

DAMN THE TORPEDOES: THE HISTORY OF SCIENCE
AND UNDERSEA WARFARE
IN WORLD WAR II

by

Gary Lee Sims

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DEDICATION

This dissertation is dedicated to two World War II Navy men from my youth, Ward Franklin Sims, and Donald Schwab, crewmates and friends who served on the battleship USS *North Carolina*. Young men like these two volunteered to fight for their country before their adult lives began. There were many other young men like these two who chose to serve on the most dangerous duty of the war with the U.S. Navy Submarine Service. The Submarine Service was the smallest, most elite section of the U.S. Navy and sank more enemy ships than any other group of warships involved in the war. But there was a price they paid. Fifty-two submarines, three hundred seventy-four officers and 3,131 submariners perished during the war. This dissertation is dedicated to them, as well.

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ABSTRACT

After the attack on Pearl Harbor, the U.S. Navy Submarine Service had the submarines to, if not repel the attack on the Philippines, at least slow the Japanese Navy's disbursement of troops and material on Luzon. They could not because of defective torpedoes. This book examines the US Navy's submarine service's torpedo controversy during World War II from December 7th 1941 through the resolution of the torpedo problems in October, 1943. By investigating War Patrol Reports, Action Reports and other official documents including personal and professional communiques between combat theater, command at Pearl Harbor and Bureau of Ordnance (BuOrd) in Washington, D.C., this work shows how the Mark XIV/VI torpedo was a highly-technical, high-risk invention for war. Failures occur in high-tech, high-risk systems such as this. The U.S. Navy should have been expected and prepared for these failures but they did not. To make matters worse, command in Washington went into denial that there even was a problem. This abstract explains that denial of the problem for almost two years by BuOrd and Naval Command in Washington D.C. was inevitable. Using modern theories of the construction of knowledge, their repudiation of the problem can be predicted response by response.

To support my conclusions, I rely on work of historians and sociologists such as Charles Perrow, Tim Bedford and Roger Cooke about high-risk technologies as a framework to view the science and technology behind the Mark XIV/VI torpedo. Supporting my conclusions that Naval Command's denial of the problem was inevitable, I apply theories of knowledge construction originating with sociologists of science such as Thomas Kuhn, Bruno Latour and David Bloor. Former submarine commanders, naval historians and those familiar with the torpedo controversy have long asked how this could have happened at all and why it took so long to rectify the problem. This book answers those questions.

INTRODUCTION

The USS *Sargo*

On the early afternoon of December 8, 1941, the U.S. fleet submarine USS *Sargo* made her way out of Manila Harbor on her first war patrol. A signal had come into Asiatic Naval Command at 3:00 am that morning stating, “JAPAN STARTED HOSTILITIES. GOVERN YOURSELVES ACCORDINGLY.”¹ In command of the *Sargo* was Lieutenant Commander Tyrell D. Jacobs, a 1927 Naval Academy graduate with a Master’s degree in Ordnance Engineering. Well respected by his crew and a proven tactician, Jacobs had earned command of one of the more modern Fleet Boats.² The *Sargo* was a state of the art piece of engineering and construction, carrying one of the most sophisticated weapons of the war, the MK XIV torpedo armed with the top-secret MK VI magnetic influenced exploder.

After a stop at Marivales Bay, the *Sargo* continued its patrol through the Palawan passage and on to their assigned area off the coast of Indochina.³ The evening after arriving on station an enlisted man, posted as a top lookout, spotted a Japanese merchant

¹ Joel Ira Holwit, *Execute Against Japan: The US Decision to Conduct Unrestricted Submarine Warfare* (College Station: Texas A&M University Press, 2009), 146.

² Captain Tyrell D. Jacobs, United States Navy, Naval History Division, Navy Biographies, Section OI-450, 15, November 1955. (Hereafter cited as Navy Biographies) Clay Blair Jr. Papers, American Heritage Center, University of Wyoming, Box 68, File 3 (Hereafter cited as Blair Papers).

³ First War Patrol of the USS *Sargo* (SS-188), Filed January 24, 1942. Naval Publication and Printing Service Office, NPPSO-Naval District Washington Microfilm (Hereafter cited as NPPSO) Reel E-108, Roll AR-2, Record Group 75. Sourced at United States Naval Undersea Museum, Keyport, Washington. (Hereafter cited as Keyport) All information concerning this *Sargo* patrol comes from this report.

ship. “Battle stations, torpedo” was sounded.⁴ This was the moment for which the crew of the *Sargo* had trained for months.

Although the MK VI could be set as a contact exploder, it was specifically fashioned for magnetic detonation. The magnetic influence exploder was designed to sense the steel of the target ship and was engineered to explode *underneath* the target, thereby creating the fluid dynamics to break the back of the ship. Jacobs set the depth at fifteen feet. In scores of peacetime training runs, the *Sargo* had participated in and excelled at just this type of setup. When the Torpedo Data Officer told Jacobs that he had a solution to the firing problem, Jacobs fired a single torpedo at the target.

The torpedo steamed towards the target as Jacobs monitored his watch. Eighteen seconds after the torpedo left the tube the crew heard an explosion. The crew cheered but Jacobs knew the truth. The torpedo had exploded prematurely. He looked through his periscope and saw that the ship was turning, making its escape. After the attack Jacobs and the crew analyzed the problem and concluded that the magnetic feature on the exploder was defective. He ordered the magnetic feature disabled on the rest of his torpedoes and set the exploders to contact.

The *Sargo* continued its patrol, working north off the coast. On December 24, it encountered two cargo ships sailing together steaming in a column. Just after noon Jacobs fired two torpedoes at the lead ship and one at the ship following. Both torpedoes were set for contact detonation. Firing the torpedoes affected the trim of the submarine and

⁴ I.J. Galantin, *Take Her Deep! A Submarine Against Japan in World War Two* (New York: Pocket, 1987), 3. As opposed to a surface attack which would be ‘Battle Stations, Guns.’ This was a submarine’s call to General Quarters, or for all hands man to man their battle stations.

before the diving officer could compensate the trim tanks, the *Sargo* breached the surface. The tankers saw the submarine and began to turn away. Regardless, the three torpedoes should have hit but no explosions occurred. Not one to surrender to disappointment, Jacobs maneuvered his submarine and shot two more torpedoes from his stern torpedo tubes. Still no explosions.

After being chased by a Japanese Amagiri Class Destroyer, Jacobs and officers met to discuss the last enemy contacts and firings. Six torpedoes had been fired, resulting in one explosion and five misses. On December 27, the *Sargo* sighted another pair of merchant ships. They moved into firing position closing 900 feet, setting the torpedoes to a shallow, ten-foot depth. The *Sargo* fired two stern shots and waited. Since this was close range, the crew did not have long to wait. No explosions. The target vessels continued cruising unaware of the submarine's presence.

Within the hour, two more targets presented themselves. These were Japanese freighters. Jacobs moved into firing position, double checking every aspect of his approach, and fired a two-torpedo spread at each freighter. These torpedoes missed, just as the others. In analyzing the attack Jacobs thought the torpedoes were running deeper than set. He ordered the torpedomen to set torpedoes to run at a shallower setting. On January 4, 1942, the *Sargo* met another target. Again, no explosions.

The mission of the Japanese merchant ships, and the troop ships sailing from Cam Ranh as well as Hainan, was to supply the Japanese war machine landing on the Philippine Island of Luzon for the push down the Bataan Peninsula. The Japanese soldiers who were landing in the Philippines would overwhelm the U.S. Army Forces in

the Far East (USAFFE, the combined force of the United States and Filipino armies) in the upcoming battle for the Philippines. The USAFFE was not equipped or trained adequately to fend off the military machine of the Japanese. Because of this lack of support and training, the USAFFE would lose thousands of men to warfare, disease and Imprisonment. In addition, the U.S. Navy was paralyzed by the attacks at Pearl Harbor. The only unscathed military force left in the Far East was the U.S. submarine force.⁵

In comparison to the beleaguered American and Filipino armies, the submariners were well trained and well equipped with a full complement of weapons, ammunition, and supplies. Their training was so rigorous and complete that the submarine force was considered an elite arm of the U.S. Navy. But, even with perfect approaches and close range shots, the *Sargo* was unsuccessful in their first combat tour against the Japanese. To win this war, the undersea weaponry of the U.S. Navy would need to improve.

The story of the *Sargo* was common for dozens of U.S. Navy submarines that served in the Pacific during the first year and a half of World War II. The main armament of the Navy's Fleet Submarines was the MK XIV torpedo, armed with the top-secret MK VI magnetic influenced exploder (MK XIV/VI). This torpedo and exploder did not work with any consistency. In fact, during the first year of the war the torpedo failed much more than it worked properly. Report after report degrees of these failures, written by men like Tyrell Jacobs, Annapolis graduates, almost all of them with

⁵ Michael Norman and Elizabeth M. Norman, *Tears in the Darkness: The Story of the Bataan Death March and Its Aftermath* (New York: Farrar, Straus and Giroux, 2009), 3.

engineering degrees, alerted Pearl Harbor that there were issues with the MK XIV/VI torpedo.

These reports went to Naval Command and the Bureau of Ordnance in Washington, D.C. and from there to the manufacturing site of the torpedoes, the Newport Torpedo Station at Newport, Rhode Island. Reaction from Pearl Harbor, Washington, and Newport was not what anyone in the Pacific had expected. Instead of responding quickly to resolve the problem with the torpedoes and exploders, these organizations denied that a problem existed at all. The official position was that any problem with torpedoes not sinking ships had nothing to do with the armament. Rather, the crews using them were to blame.

Thesis and Organization

Given the importance of undersea warfare, all that had gone into the development of submarines and torpedoes (Chapter One) and how much was at stake in World War II (Chapter Two), how could the U.S. Navy have sent out its submarines with faulty torpedoes (Chapters Three and Four)? And why did they allow that situation to continue for so long (Chapter Five)?⁶ For the first time, this dissertation answers both questions through an historical analysis of the people, institutions, and social and cultural forces involved. This dissertation argues that the MK XIV/VI torpedo was a high-tech, high-

⁶ Fletcher Pratt, "The Torpedoes that Failed," *The Atlantic Monthly Magazine*, Vol. 186, No.1, July, 1950, 25.

risk system and that it was bound to fail.⁷ The U.S. Navy should have had a system set up for superior testing prior to its release and a program to quickly address the inevitable failures in combat. There is also an explanation for the fact the problems took so long to resolve. The Bureau of Ordnance and Newport Torpedo station considered these top-secret, highly technical components to be infallible. Such components are known today as black boxes.⁸ Viewing this issue through science and technology studies, particularly Actor-Network Theory, this dissertation analyzes how this debacle can not only be explained, it could have been predicted.

This dissertation also analyzes other factors contributing to and arising from the denial of torpedo problems and delays in resolution. There was a terrible torpedo shortage the first two years of the war which added to the problem of accepting the fact that the MK XIV/VI had issues.⁹ However, resolving the problems of the MK XIV/VI torpedo did not affect the number of sinkings in any great manner. By the time that the MK XIV/VI problems had been resolved, the MK XVIII torpedo was coming off the assembly line and the number of torpedoes available to the submarine service had grown immensely. This meant that submarines could shoot more torpedoes at a single target. In the end, this factor alone led to the greatest increase in successful attacks. Also, the submarine service started the war with the MK X torpedo armed with the MK III contact exploder. This weapon was as dependable as the touted MK XIV/VI. The MK X/III was

⁷ Charles Perrow, *Normal Accidents: Living with High-Risk Technologies* (Princeton, New Jersey: Princeton University Press, 1984, 1999), 9-14.

⁸ Sergio Sismondo, *An Introduction to Science and Technology Studies* (Malden, Massachusetts: Wiley, Blackwell, 2010), 120-21.

⁹ Clay Blair Jr., *Silent Victory: The US Submarine War Against Japan* (Annapolis, Maryland: Naval Institute Press, 1975), 109.

a shorter torpedo than the MK XIV/VI but was the same diameter, carried about the same amount of TNT in the warhead, and could be fired from the Fleet submarines with a small modification.¹⁰ The Navy could have depended on this torpedo until the problems with the MK XIV/VI had been worked out. This dissertation is the first to make these arguments.

Chapter One introduces the central questions of this dissertation. Given how important the U.S. Navy Submarine Service and its weapon, the torpedo, were at the outset of World War II, how could the torpedoes have failed and why did it take almost two years to resolve their problems? Chapter One's argument is that if the MK XIV/VI torpedo was viewed as a high-tech, high-risk system containing multiple "black boxes" then both the questions discussed above would be answered. In high-tech, high-risk systems failures are inevitable. Why did the U.S. Navy Submarine Service allow the problems to persist for so long? When anyone suggests opening and critically evaluating a black box, denial and resistance are the norm and delays are inevitable. Chapter One introduces undersea warfare, how and why the concept was so desirable and why many decades, millions of dollars, and many lives were dedicated to its development. The U. S. Navy had an elaborate system in place, plans to make undersea warfare an integral part of their strategy and was on the verge of making the whole concept of an invisible vessel firing an invisible weapon a reality at the outset of World War II.

¹⁰ Robert Gannon, *Hellions of the Deep: The Development of American Torpedoes in World War II* (University Park, Pennsylvania: Pennsylvania University Press, 1996), 68.

This first chapter introduces the work of Charles Perrow, Diane Vaughn, and James R. Chiles and their studies in high-tech, high-risk disasters. It explains the criteria that the MK XIV/VI would need to meet for categorization as a high-tech, high-risk system. It introduces the idea that *if* the MK XIV/VI met the criteria for a high-tech, high-risk system, failures would be expected, even under the best of circumstances, which these were not. This chapter then describes the history of science and technology beginning with the Strong Program and discussing materialism and Bruno Latour's Actor-Network Theory. It outlines the criteria for a black box, and the course of events expected when challenging black boxes. Finally, it suggests that if the MK XIV/VI contains black boxes, and fixing its problems involved opening these black boxes, delays in fixing the problem should be expected.

The submarine was a weapons delivery system, the torpedo is the weapon, and neither functioned without the other. Submarines developed over time from partially-submerged, hand-propelled vessels that were detectable, limited in range by lack of sustainable propulsion, and unable to deliver a weapon successfully, to fully submersible, undetectable vessels able to travel long distances independently and to deliver weapons under water.¹¹ Germany's success with undersea warfare sparked discussions among the world's navies about the morality of this platform and nearly resulted in a ban on the technology.¹²

¹¹ Tom Chaffin, *The H.L. Hunley: The Secret Hope of the Confederacy* (New York: Hill and Lang, 2008).

¹² Eric Goldstein & John Maurer, eds., *The Washington Conference, 1921-22: Naval Rivalry, East Asian Stability and the Road to Pearl Harbor* (London and New York: Routledge, 1994). This volume contains different views on the eventual treaty.

The invisible nature of the torpedo was the key to its desirability, primarily in inter-waterway warfare.¹³ The first chapter shows that tactical needs and imagination drove the development of an “automobile torpedo,” a mine that was self-propelled, could be steered under the surface of the sea to explode against a target ship’s hull, thereby sinking or damaging it and taking it out of a battle. The U.S. Navy undertook all this activity to create a modern marvel to revolutionize naval warfare.

Chapter Two’s argument is that one cannot understand the torpedo problems in isolation. It argues that to analyze how knowledge was constructed during the MK XIV/VI torpedo failure issue it is necessary to look at the networks and relationships between different military and civilian organizations and individuals. But the network included more than people; it contained submarines and the torpedo itself. The fleet submarines performed admirably but had a weapon that did not. The MK XIV torpedo with the MK VI exploder was a highly technical system, so complicated that submarine crews, particularly torpedomen, were having trouble with it.¹⁴ Entering World War II, the U.S. Navy believed they had the ideal, a vessel that could submerge to an undetectable depth, maintain submersion and propulsion for long distances while approaching and retiring, fire an undetectable weapon upon enemy targets, and withdraw without counterattack.

¹³ Brian Hicks, Schuyler Kropf. *Raising the Hunley: The Remarkable History and Recovery of the Lost Confederate Submarine* (New York: Ballantine, 2002), 119.

¹⁴“Torpedoes Mark 14 and 23 Types” *A Bureau of Ordnance Publication, Operation Pamphlet (OP) 635*, 24 March 1945.

The US struggled to decide on the best strategic use for the submarine and that affected design, from the small S-Boats used in World War I to the state-of-the-art *Gato* and *Balao* Classes used during World War II. In the early days of the war, the submarine was vital to the United States' strategic response to the Japanese invasion of the Pacific. The U.S. Navy had superior undersea vessels going into World War II, but they did not achieve the expected success. It also takes highly trained personnel, performing flawlessly under pressure, and reliable weapons.

The second chapter discusses the theories behind the most efficient way to sink a ship. Initially, the prevailing method for sinking a ship was exploding as many torpedoes against the hull of an enemy ship as necessary. After World War I, experts believed exploding a torpedo several feet underneath a ship's hull would create the fluid dynamics that would "break the back" of the ship.¹⁵ The Mark XIV torpedo with the Mark VI exploder (MK XIV/VI) was designed specifically for this purpose, so that each torpedo shot would sink a ship. No one has written, in depth, about the inner workings and construction of the MK XIV torpedo, nor the MK VI exploder. This torpedo, without its top-secret technical manual of well over 200 pages, was dispersed to the Fleet Submarines in the Pacific and delivered to the hands of minimally trained crews. Most importantly, pre-war testing did nothing to ready the torpedo and exploder for war.¹⁶ Time and again, submarines went to battle stations, made perfect approaches, fired at

¹⁵ Buford Rowland and William B. Boyd, *US Navy Bureau of Ordnance in World War Two* (Washington D.C.: Bureau of Ordnance, Department of the Navy, 1953), 99-101.

¹⁶ Operations Pamphlet (OP) 635.

close range and suffered one torpedo failure after another.¹⁷ This chapter takes the story up to the point when torpedo failure reports flooded into command centers in the United States. It introduces the key personalities involved in the development and implementation of the MK XIV/VI, who also went on to be responsible for decisions concerning the torpedo failures discussed later.

Chapter Three argues that the torpedo failures created an overall problem that affected everyone from the eighteen-year-old torpedoman to the Chief of Naval Operations, and that it took experimentation and the persistence on the part of the men in the field to resolve the problems with the Mark XIV/VI torpedo.¹⁸ The relationship between the torpedo and the men who lived with and worked on it is central. Adding stress and frustration to this relationship was the lack of technical literature and training. These men needed to know how it worked and all its different facets to make it a dependable weapon of war. Submariners set up an experiment on the white sandy beaches of Albany, Australia that showed the torpedoes were running on average eleven feet deep.¹⁹ Torpedomen altered their torpedo depth settings to compensate. After this, premature explosions began to increase because the influencer was too susceptible to differences in the Earth's magnetism. The men in the Pacific added up the number of

¹⁷ Rear Admiral C.C. Andrews USS *Gurnard* (SS-254). Interview by mail with Clay Blair, May 16, 1972, Blair Papers, Box 66, File 3.

¹⁸ Charles A. Lockwood, *Sink "Em All: Submarine Warfare in the Pacific* (Lexington, Kentucky: Uncommon Valor Series, 1951, 2015), 95.

¹⁹ Letter to Admiral Charles A. Lockwood from Admiral W.H. P. Blandy concerning torpedo depth tests at Albany, Australia, Dated July 11, 1942. Papers of Charles Andrews Lockwood, Library of Congress Box 63. (Hereafter cited as Lockwood Papers, LOC)

premature detonations and decided to turn off the magnetic influencer.²⁰ By the time this was fixed, BuOrd was helping the men in the Pacific. Testing, under BuOrd's supervision, involved firing torpedoes into an underwater cliff and then retrieving them.²¹ The problem was that these higher-speed torpedoes used detonators designed for slower torpedoes, using metals that were not strong enough. Because of the highly technical nature of the torpedo and exploder, the time and resources it would take to re-engineer them, and shortages that already plagued the submarine service, command made the decision, in October 1943, to bypass all the malfunctioning, highly-technical systems, either by turning them off or by changing fire control techniques to circumvent or compensate for them. The U.S. Submarine Service had a torpedo that was much more reliable, yet they had to abandon the "one shot one sunk" strategy and return to blowing holes in the enemy ships' hulls until they sunk. In the last few months of the war, submarine captains learned how to surface without being spotted by enemy aircraft or destroyers, and gun battles dominated the end of the war. Torpedo battles became rare.²²

Chapter Three describes the torpedo shortage in the Pacific and how that influenced command's denial of the problems and the solutions they ultimately put in place. Admiral Lockwood's alliances with BuOrd, Naval Command, and Newport began to wane. Within this story we see how careers developed and how alliances were formed and reformed in response to events labeled failed enemy engagements by one side and

²⁰ Letter to Captain James Fife from Admiral Charles A. Lockwood, to inactivate Mark VI torpedoes at once Lockwood, Papers, LOC, Box 70.

²¹ Lockwood, *Sink 'Em*, 100.

²² Captain R.D. Risser USS *Seawolf*, USS *Saury* letter to Clay Blair, December 16, 1941, Blair Papers, Box 70, File 1.

torpedo failures by the other. Bureau of Ordnance Head Admiral William Blandy and his close relationship with Charles Lockwood showed how behind-the-scenes, personal relationships led to action.²³ Lockwood's connection to Chief of Naval Operation Admiral Ernest J. King's office are analyzed as well. Yet, the major player in this saga was not a person. It was a machine, a weapon of war.

Chapter Four argues that the Mark XIV torpedo and the Mark VI exploders were highly technical, high-risk machines that operated within a high-risk system called war. Given its complexity, the MK XIV/VI should have been put through extensive testing but it was not. Regardless, even with extensive testing, this weapon was going to fail and the Navy as well as BuOrd should have had a system set up to deal with it. Chapter Four shows that the MK XIV/VI did meet Perrow's criteria for a high-tech, high-risk system and followed the expected course of such systems, which is to fail.²⁴

Testing prior to implementation, or lack thereof, was a big contributor to the failure of the Mark XIV/VI. Chapter Four describes the two systems in detail, the Mk XIV torpedo depth mechanism and the Mark VI magnetic influence exploder. It introduces a recently found electrical schematic of the MK VI exploder and discusses the MK VI from impeller driven generator through its pickup coil to exploder mechanism. With the help of former Undersea Weapon's engineer Charles Gunderson, this chapter shows that this exploder was very technical, perhaps too technical, for its application.

²³ Letter from Admiral W.H. P. Blandy to Admiral Charles A. Lockwood thanking Lockwood for critical letter of June 9, 1943 concerning Bureau of Ordnance response to Mark 14/6 torpedo failures, June 19, 1943. Lockwood Papers LOC, Box 70. Blandy was one year behind Lockwood at the Naval Academy.

²⁴ Perrow, *Normal Accidents*, 70-71.

Lack of system testing, coupling, and interaction variables all contribute to a high-risk system failure.

One of the greatest issues with torpedo system failures are mental models, ideas about how things ought to work, that can mask reality. One of the greatest examples of a system failure is the sinking of the USS *Squalus*. This sinking was one of the darkest episodes in Naval History. It is also one of their greatest triumphs in their rescue of thirty-three crew members from the sunken submarine. This chapter recounts this story and applies to it the theories of task analysis, degree of disturbance, and linear versus coupled systems.²⁵ It also discusses construction of knowledge in scientific and technological laboratory settings vs. wartime settings, using the example of torpedomen in the Pacific. Within this example, the dissertation defines systems failure terms like redundant pathways, independent events, and tightly-coupled events.²⁶ Operator error always gets blamed when it comes to a high-risk system accidents.²⁷ It was as true with the Mark XIV/VI as it is today. The theories of Perrow, Vaughn, and Chiles speak to what the Navy, BuOrd, and Newport Torpedo Station experienced with the Mark XIV/VI torpedo.

Chapter Five examines the question of why it took over a year and a half of torpedo failures during combat to solve the torpedo issues. This chapter argues that that the actions that the Navy, BuOrd, and Newport took concerning the MK XIV/VI issue

²⁵ Peter Maas, *The Terrible Hours: The Man Behind the Greatest Submarine Rescue in History* (New York: Harper Torch, 1999).

²⁶ Perrow, *Normal Accidents*, 64.

²⁷ Perrow, *Normal Accidents*, 9.

can be explained using current theories on the construction of scientific knowledge. It demonstrates how the MK XIV/VI had black box components, so that admitting a problem would have meant opening and examining those black boxes. The conflicts predicted by Bruno Latour were inevitable and resulted in delays in resolution of the problems.

This chapter will use Latour's Actor-Network theory.²⁸ Sources include primary reports from Naval Command, Bureau of Ordnance, and the Submarine Service in the Pacific. This chapter will apply these theories and explain how and why the problems with the Mark XIV/VI torpedo took so long to rectify. One of the main problems was that the crews in the Pacific, and then later Pacific Command, were asking the East Coast organizations to open two black boxes. This chapter applies the theories of Bruno Latour specifically to this issue. It is a tale of frustration, alliances, and inscriptions.²⁹

The Conclusion brings out the significance of this study, concentrating on the main arguments concerning high-risk systems and opening black boxes. It will introduce original graphs showing that the torpedo, though it became safer and more reliable, never significantly improved its effectiveness through the war. More torpedoes fired per enemy ship made the difference. Further environmental studies will be suggested that affect torpedo travel and performance. Although not the purview of this dissertation, other scholars might investigate the effects of the earth magnetism, ship steel metallurgy, differences in sea salinity, sea surface to bottom depth, inter-island currents, ocean

²⁸ Bruno Latour, *Science in Action: How to Follow Scientists and Engineers Through Society* (Cambridge, Massachusetts: Harvard University Press, 1987), 84-89.

²⁹ Latour, *Action*, 218.

currents, and sea life on older and current undersea weaponry. The conclusion will finish as the paper started, with the story of Captain Tyrell Jacobs. Jacobs was a true torpedo engineer who finished the war developing the Mark XIII torpedo and contributing to the war effort in a greater, but less satisfactory, manner than he would have desired.

Resources and Past Scholarship

Sources from the Library of Congress include the papers of Admiral C.A. Lockwood, the commander of submarines in the Pacific, the papers of Admiral William H. Blandy, the director of the Bureau of Ordnance during the war, and the papers of Admiral Ralph W. Christie, the lead designer of the MK VI magnetic influenced exploder, one of the lead Naval Officers in charge of the development of the MK XIV torpedo, and the commander of the Asiatic Fleet during the war. Christie also served several tours at the Bureau of Ordnance and Newport Torpedo Station.

The National Archives supplied, among other sources, submarine war patrol reports as well as official biographies of Naval Commanders and submarine commanders who served during the war. Correspondence between submarine commanders, naval command and the Bureau of Ordnance resides there as well. The Naval Undersea Weapons Center Museum and Library provided blueprints and technical manuals for the MK XIV torpedo as well as electrical schematics of the MK VI magnetic influenced exploder. These technical manuals were so top secret during the war that they never found their way to the Pacific to help remedy the problems of the torpedo and exploder.

Their library houses independent studies on analysis of the MK VI exploders from an electrical engineering standpoint as well as multiple published and self-published biographies of submarine captains who served during the war.

The Clay Blair Jr. Papers collection is housed at the American Heritage Center at the University of Wyoming in Laramie, Wyoming. Blair's collection concerning his book, *Silent Victory*, contains taped interviews of Admiral Ralph Christie, Admiral Lockwood's widow Phyllis, as well as several submarine captains who served during World War II. Blair's collection also includes information he garnered from the National Archives and the Library of Congress. Most importantly, Blair communicated with former submarine commanders by mail and this collection includes these communications as well. Most are typed, while others are hand written. These personal letters contain a submarine skipper's recollection of the torpedo issues they faced during their war patrols in the Pacific. All primary sources used in this dissertation were labelled "Declassified."

The two most comprehensive books concerning the submarine war in the Pacific were written thirty years between each other. The first, *United States Submarine Operations during World War II* by Theodore Roscoe, was written shortly after the war.³⁰ The second, *Silent Victory: The US Submarine War Against Japan* by Clay Blair Jr., was

³⁰ Theodore Roscoe, *United States Submarine Operations in World War II* (Annapolis, MD: Naval Institute Press, 1950).

written in the early seventies³¹ Clay Blair Jr. served on the USS *Guardfish* during the war and was the former editor in chief of the *Saturday Evening Post*.

This dissertation has a large bibliography of secondary sources. Many are histories on the Pacific War or on World War II. Some are specifically about the submarine war and some include references about the submarine's contribution to the war effort. Foremost is Robert Gannon's book on the development of American Torpedoes during World War II, *Hellions of the Deep*.³² Gary E. Weir's *Forged in War: The Naval-Industrial Complex and American Submarine Construction 1940-1961*, helps recount the construction of the state of the art Fleet Boats of the war.³³ Richard Knowles Morris biography on the first developer of the modern submarine, *John P. Holland 1841-1914, Inventor of the Modern Submarine*, tells the story of submarine development to World War I.³⁴ Anthony Newpower's *Steel Men and Tin Fish* is the only volume that has been written specifically about the MK XIV torpedo and MK VI exploder to date.³⁵ Admiral Charles A. Lockwood's classic volume on the submarine war in the Pacific, *Sink 'em All*,³⁶ tells his personal experience as Commander of Submarines in the Pacific. In addition to these are numerous published and self-published books written by the submarine commanders, including Gene Fluckey's *Thunder Below: The USS Barb*,

³¹ Clay Blair, Jr. *Silent Victory: The U.S. Submarine War Against Japan* (Annapolis, Naval Institute Press, 1975).

