval

platforms to sink just about every type of ship, did an awesome amount of damage and had a major impact on naval warfare. When the torpedo became the first homing missile during World War II, its utilization escalated to a new level. Late in the war, the new ASW weapons demonstrated that fully submerged submarines hiding in the depths of the ocean could be targeted and sunk by homing torpedoes. These same homing torpedoes could also be deployed from totally submerged submarines to successfully attack and sink surface ships.

A nuclear submarine equipped with modern homing torpedoes in an integrated combat system is vastly superior to the submarines that caused such havoc during World Wars I and II. The high-performance nuclear submarines armed with modern acoustic homing torpedoes are capable of inflicting immense damage to naval and merchant shipping. In any future war at sea, the nuclear attack submarine, with its homing torpedoes, will be a major player.

Paradoxically, the same ASW homing torpedo that makes the modern submarine such an impressive threat is also the only nonnuclear weapon available to counter the submarine threat. Since World War II, the United States has spent billions of dollars to build submarine, surface ship, and aircraft ASW platforms to counter the ever-increasing Russian submarine threat, and all of these ASW systems share a common weapon for attack—the homing torpedo. A homing torpedo launched from an enemy submarine also poses a major threat, for which the only counter is the ASW homing torpedo. The torpedo has evolved to the point at which it is both the threat and the counter to the threat. Perhaps this indicates a trend in modern warfare, as guided weapons come into common use.

In an era when the world teeters on the brink of nuclear war, the humble torpedo also plays a significant role in maintaining the delicate nuclear balance. The American and Russian nuclear-powered, ballistic missile submarines, hidden in the opaque ocean depths, represent an awesome counter-value strike force that has a tremendous stabilizing effect on nuclear strategies because they are extremely difficult to detect and destroy. The ballistic missile submarines on patrol in deep ocean waters have only one type of weapon—the torpedo—for defense, and the ASW homing torpedo is also the only nonnuclear weapon capable of destroying the ballistic missile submarines and their nuclear payload. Again, the modern acoustic homing torpedo has become a key factor in the endless effort to counter the threat of nuclear annihilation because it is the only weapon available to counter the ballistic missile submarine threat.

Although the torpedo has not won any popularity contests with naval professionals or any accolades from naval historians, the primitive and cantankerous torpedo earned its campaign ribbons and battle stars in combat in the real world, where it was clearly established as the premier naval weapon of the 20th century. As the first guided weapon used on a large scale in modern warfare, the torpedo had a major impact on the evolution of naval platforms, on the composition of naval fleets, on naval tactics, and on naval strategy. Although the torpedo had a profound impact on naval warfare, this weapon has lacked an advocate for its rightful place in naval history because of the negative emotions aroused by the immense suffering that it caused. In fact, it would almost seem that there has been a conspiracy to ignore the role of the torpedo in 20th-century naval warfare, which is unfortunate since the torpedo has played a key role in so many major events.

The thousands of ships with torpedo holes in them that are rotting at the bottom of the ocean provide ample evidence that the torpedo was effective as the first guided missile. With the development and deployment of acoustic homing torpedoes in World War II, the torpedo became the first homing weapon used in combat. As scientific research and technological advances have made its design and deployment increasingly sophisticated in its second century, the torpedo continues to play a major role in naval warfare. The acoustic homing torpedo is the weapon that makes the nuclear attack submarine such a potent threat; it also provides the only nonnuclear ASW weapon available to counter the nuclear attack submarine threat. The billions of dollars' worth of ASW submarines, surface ships, and aircraft are totally dependent on the ASW acoustic homing torpedo to successfully prosecute their missions, and the acoustic homing torpedo is the only weapon available to both defend ballistic missile submarines and attack them. Yet, the role of the torpedo has been largely ignored in military histories and the naval analyses in the open literature. There has been little discussion about the torpedo's evolution into an underwater homing missile or the significance of this potent new weapon in the quest for naval supremacy and control of the seas.

In summary, although the torpedo's role in naval warfare has been largely ignored, there is a valid need to reexamine the lessons learned from the historical experience with torpedo warfare. Naval analysis should take into account the full effect of the evolution of the torpedo on modern naval warfare at both the tactical and strategic levels. The significant role that this remarkable weapon played in 20th-century naval warfare—in both World Wars—must be accurately reported and analyzed so that both the successes and the problems can be turned into lessons for future designs and operations. Since the modern acoustic homing torpedo could have a major bearing on the outcome of any future war at sea, there is an equally pressing need to examine objectively the role of the torpedo in modern nuclear submarine warfare—for both fast attack and ballistic missile submarines—and to assess accurately the roles that the torpedo will play in any future conflict. The record clearly indicates that the torpedo will continue to be a major threat to sea lines of communication in any future global conflict. Given the increasing dependency on imported oil and raw materials, the strategic impact will be greater than ever.

Whitehead's automobile torpedo was demonstrated to be one of the great naval weapons of all time. After over a century of development and deployment in combat, the torpedo's role in naval warfare should start to appear in more accurate historical perspective in contemporary naval writings.



Torpedoes and Their Impact on Naval Warfare recounts the history of the invention and development of the torpedo and its role in 19th and 20th century warfare. The author, Arthur E. Burke, researched and wrote this history in retirement after a distinguished career in torpedo research and development at the Naval Underwater Systems Center. His book is issued by the Naval Undersea Warfare Center Division, Newport as an educational and reference resource.