³² Robert Gannon, *Hellions*.

³³ Gary E. Weir, *Forged in War: The Naval-Industrial Complex and American Submarine Construction 1940-1961* (Washington, Naval Historical Center, Department of the Navy, 1993).

³⁴ Richard Knowles Morris, *John P. Holland 1841-1914, Inventor of the Modern Submarine* (Columbia S.C.: University of South Carolina Press, 1998).

³⁵ Anthony Newpower, *Steel Men and Tin Fish the Race to Build a Better Torpedo During World War II* (Annapolis: Naval Institute Press, 2006).

³⁶ Charles A. Lockwood, *Sink 'Em*.

Revolutionary Submarine Warfare in World War II,³⁷ I. J. Gallatin's *Take Her Deep: A Submarine Against Japan in World War II*,³⁸ and Richard O'Kane's *Clear the Bridge: The War Patrols of the USS Tang*.³⁹ Books telling the personal stories of the war from enlisted torpedomen who served in the Pacific include *We Were Pirates: A Torpedoman's Pacific War* by Robert Schultz and James Shell⁴⁰ and *Torpedoman* by Ron Smith.⁴¹

In addition to books on submarines, torpedoes, and undersea warfare, this dissertation uses the works of historians and sociologists of science in its analysis. Combined works from volumes like *Major Problems in the History of American Technology* are used.⁴² Researchers and authors including Charles Perrow,⁴³ Diane Vaughn,⁴⁴ Astronaut James Lovell,⁴⁵ and historian James R. Chiles⁴⁶ provide theories on highly technological, high-risk systems. Researchers of science and technological studies

³⁷ Gene Fluckey, *Thunder Below: The USS Barb, Revolutionary Submarine Warfare in World War II* (Urbana & Chicago: University of Illinois Press, 1992).

³⁸ I. J. Gallatin, *Take Her Deep*.

³⁹ Richard O'Kane, *Clear the Bridge: The War Patrols of the USS Tang* (New York: Ballantine, 1978).

⁴⁰ Robert Schultz and James Shell, *We Were Pirates: A Torpedoman's Pacific War* (Annapolis Maryland: Naval Institute Press, 2009).

⁴¹ Ron Smith, *Torpedoman* (Self-published, 1993).

⁴² Merritt Roe Smith and Gregory Clancy eds., *Major Problems in the History of American Technology* (Boston, New York: Houghton Mifflin, 1998).

⁴³ Charles Perrow, *Normal Accidents: Living with High-Risk Technologies*, (Princeton, New Jersey: Princeton University Press, 1999).

⁴⁴ Diane Vaughn, *The Challenger Launch Decision: Risky Technology, Culture and Deviance at NASA* (Chicago: University of Chicago Press, 1996).

⁴⁵ Jim Lovell and Jeffrey Kluger, *Lost Moon: The Perilous Voyage of Apollo 13* (New York: Pocket, 1994).

⁴⁶ James R. Chiles, *Inviting Disaster: Lessons from the Edge of Technology, An Inside Look at Catastrophes and Why They Happen* (New York: Harper Collins, 2001, 2002), Kindle Edition.

such as Sergio Sismondo,⁴⁷ Michel Callon,⁴⁸ David Bloor,⁴⁹ and Bruno Latour⁵⁰ contribute fundamentally to my analysis.

One of the most valuable resources was Mr. Charles Gunderson.⁵¹ Gunderson, who is retired, worked for the Naval Undersea Warfare Center for most of his career. He helped me understand the science and engineering of the MK XIV torpedo and especially the electronic and mechanical engineering behind the MK VI exploder.

As in any other historical niche, there is a small group of professional and amateur historians who know this story. But generally, not many people know the full extent of these problems. Certainly, any book about the US Navy's submarine participation in the war has devoted some pages to the problem. Some authors, like Robert Gannon, have devoted a chapter or two to the subject.⁵² Anthony Newpower is the only author who has devoted a book expressly to the topic.⁵³ Articles, like Fletcher Pratt's seminal *Atlantic Monthly* piece written in 1950, have described the problem, the frustration of the submarine crews, and Command's denial and how long it took to resolve the problem.⁵⁴ Few know the lengths to which people during the war went to rectify the situation.

⁴⁷ Sismondo, *Intro to STS*.

⁴⁸ Michel Callon, John Law and Rip Arie, *Mapping the Dynamics of Science and Technology: Sociology of Science in the Real World* (Basingstoke, England, MacMillan, 1991).

⁴⁹ David Bloor, *Knowledge and Social Imagery* (Chicago; University of Chicago Press, 1976, 1991).

⁵⁰ Bruno Latour, *Action*.

⁵¹ Charles R. Gunderson, interviewed by author on April 15, 2015, Naval Undersea Museum, Keyport Washington.

⁵² Gannon, *Hellions*, 73-98.

⁵³ Anthony Newpower, *Steel Men and Tin Fish the Race to Build a Better Torpedo During World War II* (Annapolis: Naval Institute Press, 2006).

⁵⁴ Pratt, "Torpedoes that Failed," 25-30.

This dissertation differs from previous approaches in that it is not just a recounting of the story of the torpedo failures, perhaps reporting the opinions of persons close to the story. Rather, by using sociology of science and history of science, this dissertation critically examines why things happened in the way they did. In addition, by evaluating and analyzing the raw data of torpedo performance, this dissertation concludes that, even once the major problems with the Mark XIV/VI torpedo were rectified, it did not greatly improve. The answer ultimately relied on shooting more torpedoes at each target, the very thing the MK XIV/VI was designed to avoid.

CHAPTER ONE

EARLY SUBMARINES AND TORPEDOES

Battle of Tsushima

Fought on May 27-28, 1905, the Battle of Tsushima was naval history's only decisive sea battle fought by modern steel battleships.¹ The Russian Navy sortied out of the Baltic Sea and sailed 18,000 miles around the Cape of Good Hope to relieve the small Russian fleet at Vladivostok. The Russian fleet had hoped to cruise through the Straits of Tsushima then the Sea of Japan undetected, gather with the ships at Vladivostok, repair and re-provision their ships, and sortie and engage the Japanese Navy on Russian terms. Instead, the Japanese Navy spotted the Russian Fleet at the Straits and, using new science and technology like wireless communication and German-made rangefinders, engaged and sank three quarters of the Russian Navy.²

This highlights a major problem with fighting on a level plane like the surface of the sea. A warship can be detected from miles away. The perfect ship could approach the enemy without exposing itself and fire a weapon that could not be detected until it hit its target, an invisible weapons carrier, firing an invisible weapon. Invisibility has another advantage. The most difficult maneuver in warfare is a rearguard action, retreating while

¹ Constantine Peshakov, *The Tsar's Last Armada: The Epic Journey to the Battle of Tsushima* (New York: Basic Books, 2008,) 261-321.

² Milan N. Vego, ed., *Joint Operational Warfare Theory and Practice V. 2 Historical Companion* (Newport Rhode Island: Naval War College Press, 2009), ii-80.

engaged without sustaining significant damage from a counterattack. Certainly, the best course is to attack the enemy and quickly sink them. If unsuccessful, then the second-best course would be to attack, damage the enemy vessel and retire.³

An invisible ship, of course, is an impossibility. But for centuries, strategists dreamt about a vessel that could sail underwater.⁴ In warfare such a vessel could approach undetected, attack an enemy and sail away with impunity. An invisible ship shooting an invisible weapon appeared to be stuff of science fiction. But there were those who thought it could be done.

Thesis and Organization

This chapter argues that the submarine was the most crucial development of naval warfare since the introduction of the ironclad during the Civil War. It fulfilled the dream of invisibility of a combat ship on the high seas. This chapter also argues that a submarine is only a weapons carrier for the weapon itself – the torpedo – and that the torpedo is the most important part of the tactical equation. Understanding torpedoes requires understanding the submarine. Torpedoes and submarines go together like gun and bullet. One cannot function without the other. They both had the same goal of invisibility. The development of submarines and torpedoes involved steps toward this goal.

³ Wayne P. Hughes Jr., *Fleet Tactics and Coastal Combat, Second Edition* (Annapolis: Naval Institute Press, 2000), 2-5.

⁴ Captain Brayton Harris, "Submarine History Timeline Part One, Key Events in the History of Submarines," *Nova Magazine*, January 2015, accessed June 14, 2016, <http://www.submarine-history.com/NOVAone.htm>

This chapter introduces the two central questions of this dissertation. Given the importance of undersea warfare, all that had gone into the development of submarines and torpedoes and how much was at stake in World War II, how could the U.S. Navy have sent out its submarines with faulty torpedoes? And why did they allow that situation to continue for so long? This chapter proposes that these torpedoes were high-risk systems (described below). As such, failures were inevitable. If the torpedo contained components that Bruno Latour would call “black boxes” (described below) then challenging these components would lead to denial, conflicts, and delays. The first step is to show the importance of undersea warfare and everything that went into the development of the submarine and the torpedo.

This chapter shows that the development of the submarine and torpedo are both complex, high-risk systems that took decades of design and development. It will introduce high-risk systems and black boxes, and demonstrate how these terms applied to the U.S. Navy submarine and torpedo. Undersea warfare had advantages. To achieve these advantages, submarines developed over time from partially-submerged, hand-propelled vessels that were detectable, limited in range by lack of sustainable propulsion, and unable to deliver a weapon successfully, to fully submersible, undetectable vessels able to travel long distances independently and deliver weapons under water. This chapter describes the development of torpedoes from mines floating downstream with the hopes of hitting something, to submerged mines, to the auto-mobile torpedoes, self-propelled weapons detonating on contact with enemy vessels. Germany’s success with

undersea warfare highlighted its value but sparked discussions among the world's navies about the morality of this platform, nearly resulting in a ban on the technology.

Because submarines have become a norm, the world takes the idea of an undersea vessel for granted. But the thought of a submarine is daunting. The idea of a seagoing ship that could become undetectable and travel great distances under water by submerging to hundreds of feet below the surface, then surprise and sink an enemy vessel by launching another undetectable, auto-mobile, undersea vehicle, was fantastic. Such a technology required a whole new way of thinking about marine warfare. It took imagination, advances in science and technology, impetus through war, and commitment of those people who believed it could be done. Yet, a weapon delivery system is only as good as the weapons it delivers. During World War II, the men in the U.S. Navy's Submarine Service served in state of the art submarines. These undersea vessels were the best the world had seen. However, the Mark XIV/VI torpedoes these submarines used were failures.

High-Risk Systems

There is nothing about a submarine that is not high risk. It is an open ocean vessel designed to sink at periodic intervals. As with any highly technical machine, there is risk of failure. The submarines used during World War II were equipped with miles of plumbing and electrical lines, dozens of valves, multiple diesel engines and battery powered motors, dozens of batteries, hatches and apertures that had to be closed to the sea, and most importantly they carried steam-driven torpedoes with warheads loaded with

500 pounds of Torpex. The torpedoes themselves were as high tech and high-risk as any weapon built to date. This dissertation concerns high-risk systems and what sociologist of science Bruno Latour refers to as black boxes, in this case a piece of machinery that receives input and delivers output but whose inner workings are too complex to immediately understand. Black boxes take years and large amounts of money to develop, but once developed their inner workings need not be considered.⁵ This chapter shows the development of the highly technical and risky nature of the early submarines, torpedoes, and the black boxes they contained.

In his book, *Normal Accidents*, Charles Perrow argues that in high-risk systems, accidents are unpreventable.⁶ Indeed, the more technical and complicated a system, the more risk there is of a major problem, sometimes catastrophic. No matter how effective conventional safety devices are, risk will never be eliminated from highly technical systems.⁷ The key is to keep working at making high-risk technologies safer, but to do it in such a way that the fix does not make the system more complex, therefore even riskier. Conventional engineering approaches to ensuring safety do not work because the added system complexity creates new possibilities of accidents. These systems are usually so intertwined that the failure of one part leads to the failure of the entire system. This will become clear as this dissertation describes the development of the submarine and the torpedo.

⁵Bruno Latour, *Science in Action: How to Follow Scientists and Engineers Through Society* (Cambridge: Harvard University Press, 1987), 2-3.

⁶ Charles Perrow, *Normal Accidents: Living with High Risk Technologies* (Princeton, New Jersey: Princeton University Press, 1984) 3.

⁷ Perrow, *Normal Accidents*, 4.

Black Boxes

A black box is a scientific metaphor denoting a component, device, system, theory or object that is valued by the simplicity and infallibility of the output gained by input. Users give no thought to the internal processes of the black box.⁸ They take for granted the inner working, caring only about the information going into it and the information coming out of it

In the case of a component or invention, years have gone into the theorizing, construction, and working out of the bugs of the black box. During the time that the black box was being built, there was a lot of uncertainty as to whether it would work. Yet, once the black box was finished, there was no need to open it to see how it was constructed. There was no need to think about the intricacies of how it worked. Once a component had been black boxed, there was little need to think about it at all. It could be and, if working properly, should be ignored. In science and engineering, this was a device system or object that could be viewed solely in terms of input, output and transfer characteristics without any knowledge of inner workings.

In Latour's analysis, if a scientist made a statement, the fact of the statement was not determined by right and wrong, but by who said it and how many supported it. Fact-making was a collective process. Statements could only become facts if they were noticed and used without modification by others. Latour continued his argument that the act of

⁸ Latour, *Action*, 2. "The word black box is used by cyberneticians whenever a piece of machinery or a set of commands is too complex. In its place, they draw a little box about which they need to know nothing but its input and output."

opening a black box made science become more social, because allies were mobilized and enemies were isolated. This occurred at the outset of a scientific finding and was present when someone desired to open a black box. Latour spoke of the literature surrounding the opinion being challenged, in this case the exploder or depth control system, becoming hard to read and analyze. This was done to occupy all the opposition's time refuting scientific calculations, algebraic equations, and whatever else was used to build an impenetrable wall of uninterpretable information.⁹ The next response in Latour's model involved social circles supporting the original claim mobilizing against any person who was challenging the current science. At each stage of doubt, the cost of resistance increased. Latour argued that eventually it would become too difficult socially and economically to continue opposing the status quo. The opponent would need to build his own laboratory to contest the claim, thus impugning the reputations of those he chose to disprove.¹⁰ The challenge was successful if alliances changed.

Chapters two and three will show that the MK XIV/VI had many components meeting the criteria of black boxes. Chapter Five will describe in detail two black boxes, the MK XIV torpedo's depth mechanism and the MK VI exploder's magnetic influence mechanism, and how changing these black boxes followed the course outlined by Latour.

⁹ Latour, *Action*, 30-45. "When controversies flare up the literature becomes technical."

¹⁰ Latour, *Action*, 63-100.

Warfare on the High Seas

It is normal to consider a submarine, airplane or surface ship a weapon of war. These vehicles carried the battle to the enemy. However, in the case of the submarine it was torpedoes and four-inch deck shells that did the damage, not the submarine itself. The submarine was a weapons delivery platform. Before discussing torpedoes as weapons, it is essential to understand their delivery system, the submarine. The two were an integrated unit. The early development of the submarine parallels that of the torpedo as the value of one is totally dependent on the other.

Naval warfare for millennia consisted of battles at sea between the ships of different powers, fighting on the surface using catapults, battering rams, bows and arrows. Naval warfare eventually used muzzle-loading, heavy, iron cannons and then cannons made of steel with breech loading mechanisms. Wooden ships evolved into ones made of steel.¹¹ Surface ships fought each other in a two-dimensional world. The steel ships of the Japanese and Russian navies fighting at Tsushima were surface battleships designed to sink the enemy's vessels by firing heavy-caliber twelve-inch diameter shells weighing 850 pounds apiece.¹² If an undersea ship could obtain the same results firing an underwater projectile it would change the face of warfare on the high seas.

¹¹ RG Grant, *Battle at Sea: Three Thousand Years of Naval Warfare* (New York: DK Publishing, 2008).

¹² *Treatise on Ammunition 1887* (London: Harrison and Sons, 1887) Printed by Order of the Secretary of State for War. Fourth Edition, Corrected up to 1st January, 1887.

Early Submarine Precursors: Submersibles

Archimedes of Syracuse originated the displacement of water theorem.¹³ A ship can float, in part, because it displaces an amount of water equal to the weight of the ship. Yet, a block of steel, which also displaces water, cannot float because of its density. Therefore, the ship's hull must contain air in an airtight space to make it more buoyant. The ability to float depends upon a combination of displacement and buoyancy. A submarine's displacement varies, as it displaces more water when it is fully submerged and less water when partially submerged. Once men broached the idea of displacement, they began to experiment with submerged vessels.

The first practical combat submersible was David Bushnell's egg-shaped *Turtle* from the U.S. Revolutionary War. Bushnell's boat was a submersible about ten feet long, six feet tall and about three feet wide.¹⁴ With two, hard, wooden shells covered with tar and reinforced with steel bands, it appeared more like a clamshell than a turtle. The top of the craft had small pieces of thick glass for natural light. The diving mechanism was a bilge tank at the bottom of the vessel. To submerge, the crewman filled the tank with water and to surface he used a hand pump to expel the water with air. He could release up to two hundred pounds of lead to increase buoyancy. A single person operated the *Turtle* at up to three miles per hour with hand-cranked propellers controlling both horizontal and vertical travel. Only partially submerged, the vessel was to travel across a bay or harbor,

¹³ Sir Thomas Heath, trans., *The Works of Archimedes* (Mineola, NY: Dover, 2002), 253-263.

¹⁴ Submarines are referred to as boats, not ships. Origins of this appellation are lost to time. The early submarines could be loaded, transported and offloaded off large ships. Many had to be transported as they could not make a long trip dependably across large distances. They were smaller than ships, thus boats.

get close to a British ship and then screw an explosive charge to its hull using a brace and bit. It failed several attempts at this. The *Turtle* was sitting on its tender vessel when the British sank both in 1776. Although the *Turtle* failed, it was the first time a submerged vessel attacked an enemy ship.

The operator viewing port of the *Turtle* traveled above the surface, so a quick, sharp-eyed sentry could and did spot it. The *Turtle* was a good early experiment in undersea warfare. It failed because it lacked total submersion, propulsion, and a deliverable weapon.¹⁵

The next notable foray into submersible warfare occurred during the American Civil War. Although the south captured all the headlines with the *CSS Hunley*, both sides developed submarines. With the help of French inventor Brutus De Villeroi, the Union developed the *USS Alligator*.¹⁶ Originally powered by oars, the *Alligator* eventually used a hand-cranked screw propeller. After an unsuccessful mission on the James River, the Union Navy towed the *Alligator* to Charleston, South Carolina. During the trip a storm forced the Union Navy to cut the *Alligator* loose and the submersible was lost. The *Alligator* was not self-contained and had virtually no seaworthiness, but it was another noble experiment. The problem was that manpower does not work well under the surface of the water, as it is unreliable, and the operators burned more oxygen the harder they worked.

¹⁵ Roy R. Manstan & Fredric J. Frese, *Turtle: David Bushnell's Revolutionary Vessel* (Yardley, Pa: Whestholme Paperback, 2010), 3-139. The authors built a working model of the *Turtle* and ran it through tests.

¹⁶ Mike Smith, "Alligator: The Forgotten Torchbearer of the U.S. Submarine Force," *Undersea Warfare Magazine*, U. S. Navy, 8 (3), Spring 2006.

The Confederate Navy was more successful. A sugar broker named Horace Hunley built a forty-foot steel submersible named *CSS Hunley*.¹⁷ A crew of eight men powered the craft by turning a crankshaft which turned a screw propeller. The *Hunley* approached the enemy while submerged and attached a powder charge using a long harpoon point on the end of a long spar. The submarine then retreated, trailing a cord or lanyard attached to a detonator. The charge had a cap-and-ball style gunlock like those used on muzzle loading guns. From a safe distance, pulling the lanyard triggered the gunlock and initiated the explosion.

On February 17, 1864, the *Hunley* took the last cruise that it would take for a hundred and fifty years. In Charleston Harbor the *Hunley* crept up on the USS *Housatonic* and blew a hole in her side. Then she disappeared until April 1995. On August 8, 2000, the *Hunley* rose to the surface, along with the remains of the crew. No one is sure what sank the *Hunley*. It could have swamped or set off the explosive charge while it was still too close. The crew may have burned through all their oxygen and passed out, stopping the forward propulsion the sub needed to stay afloat. The latter problem had caused the *Hunley* to sink before, requiring salvaging. Yet, it was the first submarine to sink an enemy ship.

The *Hunley's* attack on the *Housatonic* was well thought out and produced results but it did not fulfil the role of a true submarine. The vessel depended upon surface air for the men to breathe. Therefore, the main body cruised just below the surface with a hatch

¹⁷ Tom Chaffin, *The H.L. Hunley: The Secret Hope of the Confederacy* (New York: Hill and Lang, 2008). Chaffin is a Fulbright Fellow. The following information concerning the *Hunley* is taken from this text.

open to the air. An alert Officer of the Deck spotted the *Hunley* and several seamen fired upon it with rifles. The submersible was “under its guns,” too close to the *Housatonic* for it to fire its cannons.¹⁸ Though it failed to be invisible, it did successfully deliver a weapon upon the *Housatonic*. The problem on egress could have been a failure of weapon delivery due to the shockwave of the blast or a failure of propulsion as men asphyxiated from using too much air operating the crank. Regardless, as a combat vehicle, the *Hunley* left much to be desired, lacking invisibility, dependable propulsion and, most importantly, the delivery of its torpedo probably sank it. If the *Hunley* had a weapon they could have launched from a distance, the submersible might have remained undetected and far enough away from the weapon’s explosion to avoid being affected.

After the Civil War, the idea of a craft sailing under the sea became popular when French author Jules Verne published *Twenty Thousand Leagues under the Sea*. At the time, in 1870, this book was a best seller and a hit worldwide. In the book, the fictional Captain Nemo and his undersea craft the *Nautilus* travel around the globe, under the sea, encountering adventures and, in the process, inspiring the imaginations of thousands of people. The book promoted the idea that a submarine could work not only as ship of adventure but as a combat ship as well.¹⁹ Two other ideas came along almost simultaneously that would help this become a reality. The first was a battery for storing electricity and the second was a self-propelled torpedo.

¹⁸ Chaffin, *Secret Hope*, 45. “Under its, or under their guns” is a common military term that means that cannon or artillery could not depress their muzzles low enough fire at a target.

¹⁹ Students of Brigham Young University, *Early American Best Seller* (December 23, 2010) <http://earlyamericanbestsellers.blogspot.com/2010/12/1870-1879.html> accessed, June 4, 2016. Originally serialized in the French Magazine *Magasin d'Éducation et de Récréation*.

The Submarine: Initial Basic Development

With Jules Verne's *Nautilus* in mind, a submersible vehicle could be used for transportation, shipping, scientific purposes, exploration, leisure, and for war.²⁰ A ship able to approach undetected, fire an undetectable weapon and then withdraw from a battle without getting fired upon was universally appealing.

Expanding on the ideal, this ship should sail on the surface when not engaged and then submerge whenever needed or desired, or better yet, sail under the sea and surface only when in port. The ship should have high speed both on the surface and submerged, perhaps running as fast under the sea as on the surface. Rapid submersion would allow the vessel to disappear instantaneously in the face of a threat. This type of ship would carry many men, the same number as a frigate, and many tons of weight. If it is a warship, then the ability to shoot automobile torpedoes is a must. The submarine should have a very thick, steel skin to last in combat. It should have several cannons or guns on the deck that would not be affected by seawater or could be retracted when submerged and then pop out of their compartments when needed in battle. This would reduce drag through the water and help increase the underwater speed of the ship. The ship should be able to see what is on the surface of the ocean when submerged. It should also be able to see underwater when submerged. At the lowest depths, searchlights could illuminate the undersea area around it. Much of this sounds fanciful, beyond science and nothing but imagination. But a lot of science has begun with imagination. Submarines for tourists

²⁰ Jules Verne, *Twenty Thousand Leagues Under the Sea*, <http://www.gutenberg.org/files/164/164-h/164-h.htm>. Accessed July 20, 2015.

never gained acceptance, but submarines acting as warships did. The main role of the submarine then became a delivery platform for torpedoes.

To understand torpedoes, one must understand the submarine carrying them into battle. Both require submersion for invisibility and a means of propulsion that can operate for distances under water. For the submarine this involved the development of new fuels and new propulsion systems, advances in electrical storage, optics, and a host of other areas of science and technology that brought the United States Submarine Service into World War II.

The Submarine Part One: Submersion

A submarine has displacement like any other ship. Unlike a surface ship, a submarine must control its buoyancy. A submarine has neutral buoyancy, positive buoyancy and negative buoyancy. Imagine a tube with seals at both ends, preferably of a conical shape, forming a cigar shape. This tube sits inside a larger, cigar-shaped tube that is also sealed at both ends. There is a narrow void between the two tubes called the ballast tank. There are vents on the top and the bottom of the outer tube. Within the inner tube, preferably at the top or along the ceiling of the inner structure, is an air tank. A high-pressure, high-volume air compressor supplies this air tank.

Surfaced, a submarine sits or glides along halfway in the water, almost like a regular ship. This is called positive buoyancy. When the vessel dives, it has negative buoyancy. To do this, the vents on the top and bottom of the submarine open. The bottom vents allow water to fill the ballast tanks while air escapes out of the top vents. The

submarine submerges under the surface of the sea as the ballast tank fills with water. Yet there must be equilibrium or the submarine is going to continue to go to the bottom. This equilibrium is called neutral buoyancy, where the overall density of the vessel is equal to that of the surrounding water. Once neutral buoyancy is achieved and maintained, a submarine can stay under the water. To surface, the bottom vents open and air is pumped into the ballast tank. The air pressure pushes the water out of the ballast tank, creates positive buoyancy and the vessel surfaces.²¹

There had been different attempts throughout the years to build a working submersible. This turned out to be no simple task. For example, the *Turtle* was not a true submersible. The main body of the submarine was underwater but about ten inches of the top hatch cruised above the surface of the water. However, the *Turtle* did employ some of the same concepts as later submarines, such as submerging by letting water into a tank on the bottom of the craft. To ascend, a hand-cranked pump pushed the water out and replaced it with air.²²

As has been shown, the *Hunley* was not much better. It was much bigger and, although it could completely submerge, it could not dive very deep for any extended amount of time. These vessels were almost but not completely underwater, thus any attack could be spotted, anticipated and potentially thwarted. Without the element of

²¹ Marshall Brain & Craig Freudenrich, Ph.D., "How Submarines Work," *HowStuffWorks*, 17 August 2000, accessed September 12, 2015, <http://science.howstuffworks.com/transport/engines-equipment/submarine.htm>>. There are several publications concerning how a submarine works. This site includes animated examples of a general submarine in surfacing and submerging operations.

²² Manstan & Frese, *Turtle*, 56-76.

surprise, and lacking a weapon that could be delivered from a distance, these vessels had little effectiveness.

The Submarine Part Two: Propulsion

Steam Engines

For a ship to move, it needed to be powered. For thousands of years, ships were powered by the wind or by human power. The steam engine took away the reliance on human and animal power. Steam engines eventually powered ships by the time of the Civil War. A submersible needed to be self-contained. Although it was considered, a steam engine would not work in a submarine as they were too big and heavy. Also, a steam engine needed to exhaust steam and smoke. Another form of power needed to be found.

Internal Combustion Engine

The history of the internal combustion engine is fascinating and is the topic for a dissertation in and of itself. The gist of the internal combustion engine (ICE) is that it is a reciprocating engine fueled by gasoline. Gottlieb Daimler constructed the first prototype upon which today's ICE's are based. The internal combustion engine changed industry because of its small size and fuel requirements, allowing it to fit and run in confined spaces. The fuel could rest inside an enclosed tank. The system was somewhat self-contained. All the engine needed was access to air, fuel, spark and a place or port for dispelling exhaust.

Fuel

Gasoline is not an efficient fuel. It has a propensity to burn incompletely and its exhaust is noxious. Nor is gasoline safe, even in storage. It is flammable and its fumes, although not as deadly as its exhaust, are noxious enough to render a person unconscious or even kill them.

The part of gasoline that ignites is not the liquid, it is the vapor that the fluid generates. The problem with this vapor in a submarine is that it is explosive as well as toxic.²³ Admiral Charles Lockwood, later the commander of all submarines in the Pacific during the war, experienced this himself. On a surface patrol as a young officer he found the entire crew unconscious below because the gasoline fumes had knocked them out. If Lockwood had not been on the bridge of the submarine, he would have lost the crew, the submarine, and his life.²⁴

Methane, propane, butane, acetylene, naphtha, kerosene, gasoline and diesel are all combustible hydrocarbons, distilled from crude oil. Once mixed with air or oxygen they produce combustible gases. The technical name for the process of producing these products is fractional distillation. The distillation process is complicated, separating hydrocarbons by weight into mixtures called fractionals. Fortunately, diesel would be used for later submarines. Because diesel is a heavier fuel, its combustive nature is different than gasoline. Drawing diesel fumes into the lungs, while unpleasant, will not render anyone unconscious. Its exhaust is not lethal like gasoline exhaust. Diesel does not

²³ Dudley Peak Craig and Herbert J. Anderson, *Steam Power and Internal Combustion Engines* (New York, London: McGraw, Hill, 1931), 59-90

²⁴ Charles A. Lockwood, *Down to the Sea in Subs* (New York: Norton, 1967), 83.

ignite by spark but through high pressure and heat. When a diesel engine cylinder piston is at the top of its throw, the diesel/air mixture is under great pressure. Add the right amount of heat through a glow plug and there is ignition. Diesel engines became the savior for submarines. But diesel engines still needed air to run and an exhaust port.²⁵ Enter the battery.

Diesel Engines

Diesel, another fractional of crude oil, was not considered a light fuel like gasoline; it was considered a fuel oil. Diesel was lighter than heavy gas oil yet heavier than kerosene. It was not highly flammable or volatile, and that was the key to its success as a submarine fuel.

A diesel engine runs very much like other internal combustion engines. As mentioned, a diesel engine uses no spark plug. It uses heat from a small heating element called a glow plug and compression to drive its pistons up and down. The diesel engine block was much heavier and stronger than that of a gasoline engine. Because of this, diesel engines did not work well for aviation but they were great for trucks or sea-going vessels. Diesels ran well in applications demanding high torque and low revolutions per minute (RPM). Diesels ran more efficiently than gasoline engines, producing higher compression, thus exerting more power on the down stroke of the piston. The fuel burned

²⁵ "Main Propulsion Diesels," *Navpers* (United States Naval Personnel Textbook) 16161, Produced for COMSUBPLANT Standards and Curriculum Division, Training Bureau of Naval Personnel, June 1946.

longer meaning temperatures rose more slowly. This meant more heat was converted to RPMs.²⁶

Once this technology had stuck, many companies began building diesel engines. German firms like Maschinenfabrik-Augsburg-Nürnberg (M.A.N.), and British firms like Vickers were the forerunners of many diesel companies like the American company, Busch-Sulzer Brothers Diesel Engine Company, the New London Ship and Engine Company (Nelseco) and the Hoover-Owens-Rentschler Company (H.O.R.). Later, General Motors produced diesel engines for the U.S. military, many being installed in American submarines.²⁷

Looking back, diesel saved the day. As mentioned, diesel was much safer than gasoline, less combustible and safer to breathe. The engine rooms of the Fleet submarines during the war could be flooded with diesel because of bombardment leaks. Diesel would be ankle deep and the engine crews could go on working to block the internal leakage. Had the fuel been gasoline, the fumes would have entered and contaminated every nook of the boat, knocking the crew unconscious. If a back panel had a short and a spark hit the vapors, it would have blown up the ship, perhaps igniting the Torpex in the torpedo heads. Some submarines, for example the USS *Cachalot* on its first patrol, went to station

²⁶ Navpers 16161, 4-11.

²⁷ Gary E. Weir, *Forged in War: The Naval-Industrial Complex and American Submarine Construction 1940-1961*. (Washington D.C.: Naval Historical Center, Department of the Navy, 1993), 37-60. Many of the submarines at the outbreak of the war had H.O.R engines. This was apparently because of low bidding. The H.O.R Engine was so undependable that some enlisted men would request transfers rather than be responsible to work on them. The General Motors engine became the best engine of the war and were installed on the later submarines.

with a known external leak trailing fuel oil as it cruised.²⁸ If this had been gasoline, the submarine could have easily exploded.

Battery Power for Undersea Travel

There are times that cultural occurrences influence history. Jules Verne's book, *Twenty Thousand Leagues under the Sea* piqued the imagination of a generation. Coinciding with the publication of this book, the electric storage battery, under development for years, came into being.²⁹ Using a battery for submarine propulsion solved many problems. Propulsion no longer required a fresh air supply as with a steam or combustion engine. The electricity from the battery could turn an electric motor which in turn could turn a screw propeller. The vessel now could travel long distances under the surface of the sea.

The battery made all the difference. Eventually, the United States and European countries, including Russia, and their private sectors all began to finance submarine designs. Batteries propelled some submarines. Some submarines were propelled by steam engines on the surface and batteries under the sea.

Analysis

The early attempts at producing a workable submarine during the Civil War met with failure after failure. For example, the early submarines were reliant on physical

²⁸ First War Patrol Report of USS *Cachalot* (SS-170) Dated Mark 23, 1942, NPPSO Naval District Washington Microfilm Reel Number F-108, Roll AR-125, Record Group 78.

²⁹ Richard Knowles Morris, *John P. Holland, 1841-1914: Inventor of the Modern Submarine* (Columbia S.C.: University of South Carolina Press, 1998). All information on Holland comes from this volume. Morris researched his topic heavily. This includes primary sources that had to be difficult to find.

human propulsion. There was no air system to trim the submarine nor an air induction system for the crews to breathe. But towards the end of the nineteenth century, the submarine had components that would change its impact. It was the tools, components, and metal that were produced towards the end of the century that helped advance the development of the submarine. It took imagination in design and skill to produce components like the internal combustion engines and air systems for submersion. It also took imagination and tenacity to put it all together to build a true workable submarine.

John Phillip Holland

Born in 1841, John Phillip Holland was a “wee bit” of a man and some said a “bit touched.”³⁰ Slight of build and very shy, Holland was a driven man. His first language was native Irish, learning English when attending the English-speaking St. Macreehy’s National School. Holland taught mathematics at several schools in Limerick until 1873 when poor health forced him to move to the United States. He initially worked for an engineering firm and then returned to teaching in New Jersey. While still in Ireland Holland had designed a submarine, but was unsuccessful in soliciting funding. He refined his design after arriving in the United States hoping for a contract with the US Navy.

Undaunted after his first funding refusal, Holland approached the Fenian Brotherhood, a local Irish men’s group, who financed the building of Holland’s first boat, *The Fenian Ram*, from their “skirmishing fund.” The Brotherhood was an anti-British group which planned to use it against British shipping. The *Fenian Ram* was small, less

³⁰ Morris, *Holland*, 22.

than twenty feet long, and could hold four people at the most. The displacement was one long ton.³¹ It was built with hot riveted iron plate.

The *Ram*, a sea-going vessel using ballast to submerge, could not maintain negative buoyancy while at rest. To submerge, the hull needed to keep going forward. The pressure of the sea on the boat's horizontal planes kept it under water. For propulsion, the boat used a fifteen-horsepower, two-cylinder Brayton piston engine. The engine, when used for undersea travel, depended on the atmosphere within the vessel to run. There was no battery propulsion.

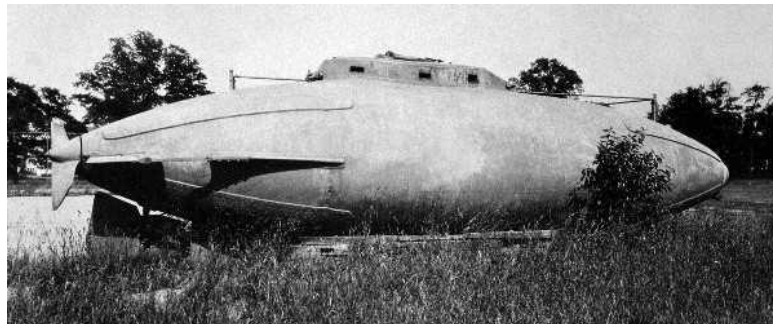


Figure 1. *Fenian Ram*

The *Ram* (above) had armament. It could fire an explosive projectile from a nine-inch-diameter pneumatic tube positioned on the surfaced waterline just like a modern-day torpedo tube. Although not practical in a military sense, this was the world's first

³¹ "Difference between Long Ton, Short Ton and Metric Ton," *Online Conversion*, [Http://www.onlineconversion.com/faq_09.htm](http://www.onlineconversion.com/faq_09.htm), Accessed January 6, 2016. A long ton is equivalent to 2,240 pounds. The term long ton has some use today measuring displacement of ships and in the trade of elemental products like Sulphur.

consistently-running submarine that could fire a torpedo from a distance and not just place it against a ship's hull.

Yet, the *Ram* could not submerge completely. Although the *Ram* had a weapon it could deliver from a distance and an engine, it had no stealth. The *Ram* could be seen from a mile away; not only did it have no element of surprise it could not retire from a battle covertly. It could not use the sea for camouflage or for protection.

Between 1878 and 1888, Holland built four submarines using internal combustion engines for surface running and electric batteries when submerged. Each submarine eventually failed but gave Holland the experience and knowledge he needed to succeed with the U.S. Navy. Officers of that era were surface officers, belonging to the early "Gun Club," whose thinking followed that of Alfred Thayer Mahan.³² Gun Club members felt weapons carriers like aircraft and submarines would have little effect on a Naval Surface war.

Early Submarine Strategy: Europe

Holland persisted with his submersibles until France became interested in the concept. The French military appreciated the concept of undersea warfare because of France's long coastline. The coast faced the English Channel, the open Atlantic and the Mediterranean Sea. France also shared borders with her archenemy, the Germans. Because of this land threat, the French had a large standing army. The army stretched the

³² Thomas Wildenberg, *Billy Mitchell's War with the Navy: The Interwar Rivalry Over Air Power* (Annapolis: Naval Institute, 2014). The Naval Gun Club was built of officers who believed the next war would be fought on the high seas by massive battleships. The term can be referenced here as the Gun Club thought battleships impervious to air attack until Mitchell proved different. More on Mahan later.

financial resources of the military so France could not sustain a large navy. Even if they could have, that navy could not have competed with the British naval powerhouse. So, the French changed their thinking on national security and their beaches. France focused on England's commerce. The French Navy planned to starve Great Britain by attacking commerce ships on the sea before these ships reached Britain. To do this, the French depended on their light cruisers. These ships were inexpensively and quickly built. If there was the threat of a major battle, the French held in reserve a small yet effective battle fleet. The idea was to divide and conquer, to lure away sections of the British fleet by getting them to chase the fast French cruisers. Once the British fleet was divided, a larger French fleet would come out of port and destroy the remaining, weaker British fleet.³³

But the French still needed to keep their shores protected from blockade. A surface ship could not take on several blockading ships, so they needed an invisible ship that could fight and retire without getting sunk. The submarine was the perfect ship for this application. The concept of a submarine for coastal protection pushed the French to be the first to design and build submarines on a strategic scale.

This action by the French captured the American Navy's attention but the United States envisioned different applications than the French. The U.S. Navy saw the submarine as a complement to the existing coast artillery or a scout to warn of an approaching fleet but not as a fighter. Seven bidders vied for the single submarine the

³³ Clay Blair Jr., *Silent Victory: The U.S. Submarine War against Japan* (Annapolis: Naval Institute Press, 1975), 35.

U.S. Navy solicited, and Holland won. The tale of Holland's first boat for the navy was filled with frustrations, competitor intrigues and demands by the naval hierarchy that often made no sense. Holland formed and reformed corporations to stay afloat, culminating in the Electric Boat Company (EB).

While working for the U.S. Navy, Holland also designed submarines, such as the *Holland VI*, for private entities. Fifty-four feet long and with one torpedo tube, it was Holland's masterwork. Though it was the best submarine of its time, the U.S. Navy had no interest in the *Holland VI*. After multiple demonstrations, two naval officers finally took notice, one being Admiral George Dewey of Manila harbor fame and the other, Richard Wainwright, then the superintendent of the U.S. Naval Academy. Finally, with the endorsements of these two men, the Navy signed on. On October 12, 1900, The US Navy christened the *Holland VI* the *USS Holland*, Submarine Hull Number 1.³⁴

By 1910, Holland's EB supplied the U.S. Navy with eleven more gasoline/battery powered boats. Three of the boats were eighty-two feet long with two torpedo tubes, five were 105 feet long with two tubes, and three were 135 feet long with four torpedo tubes. These boats were primitive by almost any standard. They were so undependable that most required other, larger ships to transport them from port to port on the high seas. Some went to Manila and Guantanamo Bays. Five of them miraculously steamed to the Panama Canal and made it. Five remaining boats stayed in the United States, defending the coast. More importantly, a couple of these submarines became training vessels for the new branch of the United States Navy, the Submarine Corps.

³⁴ Blair, *Silent Victory*, 29.

The European continent did not stand still watching France and the United States develop undersea weapons. Companies like Great Britain's Vickers Company and Germany's Krupp began to develop submarines. All the experimentation with undersea vessel production, this inventing, trial and error, led to the decision that gasoline engines were too dangerous, as explained above, and the introduction of the diesel engine.

Although a primitive idea of a submarine was now becoming a workable apparatus, there was a long way to go. These boats were dangerous environments in which to work and undependable. These vessels could not sail on the open ocean. They needed to be carried by a larger ship, thus they were mere boats. But nations by this point were becoming serious about the submarine. Countries were investing, not only in the idea of the submarine, they were investing financially and they were investing manpower into operating these vessels. The submarine and the idea behind submarine warfare went hand in hand. The submarine had come far enough that countries were initiating submarine schools and using some of these rudimentary submarines for training purposes. These covert vessels were ready for the next step in their evolution.

The First Torpedoes

As mentioned, before World War I, battle on the seas meant battle between ships. Although there might be miles between ships, they were still visible to one another. They had to be visible to one another for the ships to be able to target one another. The ideal ship to own on a naval battlefield was an invisible ship, a submarine. This ship needed a perfect weapon, a weapon that could travel under water.

Underwater weapons have been around for over 150 years. During this time, torpedoes were what we today call mines. For a torpedo to explode, a ship's hull needed to contact it. These types of torpedoes were often attached to a line that was anchored in the bottom of a river. Or they floated down a river in groups, sometimes into an estuary like New Orleans, during the American Civil War, where ships were trying to sail up the Mississippi River to attack a fort.

Some bays or harbors were blockaded by torpedoes so that enemy ships could not enter the harbors to resupply their military or their logistical support like armaments, gunpowder, clothing, or food. Admiral David Farragut had to go against torpedoes in his attack on Mobile Bay (Damn the torpedoes, full speed ahead!). The torpedoes were very powerful, deadly and destructive. However, they were essentially static weapons. If the flow of a river could not float a torpedo into a ship's hull the ship needed to run into the torpedo to set it off.

The Naval Undersea Museum in Keyport, Washington exhibited Torpedoes of the Civil War during the summer of 2015.³⁵ This exhibit was put together by curator Mary Ryan and included very rare actual torpedoes from the Civil War, including the Fretwell/Singer mine. Texans John Fretwell and E.C. Singer invented lantern shaped mines that anchored on the bottom of waterways. A ship contacted the mine and knocked a heavy plate off the top. As the plate fell it pulled a pin that released a spring-loaded plunger. The plunger exploded a percussion cap that detonated the mine.

³⁵ The following information on Civil War Mines comes from Curator Mary Ryan's exhibit at the Naval Undersea Museum at Keyport Washington. Exhibit date summer of 2015.

The Horological mine was a mine made of boiler metal. It was approximately two feet in diameter and twelve inches tall. It was donut shaped and included a clock mechanism in the middle. Once the clock reached a preset time, a spring released a hammer that exploded a percussion cap that detonated the gunpowder inside. This was a floated mine.

Gabriel Rains designed the keg mine using a wooden barrel. This was wrapped with strips of metal and its ends were conical, streamlining the shape. Contact points sat in the middle of the barrel and, when touched by the hull of a ship, the pressure triggered a chemical primer to detonate the gunpowder in the barrel. This mine could be anchored or floated.

The frame mine was made from artillery shells mounted on heavy timbers. These mines contained chemical primers. They were placed in rows on a timber, like a hair comb, and placed under the surface of a river. The pressure of contact would ignite the gunpowder within.

Electric mines were both floated and submerged. They were made from boiler metal and connected to the shore by telegraph wire. Inside the mine was an electric exploding device. Some of these exploders were nothing more than a telegraph key that would strike down on a percussion cap. When a ship came close to or grazed the mine, someone on shore connected the wires to a battery for detonation. These mines became very undependable later in the war for the Confederacy as there was a limit on insulated wire. These were the first wire line, or wired guided, armaments.

Spar mines were used by both the Confederacy and the Union navies. These consisted of an explosive charge attached to a spar, or long pole. The charge had a spear point on the end. The *CSS Hunley*, one of the very first submarines, used a spar torpedo to sink the USS *Housatonic*. Unfortunately, the *Hunley* was lost during the mission. A Union naval force attacked the small ironclad *CSS Albemarle*, led by Lt. William B. Cushing, and sunk it with a spar torpedo. These semi-static torpedoes were state of the art coming out of the Civil War.³⁶ What these navies needed was a self-driven undersea weapon, an automobile torpedo.

British engineer Robert Whitehead, a pacifist, hated anything to do with war and deeply disliked the military.³⁷ Whitehead hated anything to do with killing to the point that he became a vegetarian. In his younger years, in the mid-1850s, Whitehead worked in the shipyard trade designing ship engines and boilers for steam ships in France. At the time these products were on the cutting edge of shipbuilding. The company he worked for produced products for the Austrian Navy. In the 1860s, Whitehead met a retired engineer with the Austrian Navy, Giovanni Luppis, who, in 1860, had produced the first prototype of a self-driven torpedo. This was a true prototype as it was a miniature version of a small, explosive-carrying craft. It traveled half submerged, powered by a very large clockwork spring and steered from the shore by wires. This was not very impressive but Whitehead was intrigued. He joined Luppis and together they constructed a full-scale

³⁶ Chaffin, *Hunley*, 136.

³⁷ Robert Cannon, *Hellions of the Deep: The Development of American Torpedoes in World War II* (University Park Pennsylvania: Pennsylvania University Press, 2006), 22-25. All information on Whitehead and the early development of his automobile torpedo comes from this volume.

model. They met with numerous problems. The drive system failed, the craft's range was limited, and the steering proved to be too complicated. The two of them eventually gave up. Whitehead, however, could not get the possibilities out of his mind. He thought that if he could create a weapon that could totally submerge it might be so terrifying that it could promote peace.

Between 1862 and 1866, Whitehead worked with his twelve-year-old son and a workman for two years on his first, submerged, automobile torpedo. Forgetting about a shore launch, Whitehead and his collaborators decided to design a weapon that could be launched from a ship and travel in a straight line to its target. Although no drawings survive of the torpedo, it was about twelve feet long, fourteen inches in diameter and shaped like a cigar. To prevent roll, it had fins along the entire body. It was powered by a small rotary engine that was powered by compressed air that drove a propeller protected by a circular iron guard. The body was made of boilerplate. It carried twenty pounds of dynamite for a warhead. The "Luppis-Whitehead" torpedo came before a committee of the Austrian Navy and was successfully adopted.

The Luppis-Whitehead torpedo could not hold depth. Early models would porpoise up and down, sometimes skimming the surface while at other times almost bottoming. It took two years but Whitehead came upon the solution, as the story goes, in a dream. He installed a hydrostatic disk that flexed in and out by water pressure. If it went too deep it would flex in, too shallow and it would flex out. This was connected to two elevator levers that would raise or lower the craft as needed. Along with this, a

pendulum acted as a damper. The additions resulted in a fairly-stable machine.

Whitehead called his depth stabilization invention “The Secret.”

Word of the torpedo successes soon traveled, and in 1870 the British Admiralty purchased their first Whitehead torpedoes. In 1871, they bought the plans for the torpedo for 15,000 pounds, sterling and began producing them themselves. The Germans also began producing the Schwartzkopff torpedo in 1870 (probably from plans stolen from Whitehead’s home). In 1909, a major design change improved the drive system. Instead of using compressed air to drive a rotary engine, compressed air sprayed burning fuel oil into a combustion chamber, while adding a spray of water to control heat and generate steam which in turn drove a piston engine. As will be shown, this was the basic theory behind the Mark XIV engine. The theory was applied to the World War II German Mark G&A, the British Mark VII, and the Japanese Types 89/95 torpedoes. The American militaries during the Civil War began with basic ideas for underwater weaponry. By World War II the situation became highly technical and the art of making machines to sink ships had become finely tuned with low tolerances that ironically led to high failure rates.

Underwater Warfare Going into World War I

During World War I, science and technology of weaponry took a major leap, including recoil artillery like the French 75, the Maxim water-cooled machine gun, armored tanks, poison gas, flamethrowers, tracer bullets and interrupter gears on aircraft

propellers and machine guns. Perhaps the most rapid advancements in scientific development came with the submarine.³⁸

At the beginning of the war there were about 400 submarines in the world's navies. Most were gas powered and considered totally unsafe for any combat purposes. France led the world with 123 boats, but they hardly had any diesel power and many were old. Britain was second at seventy-two, seventeen being diesel. Russia had forty-one submarines and the United States was fourth with thirty-four, only twelve of which were diesel. Germany came in at fifth with twenty-four, half of which had the new diesel engines.³⁹ At the beginning of the war, several of these boats were so new they were still undergoing shakedown cruises.⁴⁰

Tactics and Strategy – Alfred Thayer Mahan

New weapons and their implementation have often been problematic. The battle between ironclads *Merrimac* and *Monitor* changed sea warfare.⁴¹ No longer did ships need to be built of wood. With better power plants, steel siding and without dependency on the wind, the new navies of the world needed to change tactics and strategy. After the Civil War, the United States Navy witnessed the changing science and technology of war,

³⁸ Ian Westwell, *The Illustrated History of the Weapons of World War One: A Comprehensive Chronological Directory of the Military Weapons used in World War I, from Field Artillery and Machine Guns to the Rise of U-boats and Allied submarines* (London: Southwater, 2000).

³⁹ Blair, *Silent Victory*, 42-53.

⁴⁰ *The Showboat* (no publishing history), 2. The initial long term evaluation cruise of a ship is called its shakedown cruise. The Battleship USS *North Carolina*'s shakedown was done out of New York Harbor. The presence of the ship and the articles written in the newspapers concerning its shakedown led the local New York populace to nickname the ship "The Showboat."

⁴¹ Jack Greene, *Ironclads at War: The Origin and Development of the Armored Battleship* (Boston: Da Capo Press, 1998), XVII.

adjusting their overall strategy. Captain Alfred Thayer Mahan, seeing the changing times, conceived of a plan of national destiny relying primarily on sea power.⁴²

Mahan, who at the time was a little-known professor at the Naval War College, thought that if the United States was to move forward militarily, it would need to commit fully. His imperialistic plan recognized that if a nation wanted to progress it needed to expand economically. Mahan's theories, calling for expansion of foreign trade, went against the isolationism of his time. He felt the US should build a merchant navy like none other in the world. This was a tall idea, as he was talking about competing on the seas with naval powers like Great Britain. Mahan thought that increasing the size of a merchant navy would increase the size of the Gross National Product. Having this size of a merchant navy required a network of oversea bases, ports and harbors for refueling and maintenance. Also, the times dictated protection for a merchant navy this size. Mahan further argued that the United States should build a navy equal to or better than any other. If an enemy threatened the merchant fleet, the oversea bases or the continental United States, this massive fleet would sortie, contact and defeat the enemy in a colossal, mid-ocean battle.

The United States Navy adopted the Mahan's philosophy. Money and men poured into building a huge merchant marine and navy. The submarine, however, did not figure into this strategy. The submarines, at that time, could not make a journey across the Atlantic, let alone steam along with a fleet at high speeds. Going into the war, the United

⁴² Alan Westcott, ed., *Mahan on Naval Warfare* (Mineola, New York: Dover Publications, 1941). This is a ponderous yet informative volume on Mahan and his theories. All information concerning Mahan are taken from this volume.

States did not consider using submarines for any purposes other than coastal defense or scouting.

Blockade: Gentlemen's War Part One

Once World War I began, the British imposed a blockade against the Central Powers. Germany had a strong navy but no one, not even the United States, could match the British. Germany's strategy vacillated during the war. During the early days, Germany decided to send its small submarine fleet against the British blockade.⁴³ These were totally offensive patrols. The submarines were looking for a fight. It took the German Navy time to gear up, so these German submarines were older. The Germans, effective with what they already had, knew that to be effective against the British, they needed to produce better weapon carriers.

On September 22, 1914, three months into the war, the German submarine, U-9, attacked the British cruisers, *Aboukir*, *Cressy* and *Hogue*, sinking all of them. This stunned the world, showing the submarine as an effective weapons platform. It also brought up questions of honor.

When the war began, the Germans felt that the British blockade was illegal and protested it to neutral nations. Under international law governing warfare on the sea, warships of the British fleet had the right to sink or at least capture any enemy merchant or passenger vessel. However, they were required to first remove and care for any

⁴³ Edwyn A. Gray, *The U-Boat War 1914-1918* (London: Leo Cooper, 1972). This book ties in with Blair's views but in much greater detail. Gray is also an expert on 19th Century torpedoes.

passengers or crew traveling on the vessel. The same laws gave any blockading country the right to board and search vessels flying neutral flags to make sure they were not covert, or disguised, enemy warships. No ship belonging to the Central Powers had any intention of cooperating with this but neither did the United States, or anyone else for that matter.

During the late nineteenth and early twentieth centuries, military men held standards and ideas about proper war conduct. It became apparent at the Paris Peace Talks in 1919, that many felt that stealth, despite of or because of its advantages, was dishonorable. Surface ship commanders hated the submarine for no other reason than it was un-gentlemanly to sneak up on enemies to kill them. Some men, like US Secretary of the Navy Josephus Daniels, deemed the U-boat as immoral as poison gas.⁴⁴ “I believe all submarines should be sunk and no more should be built by any nation, if and when the League of Nations becomes a fact,” said Daniels.⁴⁵

Since the German submarine force had some success in the Atlantic, the German Naval Staff argued that these boats should be used to form their own blockade of the British Isles. Admiral Von Tirpitz had his doubts. There was only a dozen or so boats that performed well enough to be worth sortieing. Von Tirpitz had in mind a gentleman’s war on the high seas. The submarine proponents thought this foolish. Boarding and searching neutral vessels, to make sure they were not enemy ships in disguise, would expose the submarine to shelling. The main idea behind submarines was that they could hide.

⁴⁴ Margaret MacMillan, *Paris 1919: Six Months that Changed the World*. (New York: Ransom House Trade, 2001), 177-182.

⁴⁵ MacMillan, 1919, 178.

Expose them and they lost all tactical advantage. But to many, including Von Tirpitz, unleashing his submarines on enemy shipping went against their moral grain. Also, Von Tirpitz was not sure it would work.

After arguing for months, Germany's pro-blockaders triumphed. In February, 1915, the Germans informed the world they were establishing a war zone around the British Isles and all ships hostile to the Central Powers were subject to attack. Care would be taken to avoid attacking any neutral ships, but neutral countries sailing these waters would do so at their own risk.

After the sinking of the three British cruisers, the Germans had little success, sinking only a small fraction of the tonnage getting through to Great Britain. One factor was the Q-ship,⁴⁶ a heavily-armed vessel disguised to look exactly like the type of target the submarines sought. These could be merchant sail boats, innocent-looking merchantmen freighters, or tramp steamers. The typical Q ship had apparent cabins or cargo on deck. The cabins were roofless with collapsible walls. Inside these false cabins, or underneath cargo tarps, lay armaments. When a submarine surfaced to search the vessel, the armaments quickly came out of hiding and into use. These might include a four-inch, quick-firing naval deck gun, a couple of twelve pound canons, assorted-caliber machine guns and rudimentary underwater bombs set to detonate at a prescribed depth, later called depth charges. In truth, the Q ships were decoys, offensive units disguised as hapless, would-be victims. The Q-Ships created a problem for both sides of the conflict.

⁴⁶ Deborah Lake, *Smoke and Mirrors: Q-Ships against the U-Boats in the First World War* (Stroud, Gloucestershire: The History Press, 2006). The following information on Q-Ships is taken from this volume.

The most obvious problem was for Germans submarines. As mentioned, approaching a Q-ship with a board-and-search party could expose the German submarine to attack or sinking. Q-ships sank over twenty submarines during the war. If the Germans had not relied so much on submarines there would have been no need for Q-Ships. Yet, if German submarines had not been so worried about fire from Q-ships posing as neutral ships, they might not have resorted to unrestricted warfare later in the war.

Unrestricted warfare brought significant tactical results for Germany, but then disaster for German strategy. U-boats sank the *Lusitania* and the *Arabic*. Included in the 1,200 lives lost on the *Lusitania* were 126 Americans. The world was shocked. Something like this could bring the Americans into the war. Besides, there was still the matter of honor. The *Lusitania* had no warning before it was fired upon. After these sinkings, the Kaiser himself put such strict limitations on the U-Boat officers that the campaign was abandoned.⁴⁷

By 1916, with no improvement in the German military situation, the land conflict in stalemate, the German overall military staffs argued for a resumption of the U-boat campaign. Germany's boats had grown bigger, more powerful and trustworthy on the seas. Many were coming off the ways every month. In March of 1916, almost a year after the sinking of the *Lusitania*, the Kaiser relented and gave the go-ahead to resume unrestricted submarine attacks. This was considered the second phase of Germany's blockade response. Immediately, a U-boat attacked a cross-channel packet.⁴⁸ Though the

⁴⁷ Gray, *U-Boat War*, 142.

⁴⁸ Gray, *U-Boat War*, 143. Packets were steamers that carried the mail. This was, then, not just an ordinary ship. It carried official, yet civilian, government employees along with other passengers.

packet did not sink, fifty out of 436 men women and children were killed by the torpedo explosion. U.S. President Woodrow Wilson, already outraged over the *Lusitania* incident, was further enraged. He demanded the Kaiser back off passenger ships and freighters or the United States would sever diplomatic relations. The Kaiser acquiesced yet again, for a while.

By 1917, setbacks on the continent and in the Middle East made the German military press the Kaiser again to send submarines against the blockade and warships of the Allies. The German Navy assured the Kaiser it would prevail if the United States came into the war.⁴⁹

The Submarine Comes into its Own

This became the beginning of the submarine era. By the time of this third and final phase of Germany's U-boat campaign, they had built a dependable vessel, one that could travel great distances, contact the enemy, sustain action and retire intact. On February 1, 1917, the Germans sent fifty-seven dependable boats into the Atlantic.

German U-boats sank over a half million tons (the preferred unit of measurement for fleet strength or damage done) in February and March, then 800,000 tons in April. Sinkings remained high for months, shutting off the British Isles and almost starving them. This success created major consequences for Germany.⁵⁰

The sinkings changed the United States' isolationist thinking. On the third day of the campaign, President Wilson broke with Germany and withdrew diplomatic relations.

⁴⁹ G.J. Meyer, *The World Undone, The Great War, 1914-1918* (New York: Bantam Dell, 2006), 610- 649.

⁵⁰ Gray, *U-Boat*, 200.

On the twenty sixth of February, Wilson ordered US merchant ships to be armed. On April sixth, President Wilson asked Congress for a declaration of war to make the world safe for democracy. The United States Army and Marine Corps were heading to the continent and the U.S. Navy was opposing the navy of Germany.⁵¹

The US Navy went into the war clinging to the ideals of Mahan. They waited impatiently for the German Navy to sortie and gather in the mid-Atlantic for a showdown on the high seas. The US Navy officer in command in Great Britain, Admiral William Sowden Sims, seeing this was not going to happen, grew frustrated about the naval hierarchy's attachment to such antiquated strategies.⁵² Sims requested destroyers to counter the U-boat stranglehold on the British. Naval command in the United States sent six ships as a goodwill measure to the British.

When the Allied powers finally realized that there was to be no great mid-Atlantic battle, they sprang to work quickly and efficiently. The U.S. Navy concentrated on building destroyers, mines, and other anti-submarine vessels. Most importantly, they convinced the British to adopt a convoy system. Before this, ships approached the British Isles in great numbers but in a helter-skelter fashion and without protection. The convoy system gathered all ships into large groups, traveling with destroyers on their flanks, herding and protecting them from origination point to home port. This made a significant difference, as merchantman sinkings plummeted.⁵³

⁵¹ Barbara A. Tuchman, *The Zimmerman Telegram* (New York: Random House, 1958). Tuchman argues that the U-Boat threat was significant but the Zimmerman Telegram was the final straw that led to the declaration of war by the United States.

⁵² William Sowden Sims, *Victory at Sea* (London: J Murray, 1920). Facsimile copy. Sims won the Pulitzer prize in 1921 for this volume.

⁵³ Blair, *Silent Victory*, 29.

The British often successfully engaged the U-boat threat with their own submarine fleet. This impressed Sims. Sims requested the U.S. Navy send its own submarine fleet to the waters of the war zone. The U.S. Navy approved and sent a submarine commander, Captain Thomas Hart,⁵⁴ and young diesel expert, Lt. Commander Chester Nimitz,⁵⁵ to sail with this small fleet.

Problems arose from the beginning. Since the U.S. Navy had not been in war and their central strategy favored surface ships, little if any improvement had been made in the submarine fleet. Nimitz and Hart had difficulty finding enough submarines to make the trip, let alone be ready for combat. Out of forty-six boats, only half of all the U.S. subs were diesel. The rest were ready-to-explode, gasoline-powered units. Only fifteen potentially-effective submarines would sortie. Four of these were doing coastal watch in Hawaii. Finally, eleven combat-worthy vessels and Nimitz's old boat, the *Skipjack*, sailed to Great Britain. Four of these were K-boats and seven were L-boats. These boats could not compete with the British, let alone the Germans.⁵⁶

The U.S. contingent did not sink any German submarines, despite several contacts, but what they got out of the war was exposure. During the war, the U.S. Submarine Service freely begged, borrowed and stole submarine technology from their ally, and then when the war ended, they took freely the science and technology from their

⁵⁴ Admiral Thomas Hart, Navy Biographies, Blair Papers, Box 74, File 1. Hart Commanded all Naval Forces in the Southwest Pacific from Manila Bay at the outbreak of World War II.

⁵⁵E.B. Potter, *Nimitz* (Annapolis: Naval Institute Press, 1976), 38. Nimitz was CINPAC, Commander in Chief United States Pacific Fleet during World War II.

⁵⁶ Blair, *Silent Victory*, 43. Numerous books on the World War I German U-Boat are available. None could be found that specifically concerned the American submarine during the First War. Investigating this boat by boat seems to confirm this number.

enemy. Through this they adapted the far superior engines, guns, torpedoes, periscopes, sonar, air conditioning, screws, pumps and many other features from the British and Germans. The British boats could travel farther, faster, dive and surface more efficiently than American submarines. The German boats were superior to those of the British. Along with the technological information they gained, the Americans found that the British and German tactics were better, more efficient and much more deadly than theirs.

The Germans lost the war but the German U-boats were not defeated. Rather, they were neutralized. Some fascinating facts emerged. One hundred seventy-eight U-boats were lost. The British submarine service sank eighteen U-boats, Q-ships sank a little more than that, and aircraft protecting the submarines sank a third of that. Destroyers, auxiliary ships, mines and unknown causes sank the rest. For every U-Boat sunk, the allies lost thirty-two ships to the Germans.⁵⁷

The British did not have success with submarines on the level that Germany did during the war. Undersea warfare was somewhat of an afterthought. Great Britain was looking for a victory against the Imperial German Navy equaling Vice Admiral Horatio Lord Nelson's feat at Trafalgar, off the coast of Spain, in 1805. A distinct battle happened off the coast of Jutland, but unlike Nelson's decisive victory at Trafalgar, the winner at Jutland is still debated today.⁵⁸

⁵⁷ Gray, *U-Boat*, 259.

⁵⁸ Geoffrey Bennett, *The Battle of Jutland* (London: Wadsworth, 1964). The printing of this and several other books marked the centennial of the Battle of Jutland. Most, including this book, were concerned with who won the strategic battle versus who won the tactical battle. The debate goes on. Information on the Battle of Jutland come from this volume.

European naval operations during World War I highlight two occurrences, the Battle of Jutland and the submarine's impact on the world. As discussed, the outcome of the Battle of Jutland is still debated. The Germans saw the future of the submarine and integrated it into their naval strategy early. This produced considerable success for them. Germany sank a great deal of shipping. It cost them as well. If not for unrestricted warfare, the United States may have not entered the war or may have entered the war later than they did. Regardless, the German Navy put a lot of effort into developing the submarine. After the World War I the British and the Americans stole their technology. The world now had an undersea vessel that was on its way to becoming an effective weapons platform. Even so, this new way of warfare did not sit well with everyone.

Interwar Years: Gentleman's War Part Two

Although the submarine services had gained respect within naval circles, Germany's U-Boat campaign against merchant (civilian) shipping had resulted in the worst image possible. If there had been a choice between poison gas or the submarine, the submarine would have lost the contest, especially in Great Britain.⁵⁹

Great Britain suffered greatly from the submarine. During the Paris talks, the British Admiralty offered to abolish their submarine force if everyone else would do the

⁵⁹ Giles Milton, "Winston Churchill Shocking Use of Chemical Weapons," *The Guardian*, September 1, 2013, <https://www.theguardian.com/world/shortcuts/2013/sep/01/winston-churchill-shocking-use-chemical-weapons>. Accessed January 6, 2016. This article contains letters and memos written by Winston Churchill concerning the use of poison gas. Churchill was not squeamish about using mustard gas on the Germans had they crossed the channel during the Battle of Britain. The submarine was a much more dangerous weapon.

same.⁶⁰ Great Britain, an island empire, was totally dependent on sea transport for survival. If another war were to occur, a submarine blockade could potentially starve the British. In addition to this, German U-boats sank twenty-eight Allied capital ships in World War I. An unseen predator could take even the largest, best-trained navy out of action before the firing of the first shell. To some, such as Lloyd George, if submarines were undetectable, they were virtually invincible.⁶¹

In 1916, Canadian physicist Robert William Boyle, working for the British, undertook an active underwater sound project, building prototypes of an early Sound Navigation and Ranging (SONAR) system.⁶² The British called this the Anti-Submarine Detection Investigation Committee (ASDIC).⁶³ The British felt that ASDIC rendered undersea vessels obsolete. Also, because submarines had limited dive capabilities, aircraft could easily spot submarines from the air. This made the submarine less invincible, and thus less frightening. Simultaneously, the aircraft carrier was gaining strength. The US Navy deemed efforts applied to aircraft carriers more important.

After the World War I, the United States returned to its pacifist, isolationist ways. Enough precious money had been spent on the navy and if more ships were needed, they should build a man's navy with surface ships, not a clandestine navy with surreptitious, devious submarines. Many British agreed. "These pests ought to be disposed of," said

⁶⁰ MacMillan, 1919: 180-182.

⁶¹ MacMillan, 1919, 177.

⁶² Jeffrey Proc, "Sonar and Asdic Systems in the RCN," last modified January 2016, *ASDIC, RADAR and IFF SYSTEMS used by the RCN - WWII and Post War*, Accessed January 15, 2015, http://jproc.ca/sari/asd_gen.html. Boyle was working under the British Board of Invention and Research.

⁶³ "Sonar and Asdic Systems." Asdic was used by all powers, even Japan, by the advent of World War Two.

British Prime Minister Lloyd George.⁶⁴ King George V of Great Britain joined in, pushing the abolition of submarines.⁶⁵

There was a paradox: After the war, there was talk of peace yet the United States and Great Britain involved themselves in naval arms-building. Making matters worse, the United States and Great Britain were concerned about Japan's growing naval influence in the Pacific. In late 1921, the British proposed a naval arms limitation conference. The United States concurred. President Harding called the Washington Naval Conference into session immediately.⁶⁶

The Washington Naval Conference showed the world how tired of battle the allies of the Great War were and how much they mistrusted the other countries that had shared in the spoils. The total tonnage of the battleships among the U.S., Great Britain, and Japan was a big concern. The submarine was also a bone of contention. The British offered to scrap their entire submarine fleet and disband their highly-trained submarine force if other powers would do the same. The French and the United States navies would not accommodate the British. The French, certainly one of the weaker powers, depended on the submarine for coastal protection and thought the abolition of such a weapon was not thoroughly considered. The United States continued to look at the submarine as an impressive coast-watching vessel, one that was effective yet inexpensive. It was perfect to protect interests in the Philippines, Caribbean and along the continental American

⁶⁴ MacMillan, 1919, 177.

⁶⁵ MacMillan, 1919, 179.

⁶⁶ Eric Goldstein & John Maurer, eds. *The Washington Conference, 1921-22: Naval Rivalry, East Asian Stability and the Road to Pearl Harbor* (London and New York: Routledge, 1994). This volume contains different views on the eventual treaty. All this paper's information concerning The Washington Naval Treaty is from this book.

shore. To counter the British desire to eliminate the submarine, the French and U.S. Navies suggested limiting submarines to 90,000 tons for each state.

Just as the French and the Americans would not yield on the submarine question, the British would not agree to limiting tonnage. The issue worsened for the American submarine lobby. Former Secretary of State and current United States Senator, Elihu Root of New York, proposed several resolutions that would restrict the wartime use of submarines, including the stop, board, and search tactic before a submarine could sink another vessel. The U.S. Navy's General Board thought this ludicrous. The submarine was a legitimate weapon of war and restrictions like this would result in too many ambiguities in the rules governing submarine use.

In the end, the Washington Naval Conference resulted in setting the tonnage of capital ships built in the United States, Great Britain, and Japan. In addition, the United States was not to invest any more in the strengthening of bases west of Pearl Harbor, including Midway Island, Guam and the Philippines. The Washington Naval Conference did nothing directly affecting the use of submarines in warfare. The 90,000-ton limitation never took effect.⁶⁷

We know now that Nazi Germany did not abide by the Versailles treaty nor did they abide by anything that came out of the Washington Naval Conference. For instance, Germany could produce submarines for other countries but not for themselves. They were not allowed to train any naval officers as submariners. They circumvented these restrictions by sending "product technicians" along with the sale of a submarine. German

⁶⁷ Goldman and Maurer, *Washington Treaty*, 232.

submarine officers would sail with Norwegian submariners on Norway's brand-new, German-built submarines to gain practical experience.⁶⁸ These German submarine officers went into World War II with plenty of experience.

Japan went on building. By the time of their attack on Pearl Harbor the Japanese Navy was far superior to that of the United States. Their Navy, and military in general, was better trained and more experienced because of Japan's invasion of China and South East Asia.⁶⁹

After the success of the submarine during the war, few powers would abide by agreements limiting its use. It was fortunate that the United States did not sign any type of treaty outlawing submarines. When World War II began, the United States was coming out of the Great Depression again as an isolationist nation, still limiting ship building per the Washington Naval Conference. If there had been the same type of limitations on submarines, the United States Navy would have been in even more dire straits than it was on December 7, 1941.

Designing the Fleet Submarine

Before World War I, the Navy set up a design competition between private companies and Portsmouth Naval Shipyard to construct submarines. Portsmouth boats were found to be superior to those of Electric Boat Company (EB) and Lake Torpedo

⁶⁸ Melanie Wiggins, "Pages from a U-Boat Commander's Career," *Naval History Magazine*, Volume 30, No. 5, October 2016, 48-53. Personal interview between Wiggins and Admiral Hans-Rudolf Rosing conducted March 21, 1995.

⁶⁹ Iris Chang, *The Rape of Nanking: The Forgotten Holocaust of World War II* (New York: Basic Books, 1997)

Boat Company (Lake Torpedo). Because of this, Portsmouth ended up with the most work.⁷⁰ There were reasons for this.

When submarine construction began, private shipyard construction companies dictated what the U.S. Navy would get. Of the major competitors, the Lake Torpedo, The Bethlehem Shipbuilding Company (BethShip) and the EB, the latter dominated the private industry. By 1914, EB had built most of the submarines in the Navy's fleet. A private manufacturer, looking for profits, lobbied for funding on Capitol Hill then told rather than asked the government what they needed. Lobbying paid off so well that, even when the Navy did not ask for submarines, they were included on invoices.⁷¹

Even before the Washington Naval conference, with the fiercely-contested Naval Act of August 29, 1916,⁷² the Congress of the isolationist United States authorized a construction program of 156 ships, including thirty new submarines. The Appropriations Act of March 4, 1917, added funding for eighteen more.

Funds for submarine construction in hand, the naval hierarchy began to address basic issues that they had neglected due to the submarine's low priority. The navy began to put a plan together to address design, construction planning, and construction itself. U.S. Naval submarine building at New Hampshire's Portsmouth Naval Shipyard swung into production. Private companies like EB and Lake Torpedo also began building

⁷⁰ Rodney K. Watterson, *32 in '44: Building the Portsmouth Submarine Fleet in World War II* (Annapolis: Naval Institute Press, 2011)

⁷¹ Weir, *American Submarines*, 52.

⁷² Joseph W. Kirschbaum, "The 1916 Naval Expansion Act: Planning for a Navy Second to None," (PhD Diss., George Washington University, 2008). This dissertation is a complete look at the Naval Act of 1916. It goes on to cover part of the Washington Naval treaty.

submarines but without any standardization. Some of the designs were seriously outdated before launch day.

When Germany showed the world the capabilities of submarines through the U-boat threat during the World War I, thinking changed. The navy and the country demanded bigger, better, faster, more dependable submarines, just like the ones Germany had. Instead of settling for what EB and Lake Torpedo gave them, the navy engineering bureaus sought more input and a greater role in the design and construction of the boats. Naval architects and engineers began providing expertise. This resulted in construction awards to Portsmouth Naval Shipyard and California's Mare Island Naval Shipyard, in addition to the private firms, for submarines for wartime use. Prior to this, Portsmouth and Mare Island were fleet repair and overhaul centers. In 1916, these private firms and the naval shipyards had to use design plans for the S-class submarine.⁷³ The private firms were now in competition with the United States Navy.⁷⁴

If a manufacturer fails to question what their product is intended to do or how the end users are supposed use it, the product will fail. The American submarine was no different. One of the factors hindering submarine production was that the United States Navy lacked consensus on the ideal strategical use for their submarines. During the Great War, it became apparent that the American submarine was inadequate for its envisioned role at that time, especially compared with the German U-boat. The United States Navy

⁷³ *History of USS-S-44* (SS-155) NPPSO Reel Number E-108, Roll AR 39 Record Group 78, Keyport. These boats were small at 906 long tons, had a 5,000-mile range, maximum surface speed of 14 knots, and a dive depth maximum of only 200 feet. 51 of these "older" S-Boats were built. Some, like the S-44 were overhauled and saw service in World War Two.

⁷⁴ Weir, *American Submarines*, 69-101. Weir's primary documents include tables of production from the Bureau of Ships that shows production increases.

knew that the submarine had a place in its fleet but did not know how they wanted to use it. If a submarine was to be used for coastal defense it need not be a hearty machine. Fuel storage and consumption would not be that consequential. Crew habitability would not be a concern either. But if a submarine was to go to sea it needed to be a dependable long sailing vessel for which crew comfort was a concern. The Navy at this point needed to answer tactical and strategic questions concerning the submarine.

War Plan Orange

After the First World War, the Japanese military and navy had the U.S. Navy worried. The U.S. military persisted with the Mahan philosophy. Though their European enemies had not cooperated with them to create the big battle on the sea, surely the Japanese would.

War Plan Orange was of Mahan thinking. The U.S. Navy assumed that if the Japanese attacked U.S. possessions in the Pacific it would begin in the Philippine Archipelago. American and Filipino soldiers would keep the Japanese in a holding maneuver, falling back southward on the Bataan Peninsula, just north of Manila. If needed, the U.S. and Filipino forces could fall back as far as Corregidor Island at the mouth of Manila Bay. Meanwhile, the U.S. Fleet would steam through the Panama Canal and gather with other forces in the Pacific, most of which were stationed at the little-known Pearl Harbor, Hawaii. The fleet would steam on to the territory of Guam to refuel, replenish and then steam to meet the Japanese fleet in a major, decisive battle. After defeating the Japanese navy, the U.S. fleet would blockade the Japanese Islands, eventually forcing the Japanese to surrender. While the siege was going on, parts of the

U.S. fleet would depart from the main force and convoy U.S. troops to relieve Bataan and Corregidor. Here, the horribly extended Japanese troops would fall.⁷⁵

The graduate school for U.S. Navy personnel is The United States Naval War College. All attendees studied War Plan Orange from the beginning of the century until World War II. This naval doctrine was so antiquated yet so strong that it influenced the building of the Panama Canal. War Plan Orange dominated the U.S. Naval hierarchy psyche in the interwar period and became famous among World War II historians because of the utter failure at implementation.

This plan depended on a much greater and more modern navy than the United States had produced. More importantly, it depended on the opponent doing exactly what you wanted them to do and United States military theater commanders making the right tactical decisions every time. The United States severely underestimated the Japanese soldier and sailor as fighting men. Dependence on War Plan Orange was a disaster waiting to happen.

By 1919, Naval War College problems called for submarines to operate by divisions, working in direct support of the fleet. They called for submarine divisions to go before the fleet to locate the enemy, scout, gather intelligence and disrupt communications if possible. But even with a limited mission, the contemporary submarine following the World War I was far too slow to sail with the fleet. The hierarchy of the U.S. Navy still viewed the disruption of commerce as ungentlemanly and

⁷⁵ Edward S. Miller, *War Plan Orange: The U.S. Strategy to Defeat Japan, 1897-1945* (Annapolis, Naval Institute Press, 2007). The Naval Institute points out that Miller put twenty years of research into this volume accessing formerly secret archives. All War Plan Orange information is from this volume.

distasteful. The navy also never seriously considered independent action by a submarine as a viable combat option.

German Influences

The Navy formed engineering standardization boards after the standard S-boat but technological and financial considerations limited the possibilities. For example, submarines at the time could not achieve or maintain the desired speed on the ocean using the American diesel engine technology of the time. Another example was crew habitability. Ventilation issues and power plant compartment temperatures threatened crew members' health and survival.⁷⁶

As mentioned, Great Britain took possession of several German U-Boats after the Armistice. The U.S. Navy decided it should have German submarines of its own. Officers and men of the U.S. Submarine Service sailed several German boats from Germany to America's East Coast. The officers who sailed these boats were astounded at the differences. The single most impressive German boat was the U-135, called the U-135 class or the U-135 design, against which the United States' wartime submarine, the S-class, would be compared. Just when the Navy had achieved a standard boat, they found the Germans had such technical superiority that the S-class was obsolete before it ever sailed in blue water.⁷⁷

Unfortunately, the German designs pitted interested parties against each other. The navy would not part with the German science and technology and the private

⁷⁶ Weir, *American Submarines*, 35.

⁷⁷ Weir, *American Submarines*, 74.

companies desired to design and build their boats to their own specifications with little input from the Navy. Within the navy, the engineering and technical bureaus, reluctant to abandon designs they had developed and built with American ingenuity, battled with the operation officers who sailed and would be fighting from these submarines, and dragged their feet on adopting German improvements.⁷⁸

The frustrated operations people favored the immediate production of new, improved boats over the continued wrangling among the engineering and technical bureaus and Naval Command. The conflicts about what to do with a submarine fleet, combined with what to do with the new technology, paralyzed the progress of submarines for years.

By 1930, American responsibility in the Pacific and Asia had changed. Thus, there was a need for a better equipped Pacific Fleet. Simultaneously, the navy completed a detailed analysis of German submarine design. A consensus of what to do with the submarine fleet emerged. Early favor for an 800-ton submarine started moving towards a larger 1,500-ton boat. To maintain speed, a boat this big would need power plants that would greatly affect the living conditions and maneuverability of the submarine.⁷⁹

Considering speed and habitability concerns, men like Commander Thomas Withers challenged the proposed role of a submarine as a fleet ship or its being used exclusively for coastal defense. Withers and most commanders preferred the submarine sail independently to take better advantage of the submarine's stealth capabilities, gather

⁷⁸ Watterson, 32-44, 78-91.

⁷⁹ Blair, *Silent Victory*, 35.

intelligence and attack enemy warships without the enemy knowing their position from the presence of the surface fleet.

Withers moved to the Naval War College in 1930, where he argued that submarine strategy should move to an exclusively offensive posture. Submarines should be used for independent attack positions and reconnaissance. Rather than focusing on speed, designers should make stealth, habitation and reliability in long range independent missions the priorities. For the first time, available design features met with strategic desires and a direction emerged.⁸⁰

Minds were now coming together to design a submarine to meet the requirements that submariners demanded.

Conclusion

Fifteen years ago, nobody would have thought a cellular telephone could be used in the same way as a personal computer. Nor could anyone have envisioned that this phone could have connected to the internet using radio waves or operated by touch only. When machinery like this becomes so modern and so complex, it is difficult not to become overwhelmed with both the machinery and the idea of what it does. The mind first becomes inured to it and then quickly takes it for granted. This same is true with the idea of a sea going vessel that sails under the surface of the sea. Like the smart phones of today, this was once truly the stuff of science fiction.

⁸⁰ Rear Admiral Thomas Withers, Navy Biographies, Blair Papers, Box 74, Folder 3.

This chapter has shown the development of the submarine from a hand driven semi-submersible to engine powered, ballasted diving machine to a true war machine that could dive hundreds of feet below the surface and deliver devastating weapons that could sink large ships. Because of its stealth, this machine was first feared and almost outlawed. But it was too good a weapons carrier and weapon to forgo. This type of sea vessel tipped the strategic and tactical balance on the seas. Countries like France, Great Britain, Russia and Germany had to have a weapon like this. The United States, a relative latecomer, saw its potential as well and jumped into development. Before the war, the United States was not serious about the submarine. After Germany's successes, the U.S. Navy decided that submarine development was an area they wanted to explore in depth. The problem was they did not know what direction to take it. As this chapter ends, we see the U.S. Navy discussing design parameters, serious about designing a boat that will meet future needs.

The torpedo went from a floating keg of gunpowder lit by a fuse floating down a river, to enclosed soldered compartments armed with alarm clocks to true automobile torpedoes. These torpedoes had rudimentary depth control as well as primitive steering. An automobile torpedo could do a lot of damage. The Germans proved this during the first World's War. This chapter ends with the U.S. Navy on the cusp of going forward with serious development of the Fleet Submarine and combat torpedo. Chapter Two describes the readiness for undersea warfare of the U.S. Navy going into World War II and sets the stage for the main story of torpedo failures, told in Chapter Three.

CHAPTER TWO

MODERN MARVELS

The USS *Halibut*

August 29, 1943, was a clear Sunday morning. The fleet Submarine USS *Halibut* had sailed from Midway Island to the Central Pacific and then to the coast of the island of Honshu, Japan. The *Halibut* cruised the surface of the sea all night, charging her batteries. At daylight, they submerged to remain invisible to enemy patrol planes and warships. The boat had completed five previous war patrols and was armed with twenty-four Mark XIV Torpedoes. The *Halibut* had a new commander, Lieutenant Commander I.J. Galantin, in the conning tower.¹

Ensign Ray Stewart stood watch on the periscope and noted that the green hills of Honshu were visible through the sub's periscope. Suddenly, Stewart spied a loaded freighter cruising close to shore. Unfortunately, the freighter's escort was a *Shigure*-class destroyer. Stewart alerted the new captain and Gallatin commanded, "Battle stations, torpedo!" The crew came alive and the boat's officers went to their fire control party stations. The *Halibut* made speed and maneuvered to 2,000 yards of the target. The Japanese Tin Can unknowingly maneuvered between the submarine and its intended

¹ Admiral I. J. Galantin, *Take Her Deep! A Submarine Against Japan in World War Two*. Pocket Books: New York, London, 1987. pp. 3-7. Galantin was one of the most successful submarine commanders in the Pacific in World War Two. This personal recollection is from his first patrol on the *Halibut*. This shot was made in August 1943, three months before the Mark VI issues were resolved. The three torpedoes fired from the *Halibut* during this enemy contact failed to explode.

target, the Japanese *Maru*, a type of merchant ship. Because of this, the freighter began to slip away. Galantin decided to shoot at the destroyer, a dangerous decision as destroyers were built to hunt and sink submarines.

The captain relied on the sonarman to tell him the course and speed of the destroyer on the surface. "Make ready tubes one, two and three," the executive officer (XO) commanded. The sonarman called the bearing of the enemy ship which was at 318. The captain turned the periscope to 318, confirmed, and the quartermaster called out the bearing mark.

The destroyer did not see the periscope. Galantin ordered, "Angle-on-the-bow, starboard thirty-five, mark the range, down periscope, all ahead two thirds."² He asked the Torpedo Data Computer (TDC) officer the course for an eighty-degree starboard track with zero gyros. "2-6-5," was the response. The captain ordered steering turned to 265 degrees.

The XO ordered outer torpedo doors opened. When the doors were opened, the captain told the XO that he would give a final bearing and then shoot. The torpedo room stood by. Galantin went into his final fire control commands. "Up scope. Final Bearing. Mark!" the XO called out with the final bearing of 336. The TDC officer responded, "Set, checking nicely." This meant the analog TDC had a solution to fire. Galantin gave the order to fire tube one. The XO repeated the order. The quartermaster pushed a plunger on the port bulkhead firing tube one. At six-second intervals, tubes two and three also fired.

² Galantin, *Take Her Deep*, 5. This is the location of the target in reference to the bow direction of the submarine.

Sonar called out that all torpedoes were running “hot, straight and true.”³ The crew waited for the explosions that would tell them the torpedoes they had just fired struck the hull of the Japanese destroyer, punching holes in her hull and soon sinking her. The crew waited until the pre-determined times of the hits. That time came and went. No explosions were heard. The torpedoes had failed to explode.

This fire control scene has been played out in dozens of World War II submarine movies. Thus, everyone knows that the best way to sink a ship is to punch holes in it, ruining the hull’s integrity, letting water rush in and sinking the vessel. Yet, using the ideal method for sinking a ship, the torpedo should not make actual contact with an enemy vessel at all.

Thesis and Organization

This chapter argues that to analyze how knowledge was constructed during the MK XIV/VI torpedo failure issue, it is necessary to look not only at the torpedo but also at the submarine as well as relationships between different military and civilian organizations and individuals. This chapter shows how the fleet submarines performed admirably but had a weapon that did not. It argues that the MK XIV torpedo with the MK VI exploder was so complicated that submarine crews, both commanders and torpedomen, were going to have trouble resolving issues concerning it.⁴

³ Galantin, *Take Her Deep*, 6. “Hot, Straight, and True” was a well- running torpedo. An experienced sonarman could determine any problems with a torpedo by the sound it made.

⁴“Torpedoes Mark 14 and 23 Types” *A Bureau of Ordnance Publication, Operation Pamphlet (OP) 635*, 24 March 1945. Keyport.

This chapter also explores how the United States struggled to decide on the best strategic use for the submarine and how that affected design, from the small S-Boats used in World War I to the state-of-the-art *Gato* and *Balao* Classes used during World War II. These latter models, the fleet submarines, truly were marvels of modern science. Yet, they were only as effective as their weapons, the torpedoes.

This chapter goes on to discuss the theories behind the most efficient way to sink a ship. Initially, the prevailing method for sinking a ship was exploding as many torpedoes against the hull of an enemy ship as was necessary. After World War I, experts came to believe exploding a torpedo several feet underneath a ship's hull would create the fluid dynamics that would "break the back" of the ship. This chapter discusses the reasoning behind this theory, the science and technical detail required to make it happen, and the efforts involved.⁵ It lays the foundation for the detailed discussion of torpedo failures in Chapter Three, by discussing economic and social pressures from torpedo shortages and other production issues, the lack of testing before implementation, and the complexity of the MK XIV/VI itself. Finally, this chapter introduces the men in command who would become the major players in the events to follow.

Designing the Fleet Submarine

Using the German U-135 class as a prototype, naval engineers and technicians made improvements. Size mattered with submarines. Space and weight versus power

⁵ Buford Rowland and William B. Boyd, *US Navy Bureau of Ordnance in World War Two* (Washington D.C.: Bureau of Ordnance, Department of the Navy, 1953), 99-101.

were as important considerations for a submarine as for an aircraft. For example, the heavier the sub, the more power it took to move through water. Sometimes a bigger engine in a smaller boat could create torsional vibration problems with propeller shafts. Putting more engines in a submarine doubles or quadruples the risk of failure. The lighter a submarine, the more difficult it was to control during heavy weather. When a submarine carried a compliment of torpedoes and men, it moved more slowly. The more people and weapons, the less room for basic components, such as periscopes, sonar, and air conditioning. A larger submarine had more room but it was slower and easier to spot under the surface from the air. There were always tradeoffs. By 1934, submarine design at 1,500 tons, cruising distance of at least ten thousand miles, three to four-hundred-foot dive depth, at least four torpedo tubes forward and two aft, hydraulic periscopes, and twenty knot surface speed prevailed as the best size for range, reliability, habitability and armament.

As mentioned, submarines designed before the availability of World War I German submarines to aid in design were obsolete before they ever sailed. These included the small, slower S-boats,⁶ whose torpedo tubes were too short to handle the MK XIV/VI,⁷ the large, slow-to-dive early V-boats (Classes V1, V2, V3,⁸ V4 –

⁶ Norman Friedman, *U.S. Submarines Through 1945: An Illustrated Design History* (Annapolis: Naval Institute Press, 1995). To describe the following submarines, I am combining information from this volume and the submarine histories from the National Archives.

⁷ S-11 (SS-116), Naval Publication and Printing Service Office, NPPSO- Naval District Washington Microfilm, Dictionary of American Naval Fighting Ships, Vol, V, 1976, Naval History Division, Department of the Navy, (Hereafter Cited as NPPSO-NFS) Reel Number G-108, Roll AR-45, Record Group 80, Original Microfilm Reels are located at National Archives, these records are sourced at Naval Undersea Museum at Keyport Washington, (Hereafter Cited as Keyport), 1-3.

⁸ *Barracuda* (SS-163), NPPSO-NFS Vol. I, 1959, Reel Number E-108, Roll AR-51, Record Group 78, Keyport, 1.

Argonaut,⁹ V5 - *Narwhal* and V6 - *Nautilus*),¹⁰ the smaller, the mid-sized V7 (*Dolphin Class*)¹¹ which was one of a kind, the underpowered later V-boats (V8 - *Cachelot*, V9 - *Cuttlefish*)¹² and the *Porpoise Class* (V7)¹³ which was getting closer to what the submarine commanders and command wanted in a fleet sub.¹⁴ Some of these submarines saw service in World War I, primarily for coastal defense, reconnaissance and supply roles. Some operated out of Australia. By 1935, the Navy began producing the submarines that would be considered the new Fleet Boats.

Salmon and Sargo Class submarines were the beginning of the *new* S-Boats. With four H.O.R. diesel engines, they could cruise on the surface at twenty-one knots. But these boats had issues. The H.O.R. engines failed so frequently that a submarine would often come into harbor on one engine, the other three having been cannibalized for parts. They cruised 11,000 miles on one fueling and dived to over 250 feet. With four tubes forward and two aft, and weighing about 1,400 long tons, these boats were approaching the ideal.¹⁵

⁹ *Argonaut* (SS-166), NPPDO-NFS Vol. I, 1959, Reel Number E-108 Roll, AR-2, Record Group 78, 1, Keyport, 1.

¹⁰ *History of USS Narwhal* (SS-167), NPPSO-NFS Reel Number H-108, Roll AR-229, Record Group 76, Keyport, 1-16.

¹¹ *Dolphin* (SS-169), VI, NPPSO-NFS Vol. 2, 1963, Reel Number HR-108, Roll AR-179 Record Group 76, Keyport, 1. There is a discrepancy here. This publication has this as Dolphin VI. Friedman shows this as Dolphin 7.

¹² *History of USS Cuttlefish* (SS-171), United States Navy Division of Naval History (Hereafter Cited as NHD) NPPSO Reel Number F-108, Roll AR-116 Record group 78, Keyport, 1-7.

¹³ *History of Ships Named Pollack* (SS-180), NHD (OP-O9B9) NPPSO Reel Number H-108, Roll AR-184, Record Group 76, 1-8.

¹⁴ Blair, *Silent Sea*, 98.

¹⁵ *History of USS Sargo* (SS-188,) NHD (OP-29) NPPSO Reel Number E-108, Roll AR-2, Record Group 78, Keyport, 1-6.

Tambor Class submarines used the base design of the World War II fleet boat but went faster and farther. They contained air conditioning, fresh water dispensers, six torpedo tubes up front, four aft along with a three- or four-inch deck gun. They had Torpedo Data Computers (TDCs), early SD sonar and small-head periscopes. *Tambor* could quick-dive and surface. They used the more dependable Fairbanks/Morse diesel engines but they housed all four diesel engines in one engine room, making it more prone to failure from a single direct hit from the enemy.

16

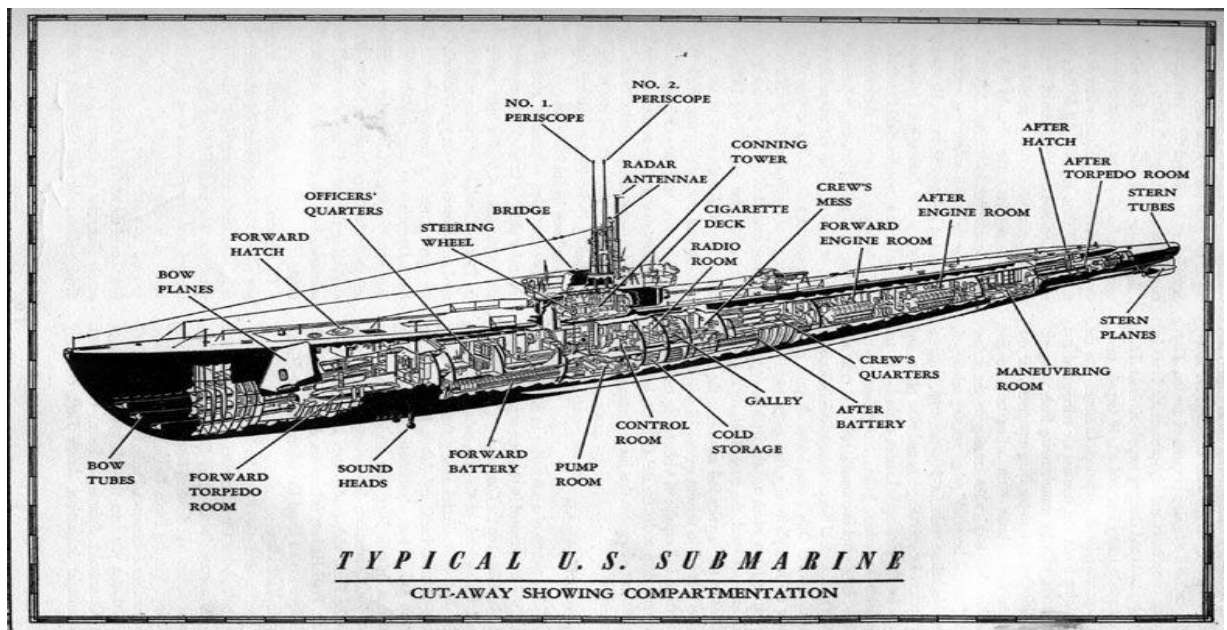


Figure 2. Typical U.S. Fleet Submarine

¹⁶ *History of USS Tambor (SS-198)*, Office of Naval Records and History, Ships Histories Branch (Hereafter Cited as Ships Histories) NPPSO Reel Number F-108, Roll AR-1, Record Group 79, Keyport, 1-7.

The *Gato* Class was the first mass-produced submarine. It was a football field long, ten yards wide, displaced about 1,500 tons, and carried around fifty to sixty enlisted men and ten officers. It was double hulled, having a pressure hull surrounded by a hydrodynamic outer hull. The void between the hulls provided the space needed for ballast and extra fuel tanks. The double hull lent itself to a deeper diving range and more stability on the surface.

Engineers streamlined the outer surface of the submarine to have as few attached or protruding items as possible. If bombarded by Japanese depth charges, the less on the outside of the vessel the less was vulnerable to damage. Also, the less drag the faster the dive, the less power needed and the faster the sub would make way under the surface. The periscope had a 1¼" diameter lens so the vessel was barely visible to the enemy.

With the *Balao* and the *Tench* classes, the *Gato* boats were the backbone submarines of the war. Test depth of the *Gato* was 300 feet, though it frequently dove from 400 to 600 feet during Japanese depth charge attacks. It had two engine rooms. Originally using the Fairbanks/Morse diesel, the *Gato* eventually ran with the most dependable General Motors diesel.¹⁷ The *Gato* was much bigger than its British and German counterparts, so was slower to dive. Still, crews learned to dive in under thirty-five seconds. *Gato* had air conditioning, fresh water dispensers, refrigeration, clothes washers and two bathrooms (heads). The usual complement was six officers and fifty-four enlisted men, although there could be up to seventy-four submariners in a *Gato* on a

¹⁷ *History of USS Wahoo* (SS-238), Ships Histories, NPPSO Reel Number F-108, Roll AR-158, Record Group 78, Keyport, 1-10.

combat Cruise. *Gato*, unequalled in all its amenities, was state of the art at the time, only getting better with the later Class models.¹⁸

The *Balao* Class, introduced in 1942, had higher yield skin and a test depth at 400 feet.¹⁹ The *Tench* Class, introduced in 1944, had a little more internal room, weighing forty tons more. A repurposed ballast tank, converted to a fuel tank, gave the *Tench* the capacity to sail 16,000 nautical miles. It carried a five-inch deck gun as opposed to a four-inch gun.²⁰

Basic Function

The Fleet submarine was a surface ship that could dive underwater during an attack. These submarines cruised on the surface at night for hours, recharging their batteries, and ran deep during the day. Lookouts with binoculars on the tower and radar guarded from surface attack. This vessel could not elude its enemy by speed, however. Top (flank) speed was twenty-one knots on the surface and about nine knots under water. A boat usually cruised at ten knots on the surface and two to three knots underwater to conserve battery power. A submarine and crew could run about 11,000 to 12,000 miles before needing to refuel. All this was to maneuver within a few thousand yards of a target.

¹⁸ USS *Pampanito* (SS-383), personal tour taken June 13, 2016. It is almost unimaginable that thirty men could fit on this boat let alone as excess of seventy. The interior of the boat is all steel, brass, Plexiglas and linoleum. Compared to the digital technology of today this submarine is antiquated. But the technology of the time was cutting edge.

¹⁹ *History of USS Balao* (SS-285), Ships Histories, NPPSO Reel Number E-108, Roll AR-51, Record Group 78, Keyport, 1-8.

²⁰ *History of USS Tench* (SS- 417), Ships Histories, NPPSO Reel Number H-108, Roll AR-12, Record Group 80, Keyport, 1-5.

Fleet submarines were confined, complicated, and dangerous environments. The TDC solved the geometric problems of shooting a moving torpedo from a moving vessel at a moving target. The steel skin and the dynamic design of the hull often absorbed dozens of depth charges. Sonarmen could discriminate the type of ship overhead just by the sound of the enemy ships' screws.²¹ The engines became faster and dependable. The ship had refrigeration, fresh water and air conditioning. There was no other submarine like this in the history of warfare to this point.

Submarines in Combat

As mentioned, the story of the Mark XIV/VI intertwines with that of the submarine. The two developed in tandem, approaching the functional goals of invisibility and propulsion as well as the strategic goals of reconnaissance, interrupting Japanese commerce and coastal protection.

When World War II began, the submarine captains and their crews had gone through extensive training and felt they were ready for war. The submariners had participated in war games and multitudes of undersea exercises, honing their skills so they would be effective against the Japanese Navy and Merchant Marine. In doing this, the crews spent days making stealth approaches, making sure they were not discovered. They fired scores of torpedoes with exercise heads, the results being tracked by aircraft

²¹ Edward L. Beach, *Submarine! The Classic Account of Undersea Combat in World War II* (New York: Pocket, 1980), 13. Screws are another name for propellers. Some sonarmen could identify a ship by the sound of an enemy ships screws as well as their speed. Sound travels differently under the sea. When a ship was sinking, a crew could determine when bulkheads were breaking as well as when boilers were exploding at deep depths.

during the day and or following the headlight that was enclosed in the exercise head at night.

Most importantly to these submariners, they had the armament to go against the enemy. The new Mark XIV torpedo, equipped with the Mark IV magnetic exploder, was promoted as one shot, one sunk ship. With these new torpedoes the United States Navy submarine service believed they could take the battle to the enemy and win the war. However, these crews had faith in a high-risk, highly technical system that had been untried and untested. Failure was inevitable.

The Science Behind Sinking a Ship

The Allied and German Navies sank hundreds of merchant and warships during World War I by contact torpedoes. The sides of these ships were made of iron with steel reinforcement in places of stress. Warship hulls were made of uniformed steel. After the war, the major world powers decided to increase the armor plating used on these capital ships to counter torpedo attacks. Yet the bottom of the hulls was kept to a thinner, weaker steel. To counter the reinforced, stronger, armored steel on the ship's sides, a new theory proposed exploding torpedoes under the weaker, more vulnerable keel of the ship. This torpedo would not touch the target's hull but would explode a set distance below the hull.²²

²² Official communication to Rear Admiral R.S. Edwards from Rear Admiral Ralph Christie, May 19, 1942, Papers of Ralph Waldo Christie, Library of Congress, (Hereafter Cited as Christie Papers, LOC), Box 181. After torpedo failures were adding up in the first months of the war Christie first blames the crews and then mentions that the "Mark 6 magnetic feature be used only against the type of ship it was designed for—the BB," (Battleship).

Water cannot be compressed to a measurable degree, so with a contact exploder, the bulk of the explosive power of a torpedo's warhead traveled upward along the side of the ship with only a small part of the warhead's explosive force impacting the ship's hull. After World War I, the big three naval powers, Great Britain, Germany, and the United States, wondered if it might be possible to explode a torpedo under a ship. If a torpedo exploded fifteen to eighteen feet below the keel of an enemy ship, the ship would be lifted out of the water. The ship then bent in the middle, as it rode the bubble generated by the explosion, with the bow and stern remaining in the water. The hull of the ship was designed to flex but not that much. Once the bubble cleared the surface it burst and vanished. The ship's keel then flexed downward under the surface as the bow and stern rose out of the water. Like snapping a twig, the back of a ship fractures, the ship breaks in two and sinks. Later in World War I, some of the transport ships that succumbed to this type of hit went under in less than a minute. The question was how to explode a torpedo five to six yards under a ship. Scientists and electrical and mechanical engineers now came into the equation as did the magnetic characteristics of a ship.

As a metal ship passed through salt water it created an electromagnetic field (EMF). This field enveloped the entire hull cruising through the water. A simple antenna built into the torpedo warhead detected the EMF. Contact exploding torpedoes had a small propeller mounted in the warhead, used to arm the contact exploder. Modifying this propeller allowed a tiny generator to charge a capacitor tube with electrical energy. The goal was a magnetic device that engaged when it ran a certain number of feet beneath the target's hull. When the torpedo entered the ship's EMF, its antenna in this detected the

field and relayed the impulse to the capacitor tube which, after a slight delay to allow the torpedo to get beneath the target, relayed its electrical energy to the warhead. The warhead theoretically would detonate right beneath the ship destroying it completely with one shot by breaking its back. This was the theory behind the modern marvel, MK XIV torpedo with its MK VI exploder.

The Mark XIV Torpedo

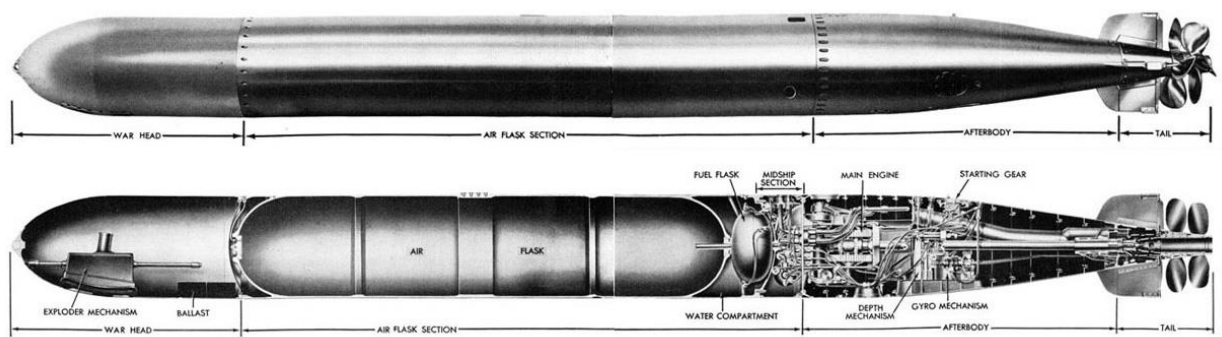


Figure 3. Mark XIV Torpedo

The Bureau of Ordnance OP 635 technical manual on the Mark 14 torpedo explained that a torpedo was a self-propelled, underwater weapon designed to carry an explosive charge to an enemy vessel and destroy it. It was equipped with mechanical devices that automatically generated the power to drive it and other devices that controlled its direction, speed, and the depth at which it traveled in the water once launched.²³

²³ "Torpedoes Mark 14 and 23 Types" *A Bureau of Ordnance Publication, OP 635*, 24 March 1945.p. 9 This manual is the 1945 edition of the manual that was labeled as Top Secret.

A World War II Torpedo had over 3,000 parts divided into four sections: the warhead, the air-flask section which included the midship, the afterbody, and the tail.²⁴ To understand the problems that the U.S. Navy Submarine Service had with undersea attacks during World War II, it is necessary to understand the Mark XIV Torpedo as well as the Mark VI magnetic exploder.

The Warhead

“The war head is the torpedo’s reason for existence. It is the ‘business end’ of the torpedo since it carries the explosive charge and the exploder mechanism which detonates it. The other section of the torpedo merely comprises the vehicle for the carrying the war head to its target.”²⁵ The warhead was made of phosphor bronze to allow the effective operation of the magnetic feature of the exploder mechanism. The live warhead had a cavity built on the bottom to accept an exploder mechanism. Thus, a warhead contained the explosive and an exploder.

There were two different types of heads, a live warhead and an exercise head. The exercise head had an ingenious mechanical setup so the torpedo could be recovered after a test. All torpedoes needed to be tested before being sent into service. BuOrd designed the Mark XXX exercise head with water or solution instead of explosive. At the end of the test run, opening a valve released air from a flask, pushing out the solution so that the torpedo became light enough to float to the surface for recovery. However, the

²⁴ Ibid. p. 9.

²⁵ Ibid, p.16.

weight of the water in the exercise head differed from that of the actual in-service warhead, an important factor later in this story.²⁶

The live torpedo warhead contained either TNT or Torpex. When the war began, all torpedo warheads contained TNT. TNT was inexpensive and, with its melting point at 170 degrees Fahrenheit, easy to cast. But it was not powerful enough to suit submarine captains. Torpex contains TNT, Research Department Formula X (RDX), and aluminum. RDX, developed in 1899, was prepared by slowly introducing toluene or hexamine into a mixture of nitric and sulfuric acid fumes. RDX was a component of the very first plastic explosives like composition A and later C-4. But it was sensitive and unstable. The British and Canadians mixed TNT, RDX and aluminum together and found a formula half again as powerful as TNT by mass if underwater, double if detonated in air. The mixture also solved the sensitivity problem as Torpex needed a detonator to initiate explosion.²⁷

Exploders

Shooting an explosive projectile, like a 155-millimeter Howitzer shell at a brick will do nothing but punch a hole in the wall without an exploder to touch off the explosive core. But first the projectile needed a propellant such as smokeless gunpowder enclosed inside a cartridge case to explode and push the bullet out of the end of the cartridge, down the barrel of a gun and on to its target. The powder in the cartridge did not explode just by the impact of a firing pin. Nor did an exploding projectile explode

²⁶ OP 235, p. 22.

²⁷ Gannon, *Hellion*, 182-183.

just from the force of impact. There was an exploder at the end of the cartridge or nose of the projectile, a small metallic cap containing mercury fulminate.²⁸ This is a primary explosive that is highly sensitive to shock and friction. It is also used for blasting caps. The mercury fulminate cap was originally used in the 1830s and, although since replaced by more efficient chemical substances that are less corrosive, less toxic, and more stable over time, it is still used occasionally today.

Since a fulminate cap is so sensitive to shock, it is perfect to initiate an explosion. All it needs to ignite is something to strike it. The MK VI exploder initiated its explosion by the release of a firing pin to strike against a primer cap which initiated the warhead detonation. However, for safety reasons, the fulminated cap was not just attached to the nose of the torpedo on the front end of the warhead like, say, a World War II military 107-millimeter shell or a United States Army Air Corps 10,000-pound blockbuster bomb. The latter exploders, or fuses, screwed into the nose of the artillery shell.²⁹ Without the fuse the shell theoretically would not and should not explode. Yet, these fuses were not simple devices like a fulminated mercury cap. They had machined parts with springs and rods. Thus, the shell would not explode when fired and needed a certain amount of impact to initiate the explosion. The MK VI required an even more complicated detonation system so that the torpedo would not explode in the submarine or when going

²⁸ W.E. Garner and HR Hailes, "Thermal Decomposition and Detonation of Mercury Fulminate," *Proceedings of the Royal Society of London. Series A, Containing Papers of a Mathematical and Physical Character* Vol. 139, No. 839, pp. 576-595 (3/1933), accessed December, 4, 2016, <http://adsabs.harvard.edu/abs/1933RSPSA.139.576G>.

²⁹ William Manchester, *The Arms of Krupp: The Rise and Fall of the Giant Industrial Dynasty that Armed Germany at War* (New York: Little Brown, 1968), 241-260. Krupp, St. Etienne, and Vickers Armament companies did the first real work on fuses before the First Worlds War. These companies used the spelling fuze. The common United States spelling is used here.

through the violent act of firing out of the torpedo tubes. These exploders were also machined and well designed to explode only under certain circumstances.

When the war began for the U.S. Navy's submarine service, skippers had experienced only Mark III contact exploders, not the new MK VI magnetic exploder. The Bureau of Ordnance and Newport met with the Submarine Service and submarine captains in the summer of 1941 to inform them about the new top secret magnetic exploder and give them rudimentary training. There were enough torpedoes for the newer Fleet Boats and some of the larger, older submarines. The Mark XIV was too large to use in the World War I era S-boats, so they relied on the Mark X/III torpedoes. By the time the war began, there was not a submarine captain in the Pacific who did not believe that the MK XIV/ VI was an effective and dependable weapon.³⁰

Since most of its force was supposed to impact the hull, rather than shooting into the air as with contact exploders, the submarine captains now felt that they had a warhead that could do some real damage. The Mark VI magnetic influence exploder was used with the Mark XIV torpedo. It was highly complex and central to this dissertation, so will be discussed in depth in chapters four and five. When the exploder engaged, it contacted and set off a fulminated cap which in turn ignited tetryl in a small copper sheeted container which in turn ignited the Torpex. Tetryl, known as a booster explosive, was also a nitramide that explodes easier and delivers a quicker detonation than RDX and is more easily touched off by a fulminated cap.

³⁰ Blair, *Silent Victory*, 84.

The problem with a warhead was that everything about it is high risk. For instance, during the war, Torpex warheads were checked periodically. Sometimes, sailors and technicians at Newport discovered a hissing sound when taking a plug or cover from a warhead. Torpex under certain conditions could produce a highly explosive vapor. Escaping vapor might have led to accidents on some of the boats in the Pacific. Perhaps some of the fifty-three lost submarines were sunk because of a high-risk element that no one had expected. The escaping vapor could have ignited, exploded a warhead in one of the two torpedo rooms causing sympathetic explosions from nearby torpedoes. If so, this would be difficult to deduce as there would not be much left of a sunken submarine to examine.³¹

The Air-Flask Section

The air system was very important because the Mk XIV was a steam-driven torpedo. The air-flask section consisted of the air compartment, fuel flask, and the water compartment. This was the main body of the torpedo, referred to as the “Boiler Room” of the torpedo.³² In the air compartment the compressed air combined with the fuel and water, providing the energy to drive the mechanisms that propelled and guided the torpedo after it left the torpedo tube.

The inside the air flask was over twenty inches in diameter and eight and a half feet long.³³ The pressure inside the Mark XIV air flask was 2,800 pounds per square inch (PSI) (for comparison, a home/garage compressor is usually rated at 130 PSI). It takes a

³¹ Gannon, *Hellions*, 185.

³² Op 635, 29.

³³ US Bureau of Ordnance Blueprint, number 79745, Air Flask general arrangement, longitudinal section.

lot of pressure to propel a 3,280-pound vessel under the surface of the sea for 4,500 feet at forty-six miles an hour. This contributed to issues that the submariners experienced in the future.

Water and fuel flasks were also located in the air flask section. The water flask was part of the torpedo body and was limited in space. The water was used for steam to propel the torpedo. The fuel flask, behind the air flask, was shaped like a thick donut to fit in a limited area inside the water compartment. Unlike the air flask, the fuel flask was rated at fifty PSI.

The entire Mark XIV torpedo is fascinating from a self-contained mechanical standpoint. Everything depended on the high-pressure air system. The pressure from this system engaged the starting motor. From there the forced air pushed fuel and water and added the air to generate steam. The air system could have been improved, though. The Japanese replaced the air in their Type 93 torpedoes with pure oxygen for a high, more efficient, and more powerful burn.³⁴ Regardless of the mechanics of the air system, it contributed to the dud problem. The pressure and capacity of the air tank caused it to explode if the torpedo hit the side of a ship. Many sonarmen and submarine crewmembers mistakenly took this to be a low yield explosion. Upon contact, the power of the air flask explosion would travel up the side of the enemy ship doing little damage.

³⁴ Newpower, *Iron Men*, 119.

The Midships Section

The Midship section was the area of the torpedo that provided a cooling chamber for those parts of the operating mechanisms which conveyed hot gases. These needed to be cooled externally so they would not be damaged by the interior temperatures. This area was not water tight, so seawater helped with the cooling. This part of the torpedo was filled with valves, check valves, stop valves and piping. The midship section had numerous ports through which the torpedomen serviced, fueled, aired up and fine-tuned the torpedo.

The midship section was the control room for the air coming out of the air flask. It was filled with tubing, valves and cooling chambers for two reasons. Heat was generated through the high-pressure systems coming from the air flask. It also received heat from the engine which was in the afterbody compartment, creating temperatures high enough to melt metal. Most notably, the midship section was the area where the torpedomen did fine adjustments for the air system.

When the torpedo failures were mounting, some torpedomen suspected flooding was the culprit.³⁵ Some submarines, such as the USS *Cuttlefish*, would flood their tubes and let the torpedo sit, sometimes for hours. Because of this, the midship section sometimes became flooded and when the torpedo left the tube it dropped to the bottom of the ocean. Regardless, the additional weight inside a flooded torpedo midsection influenced a torpedo running deep.

³⁵ Third War Patrol Report of USS *Cuttlefish* (SS-171), September 25, 1942, NPPSO Reel Number F-108, Reel Ar-116, Record Group 78, Keyport. 1-2.

The Afterbody

There were two distinct and important components to the afterbody: the drive, or engine system, and the gyroscope/depth setting system. The latter was the most complex, technical, and thus high-risk section of the Mark XIV. Being central to the thesis of this dissertation, the depth control mechanism will be discussed in detail in chapters four and five.

The afterbody contained the torpedo's propelling and controlling machinery, the mechanisms that started the torpedo. These mechanisms generated and applied power to drive the torpedo from launch to target. They also determined the torpedo's vertical and horizontal movements and maintained its course, making sure that it ran hot straight and normal.

The major mechanisms of the afterbody included the starting gear and the starting and reducing valve group, which included the sprats, igniter, and the propelling mechanism. The propelling mechanism included nozzles, the turbines, turbine bulkhead, main engine, oiling system, exhaust system, propeller shafts, sleeves, hubs and propellers. Simply explained, this part of the torpedo was the engine, exhaust, and transmission of the torpedo. The motor was a sophisticated steam engine. The air flask introduced metered air from the midship section, mixed it with specific amounts of air and fuel and water and shot it into a chamber where it was ignited by simple igniters. Special air nozzles spun the air and water, combining the vapor with the burning fuel, creating steam. The steam shot upward and spun two turbines spinning opposite one another. The turbines were connected to shafts, one inside the other, which were attached

to gears. These bevel gears engaged other bevel gears and formed a differential. The differential drove another shaft perpendicular to the turbine shafts. This shaft bolted onto the propeller shaft driving the propellers. Among this machinery was a complete oil system, with oil storage tanks, for lubrication as well as the exhaust system. The exhaust system vented the large amount of spent gases and steam through the end of the hollow propeller shaft. On the shaft were two propellers that spun in the same direction but were fluted in opposite directions. This canceled out the torque that a single propeller would force on the torpedo, causing a natural tendency to for the torpedo to circle.

Everything within this system was machined by hand and assembled by hand meeting tight specifications. The air flask section had few moving parts and was well built. There were few issues with this section. The afterbody was like looking under the hood of a car. This was where everything that drove the torpedo came together. This, together with very low tolerance specifications, was the part of the torpedo that should have failed. At times, it did but the problem with the Mark XIV/VI was not the air flask or drive system. The main issues with torpedo were the depth setting system and the magnetic influenced exploder.

The Development of the Mark VI Magnetic Influence Exploder

Up to 1922, exploder development had no more importance than any other area in torpedo development. After the introduction of the great British Battleship Dreadnaught Class, it became apparent that an effective torpedo would have difficulty penetrating the

armor plating that surrounded the hulls on these massive ships.³⁶ The theory was that even if a torpedo hit one of these mainline battleships it would not disable or seriously cripple it. Thus, the bottom of the hull became the target of the torpedo. Keeping the value of the torpedo as a weapon alive required a means of penetrating the bottom of an enemy ship's hull. Experimentation with other under-hull torpedoes began before 1922. Among designs considered were a sound-controlled torpedo, a water-kite above a deep running torpedo, an electric field around the torpedo to be disturbed by proximity to a metallic body, and finally the magnetic influence feature.³⁷

The magnetic exploder development began in 1922. That was also when the secrecy began. All work on the project, the very existence of the exploder, was classified as top secret until the submarine captains were told about it in the summer of 1941. On June 30, 1922, the Bureau of Ordnance directed Newport to accomplish an under-bottom torpedo and authorized twenty-five thousand dollars on the improved exploder, also known as the G-53 project.³⁸

Between the years 1922 to 1934, General Electric Corporation (GE) helped with the development of the generator and thyatron tube for use in in the magnetic exploder. In 1930, the project designation was changed to G-156 and the term Index mechanism ("Ind" for induction, "Ex" for exploder) was used for improved exploder. In 1934, the

³⁶ Robert K. Massie, *Dreadnought: Britain, Germany and the Coming of the Great War* (New York: Ballantine, 1991), 76-104.

³⁷ Newpower, *Iron Men*, 25-26.

³⁸ Robert J. H. Powel, *Bureau of Ordnance*, "Administrative History of Naval Torpedo Station Newport, Rhode Island," Volume III, 1946, Navy Department Rare Book Room, Blair Papers, Box 73, File 1. Powel was the Special Assistant to the Under Secretary of the Navy. These histories were written right after the war with mountains of primary documentation and personal interviews of principle personnel to document administrative aspects of the war effort.

project number was changed to G-175 and Index mechanism was replaced with the term Mark VI. This project was so secret that by May 27, 1941, when President Roosevelt declared a state of national emergency, few people in the service knew of the magnetic exploder, how it functioned or how to install it into the contact exploder itself. Every part and component of the exploder was developed in different cells, one not knowing what the other was doing or the purpose of their part of the component. A very select group from Research did the assembling and testing under rigid secrecy. It was unknown to anyone else until June 1942, when the exploder was transferred to the manufacturing department and the details became known to the Newport factory.

In the summer of 1941, as the probability of the United States being drawn into the war increased, vessels that carried torpedoes visited Newport and the facility at Keyport, Washington for issue of their torpedo outfits including the new Mark VI-I exploder and its accompanying secret Ordnance Pamphlet # 632.³⁹ It was there, for the first time, that torpedo officers serving at sea received instruction regarding this top-secret armament. The instructors were special personnel from Newport's Research Department. One research person had been assigned to Keyport Torpedo Station. No enlisted torpedomen received any instruction. At the time, neither the instruction courses nor O.P. 632 could supply enough practical knowledge to the submarine captains of this unfamiliar device. Only after the submarine crews in the Pacific took the situation into their own hands was a torpedo ordnance provided, in November of 1943.⁴⁰

³⁹ Powel, *Newport Administrative History*, 139.

⁴⁰ Powel, *Newport Administrative History*, 139-140.

Organizations and People

Requests of Vessels for Live Testing

In February, 1924, Newport had progressed enough with a magnetic exploder that Research and Development (R&D) requested a scrapped battleship for live testing. BuOrd informed Newport that a 1923 magnetic field survey, conducted by the navy with the assistance of the Carnegie Institute on two battleships in Norfolk Navy Yard, made further and more accurate surveys such as recommended by the station “unessential.”⁴¹ This response from R&D was to set the tone for requests for live fire testing to come.

In January, 1926, Newport requested a submarine hulk for live testing. Nothing happened. In July, Newport made a third request for an obsolete vessel, “...whose complete destruction can be tolerated as the only practical means of obtaining the concrete information desired.”⁴² BuOrd felt that a vessel this size would not be suitable due to its small displacement. They were right, but by this time Newport was asking small to get whatever they could. Finally, in December, 1925, the small submarine hulk, the *L-8*, was made available and sunk on May 8, 1926 by a torpedo with a magnetic influenced head. There were problems with this test.

Two torpedoes were fired at the *L-8*. The first one missed. Both torpedoes were not fired out of a submarine but a barge. More importantly, the magnetic exploder did not have a Thyatron, but a predecessor to the Thyatron, as General Electric had not

⁴¹ Powel, *Newport Administrative History*, 142.

⁴² Powel, *Administrative History*, 144. Powel cited *NavTorp Sta ltr, S75-1/L5-2 (1-116)* as his source when he researched after the war. The Naval Undersea Warfare Center at Newport, Rhode Island was unable to find this letter or any other letters concerning testing for the author.

invented it yet. This test marked the only time in the nineteen years of pre-World War II exploder development that a magnetic influenced exploder, not a true MK VI, was used in a live test.⁴³

Bureau of Ordnance, Bureau of Ships, and Bureau of Construction and Repair

As with the *L-8* test, all further testing took place in northern latitudes, usually in Narraganset Bay. Calls to the Bureau of Ordnance, the Bureau of Ships (BuShips) and the Bureau of Construction and Repair (BuC&R) for target ships for live testing went unheeded. Newport depended on the torpedoes' internal recorders for evidence of a successful or failed test. Even with the non-live-fire testing that Newport performed, they found the magnetic exploder to be unreliable.⁴⁴ In a letter on August 1, 1928, the general status of G-53 project states:

C: Of the five (non-live fire) tests that were conducted under a battleship only one functioned as designed. ...

E. the last 6 shots made in July and the first part of August 1926 demonstrated that the mechanism was not reliable, even when adjusted by the experts just before firing, and these tests also demonstrated that the relays, in addition to being electrically sensitive, were extremely mechanically sensitive to the effect of vibration of the torpedo while running.⁴⁵

Despite the 1928 testing, the Research Department felt that they had developed a satisfactory mechanism. The problem was that later that year they decided that the previous six years of magnetic exploder development "...was originally attempted with

⁴³ Powel, *Newport Administrative History*, 147.

⁴⁴ Powel, *Newport Administrative History*, 145.

⁴⁵ Powel, *Newport Administrative History*, 145. Powel cited NavTorpSta, Designing Activity Files for Folder," Index Mechanism G-156 Project, Jan. 1930-September, 1930," Report of May 1930.

no proper foundation in knowledge of the magnetic field to be encountered under ships or of the current that might be induced thereby.”⁴⁶ The only sure knowledge the Navy had, when it came to the Earth’s magnetic field, involved the compasses the ships carried on their bridges. Part of the Research Department, the Design Activity, had back files that covered the G- 53 and further magnetic exploder projects. These mentioned a tendency in BuOrd to become so bogged down in theory that essential decisions were postponed.

The lack of essential knowledge concerning the magnetic fields surrounding vessels, and of the electromagnetic current they may induce, required that secret intensive studies be performed in the winter of 1930 in southern latitudes by a Newport field study survey group. They did this for three months on temporary duty aboard the U.S. Navy Cruiser, the USS *Raleigh*. The designation of the project by this time had changed from G-53 to G-156. The torpedoes tested had the new General Electric Thyatron tube and special generator. Once the survey was completed, the officer in overall charge of the project reported on the practicability of the magnetic feature in any part of the world and on the success of their field laboratory and range tests. While admitting that a destructive test was not part of the testing, he nevertheless felt that, to get positive proof of satisfactory under bottom explosion and complete development on the Index mechanism (MK VI exploder), a war shot against an obsolete vessel was necessary. That this never happened marks four years of repeated but fruitless attempts by Newport to obtain target vessels for destructive tests.

⁴⁶ Powel, *Newport Administrative History*, 146. Powel cited NavToprSta ltr: A9-2/L5-2(A) to BuOrd of 7 December 1928.

Meanwhile, in May, 1930, the Newport officer who had directed the development of the Index mechanism throughout the middle and closing stages of the G-53 project was detached before he could make the exploder ready for implementation. Nevertheless, Newport went on to exhaustive testing of the magnetic exploder. But none of the tests were live-fire tests.

Finally, in September, 1933, the Chief of Naval Operations and Bureau of Construction and Repair told Newport and BuOrd that they could use the USS *Ericsson*, an old, four-stack, Pre-World War I, *O'Brien Class* Destroyer, for live testing with the following restrictions:

12.3 In order that the *Ericsson* may be recommissioned at minimum cost and in minimum time, if required, the vessel will be delivered as is, without removal of any of the permanent installations, the guns, however, may be removed, provided the Bureau so desired.

12.4 When firing under the *Ericsson*, the same precautions will be exercised as when firing under the active vessel assigned for this purpose, and in view of the complications attendant to the raising of the *Ericsson*, should she be sunk, as well as the loss of that ship as a potential active destroyer in emergency, such additional measures as are necessary will be taken to prevent the sinking of the vessel, in case she is hit by a torpedo.

Thus, Newport and BuOrd elected not to use the USS *Ericsson* as they had no capabilities to raise the ship and repair it once they sank it. To further emphasize the lack of forethought illustrated by this story, BuShips scrapped the USS *Ericsson* and sold it for salvage less than a year later, on August 22, 1934.^{47 48}

⁴⁷ Powel, *Newport Administrative History*, 151-152.

⁴⁸ "USS *Ericsson*," *Naval History and Naval Command*, Dictionary of American Fighting Ships, accessed January 25, 2017, <https://www.history.navy.mil/>.

Newport and BuOrd never received a hulk for testing. Since the sinking of the *L-8* submarine, the next time the U.S. Navy fired an American torpedo with a live warhead, equipped with a magnetic exploder, was fifteen years later. The vessel was Japanese.

As with any highly-technical, high-risk system, there is a story about the hardware and a story about the organizations and principle people that were involved. Within the torpedo issue were different organizations and people who were profoundly involved. Some of these people were civilians, others military men. Some involved the military unsuccessfully trying to administrate a civilian agency. Other people were military leaders attempting to get something accomplished within the strict ranked world of the U.S. Navy.

Newport Torpedo Station

Newport Torpedo Station was a civilian company operating under the guidance of the U.S. Navy's Bureau of Ordnance.⁴⁹ Known simply as Newport, the torpedo station was a design and manufacturing plant located on what was formerly Goat Island, Rhode Island. Newport was the only producer of torpedoes for the U.S. Navy from the end of World War I to the second year of World War II. After the war began, torpedoes, like every other weapon from tanks to bombers, were manufactured at a variety of different locations in the United States. However, Newport was the only manufacturing facility for the Mark XIV/VI.

⁴⁹ More discussion on Newport in Chapter Three on torpedoes.

Prior to the war, Newport did not act as an automated production facility. Craftsmen, who believed their work was art rather than industry, manufactured torpedo parts by hand. On the floor, they fine-tuned to narrow specifications and jealously guarded their knowledge. Thus, before the war, they did not produce any technical manuals. Workmen took informal notes in notebooks they stored in their work benches. When the war began, there was a dribble of beautifully-crafted torpedoes coming out of Newport with few spare parts and no service manuals. The lack of service manuals was fine with BuOrd. They believed the Mark VI exploder to be such a sensitive secret they did not want any manuals accidentally falling into enemy hands.⁵⁰ Finally, when the war began, BuOrd produced a technical manual, but because of the secrecy the manual, they never put it into the hands of the men who needed it the most, the torpedo specialists on the submarine tenders and the torpedomen on the submarines. During training, the new torpedomen would learn about all the intricacies of the Mark XIV but the Mark VI magnetic exploder was kept a secret until mid-1941. At that time, only submarine captains and division commanders had access to technical details. When the war began, the torpedomen knew some basics but far from the knowledge needed to troubleshoot any of the electrical problems.

Because of the manufacturing methods of Newport, everyone involved in the production of the Mark 1XIV/VI was protective of their art. No one wanted to admit that their torpedo was not the perfect weapon. Years went into its design and the torpedo body itself had been tested thoroughly. However, the magnetic exploder had never been tested

⁵⁰ Newpower, *Iron Men*, 31.

in a live-fire shot.⁵¹ Newport was not about to admit that there was anything wrong with their finely-crafted creation.

Several issues contributed to the torpedo debacle during World War II. One concerned the torpedo shortage.⁵² The impact of World War II on the Newport production facility was enormous. The company and its facilities required an almost overnight re-tooling and an incorporation of thousands of new people. This meant a radical change in the way they did business. The station needed to build bigger, newer, more modern facilities with a steady stream of workers.

Many of the difficulties were caused by re-tooling, new tooling, logistics, geography, town planning and psychological issues with workers and managers. It meant locating new people and training them. Perhaps the most difficult factor to overcome was philosophical. The war demanded that the regular ways of business and production conducted at Newport needed to change. This change took dozens of months. More difficulties arose from a military command structure overseeing a civilian operation.

Newport developed its own torpedo factory for production. It went through the Great War and into the 1920s producing torpedoes in a partnership with E.W. Bliss and Company until 1923. Until 1940, Newport was the sole producer of torpedoes for the U.S. Navy and the sole producer of parts for those torpedoes.. The war changed these things.⁵³

⁵¹ Powel, *Newport Administrative History*, 142.

⁵² Official Letter to Admiral Charles Lockwood, from Admiral R.S. Edwards, June 21, 1942. Lockwood Papers, Box 64.

⁵³ Official Letter Admiral R.S. Edwards from Admiral Charles Lockwood, August 27, 1943, Lockwood Papers, Box 72. By this time, Westinghouse was producing the Mark XII electric torpedo. But problems abounded with the Mark XIII. Several submarines experienced circular runs with the Mark XIII's. A Mark

Newport's production system was nothing like that of, for example, the Ford Motor Company.⁵⁴ This was because torpedoes were an intricate, highly technical piece of machinery. Armaments were tightly specified and there was no room for error. Attempting to squeeze all the different components into a tube twenty-one inches in diameter and twenty feet long was a feat of engineering and production. It took great design and great attention to detail. The people who built the Mark XIV were craftsmen. Each torpedo was constructed with care and precision, not an assembly line. This made for an excellent weapon, but also slow production.

Through the Great War and the years after, Newport produced torpedoes in constrained quantities. The peak year for production was the first year that the United States entered the war, 1917. In that year, Newport produced 381 torpedoes. In 1937, they beat that record and produced 591, and the year after that, 765. In 1939, the year the war broke out in Europe, Newport only produced twenty-three more than the year before. Because of war demands, the total of Mark XIV's leapt to 5,656 torpedoes in 1944.⁵⁵ In 1940, during its seventy-two-year history, Newport had only produced torpedoes twice under wartime conditions, for a combined total of twenty-two months and twenty-nine days. Thus, for approximately 97% of its existence as a production factory, it had functioned as a peacetime naval shore establishment for a peacetime navy that had never fought a war involving torpedoes.

XIII sank the most successful submarine of the war, the USS *Tang* (SS-306) on October 24, 1944 because of a circular run.

⁵⁴ Charles Sorenson, "Inventing the Assembly Line (Memoir), 1956," In, *Major Problems in the History of American Technology* eds., Merritt Roe Smith and Gregory Clancy (Boston, New York: Houghton, Mifflin, 1998), 320-322.

⁵⁵ Powel, *Newport Administrative History*, II.

U.S. Naval Command, Bureau of Ordnance, and Men in the Field

U.S. Naval Command and the Bureau of Ordnance (BuOrd) had produced a highly technical, very dangerous weapon to use against the enemy during World War II. Organizations and institutions like Newport and the Bureau of Ordnance were only one facet of the human factor contributing to the torpedo failure controversy. There were specific men who played major roles in the unfolding story.

Charles Andrews Lockwood

Figure 4. Charles Andrew Lockwood

On December 7th 1941, Captain Charles Andrews Lockwood, a career naval officer and submariner, found himself as far away from the fighting as he could get. He was in London and had been since the first of the year, acting as Chief of Staff to Vice Admiral Ghormley, the special Naval Observer to the British Empire. For the past many months,

he had been privy to all the British Naval action in the Atlantic. Lockwood had been a guest on British submarines and knew all there was to know about their Mark 8 contact torpedo.⁵⁶

Lockwood could not wait to get into the fight. He feared nothing more than being beached in the European Theater. On December 9, 1941, instead of going through official channels, Lockwood did the unthinkable. He sent a Western Union Cablegram to the Detail Officer, Bureau of Navigation, Navy Department, Washington DC that read, “FORGIVE PERSONAL COMMUNICATION BUT IF YOU NEED SOMEONE FOR JOB IN PACIFIC ESPECIALLY SUBMARINES HONOLULU OR WESTWARD PLEASE CONSIDER ME, C A LOCKWOOD JR.”⁵⁷

The submarine community to this day recognizes Charles A. Lockwood as the legendary commander of the Submarine Force Pacific Fleet during World War II and one of the greatest submariners of all time. Some men who reach flag command have the respect of the men who serve beneath them.⁵⁸ Lockwood had submariners respect and love. His men called him “Uncle Charlie” because of his devotion to his submariners.⁵⁹ Without exception, Lockwood saw each of his submarines off from the dock when they departed on a patrol and stood dockside when they returned. There were few commanders

⁵⁶ Vice Admiral Charles Andrews Lockwood Jr. Navy Histories, Blair Papers, Box 68, File 5.

⁵⁷ Western Union Cablegram, *The Western Union Telegraph Company*, Anglo-American Telegraph Co. Ltd. Dated 9 December 1941.

⁵⁸ Charles A. Lockwood, *Sink ‘em*, iv. When a Naval Officer obtained the rank of Rear Admiral they then were entitled to have their own flag to fly on their command ship whenever at sea. Thus, Flag Officer.

⁵⁹ Toughy, *Bravest Man*, 68. As with Toughy every book the author researched about the United States’ undersea war in the Pacific notes the men in the field referred to Lockwood as “Uncle Charlie.”

in the history of the United States military commanding more devotion and admiration, even fondness, from the men who served under him.⁶⁰

Born in 1893 in Virginia, Lockwood grew up in the age of Roosevelt and Taft on a Missouri farm. Charlie had the normal boyhood of any farm kid, milking cows and plowing fields. He was a superior student in high school and gained admission to the United States Naval Academy. However, his time at Annapolis was not extraordinary and he graduated from the Naval Academy in 1912 in the lower half of his class. Lockwood served on battleships after graduation and entered the submarine service in 1914. He served on submarines *A-2*, and *B-1*, commanding divisions during his tenure, his shore duty stations grooming him for high command. When war came to Europe, Lockwood accepted assignment to the American embassy in London as Naval attaché. Eventually he landed in Perth, Australia as Commander Submarines Southwest Pacific Submarine.⁶¹

R.L. Gross wrote:

Yes, knew both Lockwood and Christie. Worked for both at sea, I don't know how to comment on their personalities. Both were efficient leaders and submariners, Lockwood was the more level-headed of the two, I thought. Christie was less warm than Lockwood. The fact that they disagreed on many occasions (none of which I was privy to) is not to denigrate either of them. No anecdotes of interest. As for strategy, I would give Lockwood points over Christie."⁶²

Lockwood worked with Ralph Christie at Asiatic Command until he took over Submarine Command Pacific (SubComPac) at Pearl Harbor. These two men

⁶⁰ Newpower, *Iron Men*, 88.

⁶¹ Naval Department Bureau of Personnel, Washington DC, Change of Duty, detaching from duty with ANZAC forces and report as duty Commander Submarines, Southwest Pacific. Lockwood Papers, Box 62.

⁶² Rear Admiral Roy L. Gross letter to Blair, January 12, 1972, Blair Papers, Box 68 File 1.

liked and respected one another. At times, they grated on each other's nerves. Thus, began a relationship and a conflict that would afflict the submarine commanders for many months to come.

Ralph Waldo Christie



Figure 5. Ralph Waldo Christie

Ralph Waldo Christie was younger than Lockwood, being born in Somerville, Massachusetts in 1893. He graduated from the U.S. Naval Academy in 1915. Christie served on a variety of surface warships, Figure 5. starting out on the battleship *New Jersey*, and then joined the USS *Montana* for torpedo instruction. In January, 1917, he was under submarine instruction in the USS *Fulton* and, upon completion, joined the Submarine *C-1* the following July, assuming command in January, 1918. Detached from the *C-1* in 1919, he reported to duty in fitting out the USS *Camden*, a submarine tender. In August of 1920 he assumed command of submarine *R-6*.

He attended postgraduate school at Annapolis from December, 1920, until September, 1921. He then received further instruction at the Massachusetts Institute of Technology where he graduated with a Masters in Mechanical Engineering (Torpedoes) in June, 1923. He then assumed command of the submarine *S-1*. During this time, Christie sailed to the Asiatic and, after several postings, became commander of the submarine base at Cavite from July, 1925, to April, 1926.

After his return to the United States, Christie served his duty at the Naval Torpedo Base at Newport, Rhode Island for two years. After this he went to sea on the USS *Argonne*, a submarine tender, serving as the torpedo repair officer for the Atlantic submarine fleet. In February, 1931, he returned to Newport where he remained until the spring of 1933. In May, 1934 Christie served on the aircraft carrier USS *Ranger*, serving as navigator until 1936. From there he served as the head of the Torpedo Section, Bureau of Ordnance, Navy Department in Washington, DC. After duty with the BuOrd, he took command of Submarine Division 15. From December, 1940, to November, 1942, Christie served as Commander Submarine Squadron Twenty, which was re-designated as Submarine Squadron Five during his command. Between January and March, 1943, Christie returned to Newport to act temporarily as Inspector of Ordnance in Charge because of the torpedo issue. After this, he reported as Commander, Submarines, Southwest Pacific (Lockwood's old job) with additional duty as Commander of Task

Force Fifty-One.⁶³ Although an officer, Christie was a torpedoman down to his core.⁶⁴ As with most enlisted, rated torpedomen, Christie was a mechanical genius. During his second tour at Newport, Christie's focus was on the application of mechanical engineering principles to torpedoes.⁶⁵

In 1922, towards the end of Christie's graduate studies, BuOrd initiated project G-53.⁶⁶ As mentioned, G-53 was a top-secret program to develop a magnetic influence exploder for torpedoes. His involvement in the technical development of this weapons system, later designated the Mark VI exploder, became a critical point in this story.

In June, 1923, Christie graduated and returned to the submarine force. Again, in 1926, when he reported for duty at the Newport Torpedo Station, he participated in the design and development of the newest torpedo, the Mark XIV (MK XIV). The Mark VI (MK VI) torpedo exploder mechanism was far enough advanced by this time to undergo testing.⁶⁷ The torpedo and exploder were to work in unison and ended up being the primary weapon for United States Navy submarines during World War II. As accomplished as Ralph Christie was as an engineer and scientist, he also ended up being a good war commander.⁶⁸ Christie, though remembered with respect, always remained a vigorous supporter of his torpedoes.

⁶³ Vice Admiral Ralph Waldo Christie, United States Navy Retired, Navy Histories, Blair Papers, Box 65, File 7.

⁶⁴ Admiral Ralph Christie letter to Clay Blair, April 16, 1971. Blair Papers, Box 65, File 7. Christie points out to Blair in this letter, "I was considered to be a torpedo specialist."

⁶⁵ Admiral Ralph Waldo Christie, United States Navy Retired. Navy Histories, Blair Papers, Box 65, File 7.

⁶⁶ Blair, *Silent Victory*, 54.

⁶⁷ Gannon, *Hellions*, 77.

⁶⁸ Newpower, *Iron Men*, 182.

Admiral C.C. Andrews mentions, “Christie was outstanding C.O. (Commanding Officer) managed S/M (submarines) to highest degree. He required perfection but not stickler...in very quiet manner got results.” He continues,

I worked for both Lockwood and Christie and Cos with Christie as CO in peace and war time and I worked on both their staffs. I liked both of them. I feel Christie was more astute of two. Lockwood worked longer hours, both worked and did everything to support their skippers in every way and I am not critical whatsoever of anything either of them did in the war campaigns. I wouldn’t call either a strategist. I don’t think there was any sound strategy in SM operations in the Pacific.⁶⁹

Admiral Slade Cutter remembers that Christie loved “his” torpedoes:

Lockwood challenged the torpedo performance, but I think Christie would provide evidence disproving Lockwood’s allegations or suspicions. Christie had been at Newport prior to the war and felt some responsibility in the torpedo performance. I think he was sincere in how he felt, but he was in error.⁷⁰

Balancing the civilian scientists and weapons designers with military men like Ralph Christie and Charlie Lockwood took a good man like Spike Blandy.

William Henry Purnell Blandy



Figure 6. William Henry Purnell Blandy

⁶⁹ Admiral C.C. Andrews Interview by mail to Clay Blair Jr. May 16, 1972 Blair Papers, Box 66, Folder 3.

⁷⁰ Letter from Captain Slade Cutter to Clay Blair, December 16, 1971, Blair Papers, Box, 67 File 2.

Friends of William Henry Purnell Blandy called him “Spike.” One of his closest friends was Charlie Lockwood as Blandy graduated from the United States Naval Academy a year behind Lockwood. Eventually, friends or not, the two men were doomed to conflict as Blandy was the chief of the Bureau of Ordnance during the torpedo controversy.

Spike Blandy was born in New York City June 28, 1890. He graduated first in his class at Annapolis in 1913. He participated in the occupation of Vera Cruz in 1914 and served with the British Grand Fleet during World War I. During the interim between the wars, he served as a gunnery officer and commanded battleships. Between 1941 and late 1943, Blandy served as the Chief of the BuOrd with the rank of Vice Admiral. After his posting at BuOrd, Blandy went on to command Group One, Amphibious Force, Pacific Fleet and commanded the pre-invasion bombardment of Iwo Jima. Although Blandy served as a bureaucrat in Washington during most of the war, he was also regular navy. He knew ships and men. He was concerned about getting them the weapons they needed. But he was also a bureaucrat who desired to move up in the ranks. It was difficult for him to admit that he or his organization could make any mistakes, let alone a mistake of the magnitude of putting faulty torpedoes into service early in the war.

Spike was considered a hard man, one that his men respected yet feared. Being the head of BuOrd, Blandy not only had to contend with military officers and men, he also had to contend with the civilian scientists, engineers, technicians, machinists, and every other

civilian who helped to design and produce the torpedoes for the U.S. Navy during World War II.⁷¹

James Fife



Figure 7. James Fife

Unfortunately, Lockwood's huge responsibilities maintaining the underwater war against the Japanese Navy and Merchant Marine kept him from devoting his entire energies to the torpedo problems. Lockwood turned to an old friend and a driven naval officer, Captain Figure 7. James Fife, a no-nonsense man.

Fife was born on a farm near Reno, Nevada on January 22, 1897. He was younger than Lockwood and graduated from the Naval Academy as a member of the class of 1918. Because of the war, this class graduated on June 29, 1917. During the war, he served on the Cruisers *Tacoma* and *Chicago*. After the Armistice, he became a submariner, serving in and commanding submarines on both the east and west coasts of

⁷¹ Newpower, *Iron Men*, 134-135.

the United States, as well as the Hawaiian Islands.⁷² Between 1923 and 1935, he had battleship duty on the USS *Idaho* and later served on destroyers such as the USS *Leary* and USS *Hatfield*. He resumed submarine duty in the Pacific with command of the USS *Nautilus*. He also served as the commandant at the Submarine School in New London from 1938-1940. In August of 1940, he went to London as Assistant Naval Attaché. While there, he served as a submarine observer on British submarines and made numerous patrols with the British Navy. He was an experienced sailor and a stern taskmaster. When the war began, Fife was with Admiral Hart and Captain Wilkes in Manila as commander of Submarine Squadron 20. After the retreat from Luzon, Fife served in Australia, first under Lockwood and then Christie, as chief of staff to the commander.⁷³ Although respected and diligent, Fife was not well liked.

Captain George Grider remembered, “Fife was head of submarine school I went through. He was a very strict disciplinarian, He worked terrifically hard himself, he was terrifically dedicated, He knew the submarine game.”⁷⁴

Admiral Eugene Fluckey recalls:

He knew the faults of the old ships, and the possibilities of fleet boats that were coming out at that time, my impression of Fife was that he was a very astute Naval officer who knew his business, He was probably a bit too forceful and tough so it tended to cause people to hold back their frank and honest opinions instead of yessing him. However, once he had decided, if one gave him facts that controverted his decision, he would as rapidly change it, when he supported you, he did so thoroughly, energetically, and

⁷² Transcription of recording by Commodore James Fife, Milne Bay, USS *Fulton*. No Date. Blair Papers, Box 67, File 5.

⁷³ Admiral James Fife Jr. US Navy Retired, Navy Histories, Blair Papers, Box 67, File 5.

⁷⁴ Captain George Grider letter to Clay Blair, June 8, 1971, Blair Papers, Box 67, File 6,

effectively, I know from close contact with Admiral Nimitz that he had the highest respect for Admiral Fife.⁷⁵

Fife was friends with Lockwood. Almost every communication from Lockwood to Fife began “Dear Jimmy,” rather than “Dear Captain Fife.”⁷⁶ Fife, true to colors, never referred to Lockwood as anything other than Admiral. The key to Fife was that he got things done. He was smart and methodical. Fife was one of the people who helped figure out the initial problems with the Mark XIV/VI torpedo.

Command Changes in the Pacific

After the attack at Pearl Harbor, President Roosevelt decided to change the command structure of the U.S. Navy. Earnest J. King, a former submariner, replaced Admiral Stark as Chief of Naval Operations. Admiral Richard “Dickey” Edwards, a close friend of Charlie Lockwood, became King’s right hand man. King also picked Francis “Frog” Low as his operations officer. Furthermore, Chester Nimitz became Commander in Chief of the Pacific forces.⁷⁷ Nimitz was not only a submariner but was the man most instrumental for the use of diesel in submarines. These men, along with Admiral Lockwood, Christie, and Captain Fife had all commanded submarines and submarine divisions at some point in their careers. These men knew the difficulties of commanding a submarine and conducting a successful attack with a well-rehearsed fire control party. Yet, these senior commanders’ attacks were conducted in war games or practice. Not one

⁷⁵ Transcription from Taped Interview Admiral Eugene Fluckey to Clay Blair. November 6, 1972, Blair Papers, Box 7, File 5.

⁷⁶ Letter to Fife from Lockwood, July 18, 1943, Lockwood Papers, Box 71. “Dear Jimmy,” This is a typical example of a Lockwood to Fife salutation.

⁷⁷ Blair, *Silent Victory*, 125-126.

of them had taken a torpedo shot at the enemy under high pressure, hostile, true battle conditions. But this did not keep them from judging the crews' performance.

Analysis of Production Issues

Newport was not a normal manufacturing center. First, they were not a profit-making company. If Newport was not dependent on profits, then no one needed to worry about the company having a bad month financially. The biggest cost in a company is almost always payroll. That is why companies always look to layoffs first when it comes to cutting costs. The second factor a company considers when profits were down is increasing market share. The best way to increase market share is to build a better product. Neither of these affected Newport because the United States Navy sole-sourced their product, the Mark XIV/VI torpedo and magnetic exploder. Also, because of the Civil Service seniority system, the Newport workers and administrators' jobs were even safer and these people were much more complacent. This eliminated any incentive to do a good job.⁷⁸

Having a Naval Line Officer in command of a civilian operation hurt production as well. A commissioned officer had little authority over someone not in the military. If a civilian refused an order, an Officer could not have them thrown into the brig. These were two different cultures that BuOrd was trying to meld together. It was not going to work. The next problem was the turnover in command at Newport.

⁷⁸ Powel, *Newport Administrative History*, 45. Powel writes of Civil Service problems: the emphasis on seniority in promotions rather than on specific qualifications.

But the issue was not just on the manufacturing floor. During World War II, Newport went from a single factory to eight. Because of this, many of Newport's procedures, policies, and especially its view of the world in general was narrowed by its historical requirements and traditions. Newport, having had no competition in its history, was removed from the high pressure of commercial industry. They were unaccustomed to profit motive and mass production techniques. The emphasis had always been on quality not quantity, and the workers at Newport had taken pride in the excellent conditions of their products. In the case of World War II it was the Mark XIV torpedo and the Mark VI magnetic exploder.

When the war began, not only were there were limited torpedoes at Pearl Harbor and Manila, Newport did not have the production capabilities to make up the shortage.⁷⁹ As the war progressed and Newport brought more people into production and more factories on line, the production went up. By 1944, other producers like Westinghouse were producing the Mark XVIII electric torpedo, which took the pressure off Newport and the Mark XIV/VI. But before 1944, the torpedo shortage affected every commander and every boat in the Pacific.

Analysis of Exploder Development

Between 1922 and 1945, especially during World War II, exploder development was one of the most urgent, troublesome and controversial problems facing the Navy,

⁷⁹ Official Letter to Admiral Charles Lockwood, from Admiral R.S. Edwards, June 21, 1942. Lockwood Papers, Box 64. Edwards writes, "The torpedo problem is going to acute for a while. Production is not keeping up with expenditures and outfits for new construction."

BuOrd and Newport Torpedo Station's torpedo program, as chapters three through five will show. The Great War showed the world that mankind could build sturdy and powerful warships that often required several torpedo hits to sink. Submarines during this war showed the effectiveness of submarines and torpedoes as well. To protect the Dreadnaughts, it became apparent that including armor circling the hulls helped to a large degree. This led to thoughts of needing an under-hull exploding device. Newport started focusing on a magnetically influenced exploder in 1922. They worked on this product until 1941 and still did not get a fail-proof weapon out to the submarine crews. The main reason for this was the inability to conduct live fire testing. It can be presumed that Command believed that what looked good on paper, and what was tested with basic magnetic testing in alliance with General Electric and the Carnegie Institute, must work in an actual combat situation.

The case was different with the submarines that carried the torpedoes. The submarines that were built by Portsmouth, Electric Boat, Manitowoc, etc., were put through rigorous testing. Neither was it the case for armament for battleships. Each sixteen-inch round on an Iowa or North Carolina Class Battleship cost as much as a car.⁸⁰ In 1942 that was approximately \$1,100.00. So, one salvo would cost as much as a single mark XIV/VI torpedo, or about \$10,000. So, if not cost, what was the objection to live fire testing? It appears it was lack of targets. BuShips and BuC&R would not let Newport

⁸⁰ Mary Ames Booker, Curator, and Cecil Ard, volunteer historian, *USS North Carolina (BB-55) Battleship Memorial and Museum*, emails to author dated January 20, 2017. Although invoice documentation was not available Mr. Ard mentioned that in his research he found anecdotal evidence from a conversation between a gunnery officer and another topside officer. The gunnery officer estimated that actual cost per round was equivalent to a new car. A new car in 1942 is estimated at \$1,100.00.

or the BuOrd have target ships at which to shoot. But BuOrd and Newport were not afraid to spend money when needed. They just could not get the laboratory setup to do what they wanted to do when they needed it most.

Pre-War Testing. The Mark VI magnetic exploder depended upon a target's own magnetic field to work. This exploder, however, had to take into consideration how the magnetic field of the Earth interacted with the ship's field. After World War I, Germany, Great Britain and the United States all investigated the possibility of inventing a magnetic influence exploder that would detonate a torpedo warhead as it passed through the electromagnetic field of an enemy ship. The U.S. Bureau of Ordnance through the Newport Torpedo Station was the only group to go through with the scientific and technological work of developing one. The program began with a memo that dates from April, 1922, just three and a half years after the Armistice. The original funding was \$25,000, which would equate to almost \$360,000 today.^{81 82} The public's expectations of military industrial costs today make this seem like a paltry sum. In 1922, this was considered significant funding for the military. With the help of Lieutenant Ralph Waldo Christie, fresh from MIT with a Master's degree, by 1924, Newport had a weapon to test. The first live test was in 1926. With this much funding, it would be expected that the BuOrd would test the exploder through different scenarios, at different locations, through different types of seas, in different types of weather, using different types of launch

⁸¹ Historical Currency Conversions, accessed January, 12, 2017.

<https://futureboy.us/fsp/dollar.fsp?quantity=25000&currency=dollars&fromYear=1922>.

⁸² Powel, *Newport Administrative History*, 121-124.

platforms, perhaps during annual combat exercises. This did not happen. The first live test was the only live test of the exploder. BuOrd tested this new exploder, not yet in its final form, exactly one time, taking only two shots in the process.

SinkEx Testing. By 1926 the magnetic exploder was ready to test. The problem was finding a ship to test it against. Time and again BuOrd begged for a target ship. Time and again BuShips demurred. Finally, BuShips relented and provided an old, obsolete L-Boat submarine, the *L-8* for testing. This was considered a SinkEx target (exercise to sink a target). Newport protested that this was an inadequate target and did not come close to a real target, like a battleship. Since the Newport barely got a target at all, they took what they could get. On May 26, 1926, two Mark X torpedoes with experimental versions of the magnetic influence exploder were fired from Newport's Torpedo Testing Barge. The first shot missed and passed under the target without exploding. The second torpedo ran as planned (RAP run), blew the *L-8* in two and sent it to the bottom.

There were several problems with this test. The first one was apparent. A 450-ton submarine does not produce the same electromagnetic signature as a 16,000-ton Dreadnought battleship. The second was location. The test was conducted right outside of Narragansett Bay, west of Martha's Vineyard. It was not conducted in the ocean away from ship traffic or shore. On top of these issues, the magnetic exploder tested used a

dual stage power generator and electronic tubes, as a commercial Thyatron was not available yet. So, the exploder tested was not the same MK VI used in World War II.⁸³

In the years to come, the exploder improved and was more sophisticated. Thus, the exploder that came later was a different magnetic influence exploder than that which was tested in the SinkEx test. Further inert testing was done later using non-explosive warheads. In 1928, in tests performed against battleships at Newport, the exploder malfunctioned four out of five times. Mechanical relays failed from torpedo vibration, estimates of induced current were in “gross” error and “basic theoretical assumptions used in the design were invalid.”⁸⁴ As late as 1939, Newport was reporting premature activations of the magnetic exploders tested in exercise warheads on the Newport Range.⁸⁵

It was obvious to the engineers that the magnetic field outside Newport might be different than at other spots in the world. The idea was to get baseline data of the magnetic influence exploder. BuOrd conducted tests in the Pacific Ocean off the coast of Ecuador in South America. The principle officer on this project was Ralph Waldo Christie. For the testing, Christie obtained the USS *Indianapolis* (CA-35)⁸⁶ for a target ship and secured two destroyers to act as firing platforms. By this time, the country was

⁸³ Powel, *Newport Administrative History*, unless noted the following information concerning Sink EX testing is from the section: “Attempt to Conduct Destructive Test of Magnetic Influence Exploder Prior to Manufacture Fail,” 149-153.

⁸⁴ *A Century of Progress: Welcome to the Naval Undersea Warfare Center: A History of Torpedo System Development* (Newport, RI: Naval Undersea Warfare Center Newport, 1998), 66.

⁸⁵ *A Century of Progress*, 67.

⁸⁶ Douglas Stanton, *In Harm's Way: The Sinking of the U.S.S. Indianapolis and the Extraordinary Story of Its Survivors* (New York: Henry Holt and Co., 2001), 63-119. The *Indianapolis* later delivered the atomic bombs that were used against Hiroshima and Nagasaki in 1945. After delivery of the bombs to Tinian the *Indianapolis* was sunk with the loss of 1,196 men.

in the throes of the Great Depression and live-firing ten-thousand-dollar (\$185,000 in 2016 money) torpedoes was not an option. Neither was firing at a brand-new ship. Christie and his crew fitted each device with exercise warheads equipped with a photoelectric cell pointing upwards to look through a transparent viewport. As the torpedo ran under the ship, several things happened. First, the test torpedo recorded the magnetic fields and the electric eye looked upward. When the ship's shadow blocked the sun, a strip of film made a record. Finally, the tripping of the exploder was recorded. When back at Newport, the testers put together all this information. Christie was impressed with the results of how consistently the exploder tripped.

Administrative and Staffing Issues of Torpedo Construction. The defects in the Mark XIV/VI were not just caused by material problems or design problems.⁸⁷ Production and testing deficiencies within Newport Torpedo Station contributed to the problems, as well. These problems were caused by production, research and development issues. There were failures of basic policies and procedures at the Newport Torpedo Station. These included insufficient research appropriations prior to 1941, inadequate overall planning of mass procurement by numerous primary secondary contractors, normal difficulties encountered in government operations and long-established practices unsuited to the most efficient industrial management. Having the Naval command structure assume all responsibility for any administrative success or failure compounded

⁸⁷ Powel, *Newport Administrative History*, i-vi.

these problems, creating a feeling that the civilian administrators and employees had little or no responsibility for a successful weapon.

Not only were there military men attempting to use military methods in managing civilian scientists, managers and workers, there was a rapid rotation of key officers, especially in the early months of the war, resulting in a lack of continuity, sustained effort and development of a good production effort. Having different command coming and going also resulted in a wide variation in execution of projects. This ended up with unsettling effects on the overall administration of production, quality control and mass production.⁸⁸

The rollover of key officers was due to officers reporting and serving in theaters of operation. This was true of the workers as well. Losses in trained personnel during the war was chiefly due to men being transferred to outside activities and their entry into the armed forces. Because of these losses, there was a fluctuation in levels of manufacturing skill, which led to fluctuations in details such as good testing of torpedoes. The Civil Service system also caused limitations, namely their emphasis on seniority rather than on a person's qualifications and accomplishments. Senior people ended up doing things the way they did them before the war and did not have any incentive to change their way of conducting business. There was ineffective liaison between Newport administrators and contacts with outside parties involved in related activities. This resulted in a lack of

⁸⁸ Powel, *Newport Administrative History*, 49. The turnover in personnel is a major concern of Powel as is having military command of a civilian organization.

mutual understanding of problems, duplications of effort, and misunderstandings of the necessity for good research techniques.

The Bureau of Ordnance lacked a clear definition in their policies regarding Newport. This resulted in frequent changes of senior individuals' minds, the shuffling of priorities in research and development projects in peace and in war, stop and go procedures, a tendency to over-emphasize any new idea that looked hot at the sacrifice of projects already under consideration, and working with an understaffed research department. There were too few military and civilian-trained scientific minds and administrators, especially before the war. This was because private industry paid more than either Civil Service or the military. To show this, since the early 1920's, only thirty-eight officers from the regular Navy had taken both the Naval Academy's one-year, post-graduate course in engineering and the two-year course in Torpedo Design at MIT.⁸⁹ Civil Service did not attract many more men with graduate degrees. These factors contributed to slow torpedo development. Exploder development did not fare any better.

Once the war began, production needs rose dramatically. With the markedly increased production, Newport workers could no longer produce each part they needed for the MK XIV/VI. They needed to outsource parts and components. Yet, they lacked a continuous functioning group of specifically-trained and experienced officers to collaborate with the sub-contractors who were selling parts and components to the Torpedo Station.

⁸⁹ Powel, *Newport Administrative History*, 138-139.

As mentioned, Newport faced the issue of manpower shortages that other companies faced during the war. That is why women were brought in to help. But it was more difficult for Newport as they were not building wings for B-25 bombers. They were building a top-secret armament. The workers Newport hired needed background checks to ensure that they could work in a classified organization. This brought up logistical issues. Newport was a single factory company that employed 3,873 employees in 1939. This rose to eight factories that employed 12,995 employees in 1944. The organizational and management issues of just finding housing and transportation for that many people was daunting. Add in the fact that these people needed to be cleared by security, hired, trained and managed on a day to day basis and one sees just a few of the difficulties that Newport faced during the war.⁹⁰

The procurement issue was prominently described in the Administrative History of Newport. Between September 1941 and March 1943, 100 officers had passed through Newport and no steps had been taken to train any of them for duty at Newport. None of the 100 had asked for permanent assignment and, by March 1943, no reserve officers had any training in the production of torpedoes.⁹¹ Because of the turnover, organizational plans were begun but were never followed through. Officers initiated plan after plan and, before any was finished, another officer would move in and start another plan. Procurement of critical items like steel, brass, precision bearings and asbestos packings required controlling but had none. Procurement obligations piled up creating a terrible

⁹⁰ Powel, *Newport Administrative History*, iv.

⁹¹ Powel, *Newport Administrative History*, 138-139.

backlog. Over-buying of certain items created duplication issues. Because of confusion, inventory records were incorrect. Some factories shifted suddenly from producing one torpedo model to another. Progress reports of true status were non-existent. The Progress Department should have been the most important department within the system. It became just another system lost within all the confusion.

The Administrative History of Newport Torpedo station reads:

The system seems to have been geared neither to cope as effectively as it should have with the eventuality of enormously intricate torpedo development and torpedo production on the cast scale required by total war, not to protect itself sufficiently against the inevitable shortcomings of the human factor.⁹²

Newport went from doing things the way they had been doing for decades to the workers having to go to work in a high-production setting. This was difficult for the old timers to accept. No longer was quality given priority over quantity. New systems needed to be developed for more torpedoes to be delivered to the areas of combat. One of the major changes was not having the time to produce the individual parts and components within the facility. These parts and components needed to be farmed out. Thus, a good procurement plan needed to be in place. But this involved more than just a plan. Individual relationships needed to be developed as well. This was one of the most important parts of procurement. A purchasing agent and a supplier needed to know they could depend on each other's work. Sometimes a relationship like this took years to develop but Newport and its suppliers had only a matter of months. Then the Newport person would get shipped out and the whole relationship issue would start over.

⁹² Powel, *Newport Administrative History*, 49.

This chapter has covered the history of the development of the Mark VI magnetic exploder. The G-53 project grew and evolved into bigger programs. As the science behind the exploder developed, Newport knew they needed help. General Electric and Carnegie came in to help. But a high-risk project like this needed to be tested over and over. Newport ran one test, the SinkEx program. This test did not involve a capital ship but an S-Class submarine, the smallest boat the Navy has ever mass produced. After this the Navy ran tests on the exploder using camera photographing the hulls of ships after they ran underneath. The first time any Naval Captain in the Pacific saw a live fire explosion was during battle in December 1941. And those explosions were few and far between.

The problem with Newport during the war centered on two major issues. First was the quantity of torpedoes that needed to go to the Pacific. The advent and delivery of the Mark XVIII magnetic torpedo took some pressure off Newport but this did not happen until late 1943. The second was the quality of the torpedoes they were producing. There were failures after the war began, but most of the failures of the MK XIV/VI were due to policies and practices in place almost two decades before the first torpedo was fired in the Pacific in 1941.

CHAPTER THREE

CONFLICT AND RESOLUTION

The USS *Wahoo*

In January 1943, the USS *Wahoo* (SS-238), on her third patrol near Wewak Harbor, New Guinea, had a Japanese destroyer charging her at full steam.¹ After several shots at the Tin Can,² and with no time to set up, the *Wahoo* “shot down the throat.”³

U.S. Navy submarines bore the names of “fish and denizens of the deep.”⁴ A wahoo was a dark-blue fish, popular eating in Florida and the Caribbean. A football field long and ten yards wide, *Wahoo* carried twenty-four torpedoes, a four-inch deck gun, a .50 caliber machine gun, fifty-four enlisted men and six officers. Every man aboard was a highly-trained specialist at his job and, to quote one old sailor, “It was all-volunteer.”⁵ Yet, all volunteers had to meet stringent qualifications and undergo extensive training.

¹ War patrol reports of USS *Wahoo* (SS-238), 1942-1945, NPPSO Reel F-108, Roll AR-159 Record Group 78. This story is from these patrol reports

² Seaman First Class Ward Sims, interview with author conducted December 7, 1981. Born on December 7th, 1924, Sims was a gunner’s mate on the Battleship USS *North Carolina* (BB-55). “Tin Can” is sailor slang for a destroyer. A destroyer, a sizable ship compared to a submarine, was like a tin can compared to a battleship or Air Craft Carrier. They were small, lightly armored, and had shallow drafts, and they ride the sea like a tin can.

³ Lockwood, *Sink ‘Em*, 60.

⁴ Ronald O’Rourke, “Navy Ship Names: Background for Congress” *Congressional Research Service*. September 14, 2016, accessed October 15, 2016, <https://fas.org/sgp/crs/weapons/RS22478.pdf>. The U.S. Navy guidelines for naming ships. From 1937 until 1947, they named submarines after fish and denizens of the deep. In 1947, they named them after famous World War II submarines. The requirements have changed yet again since that time.

⁵ Seaman Second Class Donald Schwab interview with author conducted December 7, 1981. Schwab was also a Battleship sailor 1943 -1946 on the USS *North Carolina*.

On the first patrol in August, 1942, the *Wahoo* hit but did not sink a freighter. Then the *Wahoo* met two targets, a seaplane tender, *Chiyoda*,⁶ traveling unescorted and, later in the patrol, an aircraft carrier escorted by two destroyers.⁷ Due to overly-cautious approaches, these targets escaped. Commander Marvin “Pinkie” Kennedy’s excuses did little to placate the crew. They judged themselves, their boat, and their captain by their successes or at least favorable analyses of their failures.⁸ They sensed the dissatisfaction of their executive officer (XO) Lt. Richard “Dick” O’Kane who, though always professional toward him, thought Kennedy lacked both aggressiveness and skill.⁹ By the time the *Wahoo* had returned to base, morale was poor.

On the second patrol in November, 1942, Dudley “Mush” Morton, Lieutenant Commander and Prospective Commanding Officer (PCO), sailed the *Wahoo* as a prerequisite for receiving command of his own boat. The *Wahoo* spotted a single freighter in the Solomon Islands near Bougainville but *Wahoo*’s approach was unsuccessful. While making her return trip, the *Wahoo* encountered a convoy of three, loaded cargo ships with a destroyer escort. Kennedy fired a spread of four torpedoes at the largest tanker. All four hit but only three exploded. Some of the explosions might have been the torpedoes’ internal air flasks igniting, rather than warhead explosions, as it took two hours for the

⁶ David C Evans and Mark R. Peattie, *Kaigun: Strategy, Tactics, and Technology in the Imperial Japanese Navy, 1887–1941* (Annapolis, Maryland: Naval Institute Press, 1997), 86. In my research I found the *Chiyoda* was a mother ship to midget submarines and not a seaplane tender.

⁷ Most ships of any importance usually had a destroyer escorting, or guarding, them. Destroyers are equipped with special armaments for submarines called depth charges. The charges could be set for a specific undersurface depth explosion. Fifty-two American submarines were sunk during the war, many through depth charging by Japanese destroyers.

⁸ Tuohy, *Bravest Man*, 4.

⁹ Tuohy, *Bravest Man*, 2.

ship to sink. The Japanese destroyer attacked, pounding the *Wahoo* with over forty depth charges. The *Wahoo* escaped but allowed the remainder of the convoy and escort to go. Later, the *Wahoo* thought they had sunk an enemy submarine but after-war accounts did not confirm this. *Wahoo* sailed into Brisbane, Australia, for re-fit with only one sinking to its credit. Morton and Naval Command agreed that Kennedy was overcautious and lacked aggressiveness, so they relieved him of his command. Instead of taking over a different submarine, as customary for a PCO, Morton assumed command of the *Wahoo*.

In the third patrol, Morton and O’Kane were well-matched, aggressive leaders. Diving and engineering officer Lieutenant Junior Grade (JG) George Grider was not merely nervous but “downright scared,” feeling Morton had gone from aggressive to reckless.¹⁰ For example, against combat protocol of sailing on the surface at night to recharge the batteries and diving during the day, Morton sailed on the surface all day to shave a few hours off the sailing time to their patrol area, not even submerging when a Japanese plane flew within six and a half miles of the submarine.

As the *Wahoo* approached Wewak Harbor, a Japanese supply base on the north coast of New Guinea, the officers had navigational charts that were out of date and no charts of the harbor. Grounding the submarine was a real danger. Throughout the war, submariners adapted and improvised. During the last stay in port, a machinist’s mate had purchased an inexpensive school atlas of the South Pacific for his children at home with a fold-out map of New Guinea that had a reasonable rendering of Wewak Harbor. Grider, a

¹⁰ George Grider, *War Fish: Thrilling Firsthand Story of Courage and Action in Submarine Warfare* (Boston, MA: Little, Brown & Co., 1958), 74. By the end of the war young Grider had received his own command, the USS *Flasher* (SS-249).

photographer, enlarged the map and then he and O’Kane used tracing paper to draw a map of the anchorage, still lacking depth information.

As the *Wahoo* approached the anchorage, it sighted the Japanese destroyer *Harusame*. The *Wahoo* fired a three-torpedo spread at the target with no hits. The crew assumed that all three torpedoes missed aft. *Wahoo* fired another torpedo which the *Harusame* evaded. By this time, the destroyer picked up the steam trails of the torpedoes and headed straight for the *Wahoo*. With only two more torpedoes in her forward tubes, the *Wahoo* fired a fifth torpedo which did not explode. The *Wahoo* fired its sixth and final torpedo at a range of 850 yards. Without time to observe the results, *Wahoo* went deep, rigging for depth charges. Having only their mocked-up chart of the Harbor, there was no way to know the depth of the bottom. To avoid grounding, Grider ordered the sub leveled off at only ninety feet. The crew grabbed onto anything available to withstand the anticipated depth charging. The screws of the enemy destroyer drowned out all sounds.¹¹ Then the crew heard an explosion so close that light bulbs burst and cork insulation flew inside the submarine. The next depth charge never came. The explosion had not been a depth charge but the final torpedo hitting the *Harusame*, breaking it in two. The tin can must have turned at the last moment, giving the torpedo a broadside to hit.¹² Despite the failure of multiple torpedoes, command deemed the attack by the *Wahoo* on Wewak one of the most successful engagements of the war by an American submarine. This showed

¹¹ Weir, *Forged in War*, 145. Propellers are also referred to as screws. Some sonarmen could differentiate ship types from the sound of their screws.

¹² *Third Patrol Report of the USS Wahoo (SS-238)*, NPPSO Reel Number F-108, Roll AR-159, Record Group 78, Sourced at the National Archives (Hereafter cited as NA).

how command and the submariners differed in their perceptions of torpedo performance. The U.S. Navy had the submarines and crews to get the job done. Unfortunately, torpedoes were still not dependable weapons. Similar reports, many far worse, poured in.

Thesis and Organization

This chapter argues that the torpedo failures created an overall problem that affected everyone from the eighteen-year-old torpedoman to the Chief of Naval Operations. It took ingenuity and persistence on the part of the men in the field to figure out the causes of and resolve the problems with the Mark XIV/VI torpedo.¹³

The torpedo's relationship to the men who lived with and worked on it was central. Adding stress and frustration to this relationship was the lack of technical literature and training. These men needed to know how it worked and all its different facets to make it a dependable weapon of war. Submariners set up an experiment on the white sandy beaches of Albany, Australia that showed the torpedoes were running on average eleven feet deep.¹⁴ Torpedomen altered their torpedo depth settings to compensate. After this, premature explosions began to increase because the influencer was too susceptible to differences in the Earth's magnetism. The men in the Pacific added up the number of premature detonations and decided to turn off the magnetic influencer.¹⁵ Then duds increased. By this time, BuOrd was helping the men in the Pacific. Testing,

¹³ Lockwood, *Sink 'Em*, 95.

¹⁴ Letter to Admiral Charles A. Lockwood from Admiral W.H. P. Blandy concerning torpedo depth tests at Albany, Australia, July 11, 1942. Lockwood Papers, LOC, Box 63.

¹⁵ Letter to Admiral Blandy from Admiral Charles A. Lockwood, July 19, 1943 to inactivate Mark VI torpedoes at once. Lockwood Papers, LOC, Box 71.

under BuOrd's supervision, involved firing torpedoes into an underwater cliff and then retrieving them.¹⁶ The problem was that these higher-speed torpedoes used detonators designed for slower torpedoes, using metals that were not strong enough. Because of the highly technical nature of the torpedo and exploder, the time and resources it would take to re-engineer them and shortages that already plagued the submarine service, command made the decision, in October 1943, to bypass all the malfunctioning, highly-technical systems. They either turned them off, circumvented them, or changed fire control techniques to compensate for them. The U.S. Submarine Service had a torpedo that was much more reliable, yet they had to abandon the "one shot one sunk" ideal and return to blowing holes in the enemy ships' hulls until they sunk.

This chapter describes the torpedo shortage in the Pacific and how that influenced command's denial of the problems and the solutions they ultimately put in place. Admiral Lockwood's alliances with BuOrd, Naval Command, and Newport began to wane. Within this story we see how careers developed and how alliances were formed and reformed in response to events labeled failed enemy engagements by one side and torpedo failures by the other. BuOrd Head Admiral William Blandy's close, behind-the-scene, personal relationship with Charles Lockwood led to action.¹⁷ Lockwood's connection to Chief of Naval Operation Admiral Ernest J. King's office also helped bring forward the submariners' cause and resolve the problems.

¹⁶ Lockwood, *Sink 'Em*, 100.

¹⁷ Letter from Admiral W.H. P. Blandy to Admiral Charles A. Lockwood, June 19, 1943, thanking Lockwood for critical letter of June 9, 1943 concerning Bureau of Ordnance response to Mark 14/6 torpedo failures, Lockwood Papers, LOC, Box 70.

Torpedo Shortage and Conservation Measures

Admiral Withers instructed the Pearl Harbor submarines to stay submerged during the day when they were within five hundred miles of suspected Japanese air strips. To conserve fuel, they were to run on one engine and, most importantly, they were to conserve their torpedoes. Because Newport produced each torpedo by hand their production was not up to the demands of the customer.¹⁸ The Asiatic Fleet lost 233 torpedoes to the Japanese attack.¹⁹ Because of this shortage, torpedoes were precious. Normal fire control would have dictated three torpedoes fired per ship, one forward of the bow, one at middle of target (MOT), and one leading the stern. This compensated for a faster or slower moving target. With three torpedoes fired, two should hit. One should certainly hit. However, because of the modern Mark XIV torpedo, proven accurate during wartime training, equipped with the new top secret Mark VI magnetic exploder, command believed one torpedo per target ship should do. Captain Wilkes and his Chief of Staff James Fife told their skippers to be cautious with their torpedoes. The magnetic exploder should produce amazing results, Wilkes advised. Sink merchant ships using one, at most two torpedoes. For capital ships, use what is needed without being profligate.²⁰

The submarines from Pearl Harbor and Manila had all found targets. They took shots that missed and some that hit; they also heard explosions that were not torpedo hits. Some of these submarines had good commanders, some not. Regardless, it was difficult

¹⁸ Powel, *Newport Administrative History*, 181, Blair Papers, Box 73, File 1.

¹⁹ Powel, *Newport Administrative History*, 11-710.

²⁰ Blair, *Silent Victory*, 107-113.

to hit a moving enemy ship with a torpedo. It required an efficient, skilled Fire Control Party (FCP).

The previous chapter explained the different facets of the fleet submarines. These submarines gave the U.S. Navy the hardware to get to a battle zone and to conduct battle. But it was up to the crews and the armaments to sink enemy ships. The Submarine Torpedo Fire Control Manual, SLM 1, includes 109 pages of directions on every factor involved in successful firing of a torpedo.²¹ In this manual are personnel, definitions, drawings, approach and firing schematics. Hitting a ship with a torpedo was an inexact science requiring a combination of expertise, drilling, estimation, and luck.

When the war began, Admiral Wilkens at Pearl Harbor sent several antiquated boats to Guam, Wake Island, and the coast of Japan. Admiral Hart in the Philippines had many more submarines at his disposal and sent them in a less haphazard manner. Groups of submarines patrolled the coast of Indochina, around the coast of Luzon and south to the Java Sea, hoping they would encounter the enemy. Later, submarines relied upon intelligence, primarily from *Magic*, the broken Japanese code.²² *Magic* could get submarines in the general area of Japanese ship sorties or within known Japanese sailing routes, but it did not locate the enemy precisely.

²¹ *Submarine Torpedo Fire Control Manual, SLM-1*, May 1950, Commander Submarine Force United States Atlantic Fleet, USS *Flying Fish* (SS-229), Flagship, sourced at San Francisco Maritime National Park Association (Hereafter Cited as MNPA). This manual can be viewed at <https://maritime.org/doc/attack/index.htm>. It includes everything the Submarine Service learned about fire control during the war. It is signed by Rear Admiral James Fife. The following fire control information comes from this manual.

²² Harold C. Deutch, "The Historical Impact of Revealing the Ultra Secret," *National Security Agency*, Declassified, Approved for release by NSA on 10-26-2006 FOIA Case Number 51639, Accessed February 10, 2017 https://www.nsa.gov/news-features/declassified-documents/cryptologicspectrum/assets/files/ultra_secret.pdf. Efforts concerning *Magic* and *Ultra* were combined later in the war.

This brings up the first major challenge: sighting an enemy vessel. At the beginning of the war, the submarines had only SD radar. This radar was to warn a submarine of incoming aircraft within six miles. SD worked both ways, so the Japanese could pick up the radio waves of SD radar and follow them to the submarine. The most widely used method for locating enemy ships was spotting smoke on the horizon, by surfacing, or periscope. Surface locating, though risky, especially near Japanese occupied areas, was easier and allowed crewmen to spot smoke on the horizon on well-lit nights, match flares or cigarette glow from miles away in darkness.

Once located, the crew went to Battle Stations Torpedo. There was a specific station for every member of the crew. All men would report immediately to their attack positions. The complement during Battle Stations Torpedo consisted of three groups, the Fire Control Party (FCP), the ship handling and maneuvering party, and the torpedo handling party. During attack, the most important areas were the torpedo rooms, the control room, and the conning tower. The torpedo officer and torpedomen manned the forward torpedo room. Sometimes during an aft torpedo room shot, the torpedo officer would make his way to the aft room. Often the aft torpedomen would operate with just the chief torpedoman. Highly trained, they did not require the presence of an officer.

The FCP inhabited the control room and the conning tower. As mentioned, the con was a small space containing most of the FCP and the phone-booth-sized analog computer called the TDC.²³ Inside the con were the approach officer, almost always the

²³ Torpedo Data Computer Manual Mark 3, Mods., *A Bureau of Ordnance Publication*, OP (Operations Pamphlet) 1056, June 1944, Keyport. 5-12.

captain, who worked the periscope with the help of the periscope assistant, a senior enlisted man, usually a quartermaster.²⁴ The approach officer would handle the periscope and make target sightings as the periscope assistant called out periscope readings. These men called out sightings, marks and bearings to the TDC operator who was backed up by the assistant TDC operator, both junior officers. The TDC officer's job was to enter information into the TDC and alert the approach officer of the firing solution.

The attack and sonar coordinator, usually the executive officer (XO), monitored sonar conditions to direct the efforts of the sonar operators. His secondary duty was to assist the approach officer. The navigational plotter was an officer in the conning tower. His primary duty was maintaining a navigational plot of targets designated by the approach officer. He furnished the TDC operator and the approach officer with the values of target course and speed obtained from the plot. In addition, he furnished predicted data regarding the target's position based on the best-known target course and speed.

Before the outbreak of the war, sonar was the preferred method for planning approaches and firing against the enemy. The submarine would not even rise to periscope depth during training exercises. It was more important to Command that a submarine remain stealthy. The last thing a submarine commander wanted was a severe dressing down because his submarine had been "caught" on or near the surface by opposing forces.²⁵ Naval Command developed a theory and then examined the outcome through

²⁴ Tuohy, *Bravest Man*, 16-27. The exception to this was Lieutenant Commander Dudley "Mush" Morton. Morton elected to have his executive officer take the target sightings in the conning tower as he worked the plot in the control room. He felt doing so gave him (Morton) a better mental view on the action by looking at the plotting table.

²⁵ Blair, *Silent Victory*, 67.

the lens of that theory. Any results that backed their theory, command embraced. When results failed to back their theory, they were written off as operator error. When the war began, submarine commanders found there was a big difference between theory and the actualities of war. In the first couple of months, sonar approaches and attacks resulted in few sinkings.²⁶ Sub commanders relied upon the periscope for attacks early in the war. As sonar improved, they relied on it more for range finding and target position.

The Radar operator was an enlisted man whose station was also in the conning tower. He sat at the SD radar console. His primary duty was to furnish the approach officer with the ranges of targets designated by the approach officer. SD Radar, primarily for early warning of aircraft attacks, was the earliest radar on submarines.²⁷ The firing key operator was an enlisted man, usually a fire controlman, whose station was at the firing panel in the conning tower. His primary duties were to relay orders from the approach officer to the torpedo tubes and to fire the torpedoes when directed to do so.

Inside the torpedo rooms were the gyro angle setters, enlisted men stationed in each torpedo room at the gyro setting indicator regulators (GSIR). Their primary duty was to oversee the setting of correct gyro angles on the torpedo tubes, as directed by the assistant TDC operator. If the direct linkage from the conning tower failed, these men would manually set the gyros to the desired position with mechanical levers.

²⁶ Newpower, *Iron Men*, 25-26, 68.

²⁷ *Fleet Submarine*, Air and Sea Search Radar, Accessed January 14, 2017, <http://www.fleetsubmarine.com/radar.html>. Later SJ radar was developed. This radar had better range and could locate targets on the sea. After development, the firing party included the SJ operator, an enlisted man, who was also crammed inside the conning tower.

These men were all highly trained. As mentioned, the officers were trained at the Naval Academy at Annapolis, almost all with some type of engineering degree. The enlisted men at these positions were usually senior men, trained at special submarine schools. A good submarine commander, which is to say most of them, conducted drill after drill so the entire firing party could anticipate each other's moves. These men needed to be highly trained and highly competent, as firing a torpedo successfully at an enemy ship was a highly technical operation.

Contact, Attack, and Firing Solutions

USN SLM-1 was the Navy's bible when it came to hitting an enemy target with a torpedo. It showed the incredible difficulty that submariners faced when attempting a torpedo shot. A submarine was a moving ship, attempting to hit another moving ship with a moving undersea weapon. This undersea weapon did not move in a straight line either. The gyro setting steered this weapon somewhat towards a target. Admiral Fife mentions in the forward of the document:

The variety of targets and other unpredictable conditions, such as weather and depth of water, render it impracticable to set forth a procedure or doctrine which will apply under all conditions.... There do exist, however, tested and proved procedures and tactics which if followed will assist the submarine Commanding Officer and '*increase his chances of success.*'²⁸

Once the submarine contacted an enemy ship, sinking was not guaranteed. With so many variables and estimations in a submarine torpedo attack, it was commendable that so many submarine crews could successfully hit any ships with torpedoes.

²⁸ Fire Control SLM 1, viii.

Searching for a Target

As mentioned above, the key to finding a target was a ship's smoke on the horizon or a blip on the radar. Although a sub captain needed to target a single ship, he would hunt for convoys. Code-breakers in Pearl Harbor culled information from the Japanese *Magic* code to find convoys. A captain aimed to maneuver ahead of an enemy convoy or enemy ship. If the rare possibility presented itself, he would set up and shoot while his boat was static in the water. If it was a night shot, he preferred shooting from the surface. During the day, he would shoot under the surface. "By the book," the best shot was a ninety degree or perfectly perpendicular shot.²⁹

Periscope

Invisibility was the most important factor for submariners. The fleet submarines carried specially made periscopes with small heads.³⁰ The enemy could, and often did, spot periscopes, so the smaller the better. Plus, a smaller periscope made a smaller "feather" on the surface. The attack periscope had a head that was only 1¼ in diameter. In addition to this, the sub carried another periscope with a search, or night, head that was larger by an inch. The wider diameter increased light-gathering capabilities and covered a longer range.³¹ The user could switch from low to high power with the roll of the right

²⁹ Fire Control SLM-I, Chapter 1, Page 5, (1-5).

³⁰ *Submarine Periscope Manual*, Produced by ComSubLant, Standards and Curriculum Division, Training Bureau Naval Personnel, Navpers 16165, June, 1946, MNPA. This manual can be seen at <https://maritime.org/doc/fleetsub/pscope/index.htm> All information concerning periscope use is from this volume.

³¹ Late in the war the technology had improved that a radar wave guide was incorporated in the head. This acted as a small but effective radar dish.

wrist, a valuable feature during an attack, as each power had different measuring hash marks that helped in the measuring of the target.

The periscope had a built in stadimeter, a range finding device which was operated by a knob below the right handle. Also on the periscope, below the handles, was a bearing ring. The bearing ring was a 360-degree gauge with zero degrees being towards the bow of the submarine. Thus, if the captain turned to starboard and aimed the scope perpendicularly, the bearing of scope would be at ninety degrees, opposite would be 270 degrees, and the aft would be 180 degrees.

Shooting a torpedo successfully required several measurements: the speed of the target, length of target, the distance to target, and the direction the target was sailing. This required measurement of the target itself. The most critical factor, distance to the target, required measuring or estimating the masthead height of the target to the ship's waterline.

Masthead Height

The simplest and most reliable way to estimate masthead height depended on recognition of the type of vessel targeted. Before the war, the Office of Naval Intelligence (ONI) developed recognition books for the Navy. These books became invaluable for the Submarine Service as they included drawings and descriptions of enemy ship types, as well as photographs of the actual ships the submarines were targeting.³² The FCP would

³² *Japanese Merchant Ship Recognition Manual*, ONI-208J (Revised), 1944, Copy from Historical Naval Ships Association (Hereafter Cited as HNSA), Accessed December 24, 2016, <http://archive.hnsa.org/doc/id/oni208j-japan-merchant-ships/index.htm>. This manual has description, drawings, and measurements of all different ship types, for example, tankers, cargo ships, hospital ships, or passenger ships. There are different ship layouts for example composite superstructures versus split superstructures for freighters. Most importantly this book has actual photographs of different perspectives of 270 Japanese “*Maru*” ships, passenger liners, and tugs.

spot a vessel and identify it in the book from its silhouette and other distinct features. The book gave them important measurements and other information. For instance, a *Hokkai Maru* type ship was an 8,360 - 8,416-ton tanker or freighter, with a steaming radius of 38,050 miles at sixteen knots, capable of mounting a five-inch or six-inch gun. They also learned that this was a legitimate target and, more importantly, that the masthead height is eighty-three feet. The approach officer took that number, along with the readings from the image measurement marks built into the periscope, and using an omnimeter, which has pre-calculated charts and graphs, determines the estimated distance to target. When required, manual calculations used a telemeter, a slide-rule-based device. This produced what was called a telemeter range. However, when the FCP couldn't identify the ship type, they had to rely on other methods.

The second method for determining masthead height was to use the stadimeter.

As the periscope manual explained,

The stadimeter relies for its operation upon the formation of two identical images which, can, by means of a handwheel on the periscope, be vertically displaced with relation to each other. To obtain range, the handwheel is turned clockwise until the target masthead in one image coincides with the target waterline in the other image. The range is then read on the stadimeter scale opposite the appropriate masthead height.³³

The periscope also had vertical and horizontal hash marks, allowing estimation of both height and length of the ship.

If the approach officer thought the masthead had been altered or camouflaged, he had optional methods he could employ. He could count the number of decks and multiply

³³ Periscope Manual NAVPERS 16165, 5-4.

by eight feet to approximate the bridge height, from which he could calculate the masthead height:

The masthead heights of merchant ships were 2.1 times on average the bridge height. A masthead height which appears to be shorter than normal will be about 1.7 to 1.8 times the bridge height, while one which appears to be higher than normal is approximately 2.2 to 2.3 times the bridge height.³⁴

Similarly, he could use funnel heights to estimate masthead height. Regardless of the method, the team conveyed the distance to target to the TDC officer for entry into the TDC.³⁵

Shooting torpedoes at a 1000-foot ship was a lot different than shooting at a seventy-five-foot ship. If there was no intelligence on the target, the situation became much more difficult. For example, if the best view of the target ship was oblique, the FCP had to estimate the length using hash marks on the stadimeter and telemeter math formulas.

Target speed was always an issue. Known types of ships had known speeds. For example, a Japanese merchant ship would usually travel at eight to twelve knots. Another way to estimate speed was to take multiple sightings of the target and have the plotter estimate speed. The TDC estimated the speed using the same sightings. The sonarmen could estimate speed by counting the revolutions of the target ship's propellers. Later in the war, the approach officer could estimate the speed of a target from experience, "dead reckoning." However, because this factor was so important, the FCP had to use

³⁴ Periscope Manual NAVPERS 16165, 5-6.

³⁵ Fire Control SLM-1, Chapter 4, pages 2-4. Alternately, a sonar ping could be used to estimate distance. But this would alert the target to the submarines presence.

everything at their disposal, often using several methods at once.³⁶ Japanese vessels, in turn, purposely changed speed at random intervals to thwart these efforts.

The target bearing and the angle on the bow were two separate factors. Submariners took the bearing, or course, of the target with sightings from the periscope. On the lower part of the periscope was a bearing gauge. When the approach officer called out, "Bearing, Mark," the position of the periscope would register on the bearing gauge or compass. He called out the position to the TDC operator for entry into the TDC. Angle on the bow was the target's relation to the bow of the submarine. If a target was directly in front of the submarine the angle on the bow was zero, and if directly behind it was 180 degrees. If the target was perpendicular, the angle on the bow was starboard ninety degrees or port ninety degrees. To complicate matters, the Japanese ships would randomly zig-zag to prevent accurate measurement of bearing and angle. Also, one had to factor in the submarine's own direction and speed. The TDC regularly read these from the ship's gyrocompass and the pitometer log. The crew did not have to worry about these measurements as the TDC received these electrically and mechanically.

Torpedo Data Computer

Britain, Germany, and Japan had all developed automatic firing computers for their submarines, but none were like the U.S. Navy's TDC.³⁷ Other computers calculated an instantaneous firing solution but tracking the target was a manual process. The TDC

³⁶ NAVSPER 16165, 8-4.

³⁷ Torpedo Data Computer, Mark 3, Mods 5 to 12 Inclusive, *A Bureau of Ordnance Publication*, June 1944, Operations Pamphlet (OP) 1056, MNPA. All information concerning the Fleet Boat Torpedo Data Computer comes from this publication.

could track the target automatically. Before the advent of the TDC, the Navy relied on slide-rule-based devices. One was called a *Banjo* (it looked like a Banjo³⁸) and a previous model was called the is/was (target is now here/target was there).³⁹ Both worked on a slide rule principle and operated like an artist's color wheel. The TDC consisted of two state-of-the-art electromechanical analog computers acting in unison within one housing. One computer was an angle solver, calculating the torpedo's gyro angle. The second was a position keeper, generating a continually-updated estimate of the target position calculated on earlier target position measurements. This dial-operated unit housed gears, balanced brass wheels, lights, tubes, servos, motors and miles of electricals wire. The machine's purpose was to calculate trigonometric problems to obtain the firing solution for a torpedo (angle, depth, etc.). When in action, the TDC operator would input the readings given him from the captain. When the TDC obtained a solution to the trigonometry problem, a solution light would come on telling the TDC operator that it was the proper time to fire the torpedoes. The TDC operator would then call out to the captain, "We have a solution," and the captain would then give the order to fire.

This was a basic condensed description of what a FCP went through to fire torpedoes at the enemy. Though complex enough, it is a simplification, given to emphasize the complexity of the process. And it was only part of that process. The torpedomen had to be on top of their game, as well.

³⁸ Torpedo Angle Solver Mark VIII, *Operating Instructions*, Bureau of Ordnance, OD Number 3518, August 28, 1941, accessed December 27, 2016, <http://archive.hnsa.org/doc/banjo/index.htm>.

³⁹ Submarine Attack Course Finder Mark 1 mod. 3, OD 453, *US Navy Gun Factory*, May 2, 1922, accessed December 27, 2016, <http://archive.hnsa.org/doc/attackfinder/index.htm>.

The Torpedo Rooms

The torpedo officer and torpedomen had their work cut out for them. The Bureau of Ordnance's twenty-one-inch submerged torpedo tube manual was 144 pages of how to shoot a torpedo from a submarine.⁴⁰ The first issue was loading a twenty plus foot torpedo, twenty-one inches in diameter, weighing a ton and a half, into a 21.125-inch hole. This involved using ropes, chains, skids, block and tackle, good aim and a lot of strength by several men. The men had to be intimate with the workings of the tubes and machinery. There were water and air systems, which meant knowing what every valve, gauge, pipe and tube did. They needed to charge the torpedo's air flask to full pressure and fill fuel reservoir with alcohol. The torpedo's inner machinery could lock up if the oil system was not ready to go. Most importantly, the torpedomen needed to know how to install, service, and set the new Mark VI magnetic exploder.

The torpedomen handled the most important settings on the torpedo during an attack. Once the torpedo was loaded, the men connected the gyro setting mechanism, setting the gyro mechanism within the torpedo at the last moments before firing. When loading the torpedo into the tube, the torpedomen set the gyro at zero to insure it lined up with the gyro mechanism spindle and socket. Then they rotated the spindle to zero so it would mesh with the gyro. They attached the gyro mechanism to an analog, mechanical computer called the gyro setting indicator regulator (GSIR). This computer could set the gyro angles of all torpedoes in a "nest," one for the forward six tube nest and one for the

⁴⁰ Submerged Torpedo Tubes: Marks 32 to 39 and Modifications as in SS198 and Up, *A Bureau of Ordnance Publication*, June 1944, Operations Pamphlet (OP)1085, Keyport. The following information concerning firing of torpedoes from a Fleet Submarine come from this publication.

rear four torpedo nest. This would mechanically control the gyro setting on each torpedo. This GSIR connected electrically to the TDC. Torpedomen adjusted the depth setting on the torpedo by a specialized outside dial, spindle, and crank that engaged a spindle in the torpedo. One revolution of the handle of the crank, set manually or by the GSIR, equaled two feet of depth. The torpedo had a small handle that engaged the starting gear for the steam engine, which the torpedomen needed to set in the correct position. These are just a few of the tasks for which the torpedomen was responsible. Any mistake made a torpedo unable to find its target. For example, if the starting gear lever was not engaged, the torpedo could shoot out of the tube and sink to the ocean floor. No top-secret manuals or guides existed.

During an attack, the torpedo tubes were flooded and the other torpedo tube doors opened. When fired, a large shot of compressed air expelled the torpedo from the tube. Firing out of the tube tripped the starting gear lever, causing an internal shot of air to the starting motor of the torpedo, which would engage the air, fuel, and burner systems. The Mark XIV torpedo was self-sufficient and self-powered. It was steam driven and a marvel for the age. The worst thing about it was that a steam engine needed to exhaust, and exhaust trails could draw a straight line to the point of origin, which in this case was the submarine.

Analysis of the Fire Control Process

The above sections are meant to explain the difficulties of firing a torpedo at a target. The approach officer needed to take multiple readings. A ballet within the conning tower commenced to make sense out of these readings and enter them into the TDC.

Some of these readings were no more than estimations or dead reckoning. When a submarine was under attack it made the situation even more challenging. As problems with the Mark XIV/VI torpedo became apparent, command accused the firing control parties of not doing their jobs well enough. Yet, these men were officers and trained engineers. Some had graduate degrees in engineering. The enlisted men were highly trained and dependable. Most importantly, these men knew how to make the most with what they had on hand. Most came from a civilian world in the most trying of circumstances that the United States had seen, the depression.

Wartime Problems

Four-time Navy Cross recipient and ace submarine captain, Slade Cutter, made a significant point about going into war: “....no nation, or non-aggressor nation, had enough of the tools of war at the beginning.”⁴¹ This was certainly the case with the Submarine Service at the beginning of the war. The Submarine Service employed all types of submarines during the first months of the war. Several of these were the tiny S-Boats. Some were the huge V-Boats. Fortunately, the Navy had multiple fast and effective fleet boats as well. Problems surfaced almost immediately. As Tyrell Jacobs found in the USS *Sargo*, the Mark XIV torpedo with the Mark VI magnetic exploders were not working nearly as well as expected. In addition to this, there were problems with several of the

⁴¹ Captain Slade Cutter Letter to Clay Blair Jr, December 16, 1971, Blair Papers, Box 67, File 2.

submarine captains early on. The “Battle” of Lingayen Gulf shows how dismal the situation was.

The USS *Stingray* spotted the Japanese invasion force sailing into Lingayen Gulf. The *Stingray* had small oil and air leaks which had the potential of giving the submarine’s presence away. The captain, Ray Lamb, made a halfhearted attempt at attack but ordered no torpedoes fired. It was obvious that Lamb was not aggressive and he requested orders to return to Manila. He was relieved of command when he arrived at Manila. However, Lamb did alert Manila to the presence of the invasion force. Wilkes ordered several boats to report to that station.

The *S-38*, *S-40*, *Salmon*, *Permit*, *Porpoise* and *Saury* sailed to station. Since the gulf was crowded with ships, and it was an enclosed area, most shots were within 1,500 yards of the target. Six boats shot seventeen torpedoes with only one enemy ship hit. In response, the Japanese battered and damaged several of these subs through depth charging. Some subs, such as the *Porpoise*, having been depth charged before reaching the gulf, did not make the attempt to enter. Orders came for the first submarines to withdraw. However, Wilkes, after withdrawing these submarines, did not replace them. There were at least nine other fleet boats within the area and easy steaming to the gulf. Wilkes should have sent more boats in but he chose not to do so.⁴²

These are tales of sub skippers and an area commander who, although brilliant in peacetime, were too meek when the shooting started. Captains like Ray Lamb were often

⁴² Blair, *Silent Victory*, 145-151.

relieved of command when they returned. Other skippers were aggressive but their torpedoes did not perform. To cap it off, Command did not follow up the attack.

Command and Skipper Problems

As the war progressed, senior posts were often manned by younger men. Medal of Honor winner, Admiral (then Lt. Commander) Gene Fluckey, remembers:

If you can imagine at the beginning of the war going aboard the *Bonita*, the average age of my chiefs was up in the 50's and I even retired my Chief Electrician during wartime at age 65. I can assure you that at least half these Chiefs had no other thought than that the war would soon be over and they would return home safely. They were extremely cautious and only interested in the most cautious operation of the submarine with the utmost safety.⁴³

There was a lot of skill and organization that went into hitting an enemy ship with a torpedo. But a captain needed to get to attack position first. Once in position, he needed to be aggressive. Some skippers failed miserably. The most poignant story is that of Morton Mumma on the USS *Sailfish*. Admiral (then Lieutenant Commander) Thomas Reich recounts in an abbreviated note:

Bring in one of finest men in Navy to C.O. So brought in Mort Mumma. He been there few months (Portsmouth, in *Sailfish*, formerly *Squalus*). Great pal of Voge's. We used to wonder: who is our C.O. Voge or Mumma? Whatever *Sailfish* doing, we doing, Mumma not particularly popular. He considered most outstanding S/M officer in the fleet and had medals to prove it...⁴⁴

⁴³ Transcription from Taped Interview Admiral Eugene Fluckey to Clay Blair Jr. November 6, 1972, Blair Papers, Box 7, Folder 5.

⁴⁴ Admiral Eli Thomas Reich, Transcription of interview with Blair dated August 12, 1971, Blair Papers, Box 69, File 6.

Morton Mumma was a captain's captain. He earned decorations during peacetime and knew the business as well as anyone. On December 13, while cruising off the west coast of Luzon by the city of Vigan, Morton and his *Sailfish* sighted two destroyers. He submerged to make a sonar approach. The destroyers apparently made the *Sailfish* and dropped a couple of depth charges. Mumma fired two torpedoes at a depth of one hundred feet and fifteen seconds later heard an explosion. No one knew for sure if it was a premature detonation or another depth charge. Mumma preferred to think he not only hit a destroyer but sank it as well.⁴⁵ Immediately afterward, the second destroyer began to depth charge the *Sailfish* heavily and Mumma went to pieces. He summoned his XO, Hiram Cassidy, to take command and to lock him (Mumma) in his stateroom. Cassidy did so and radioed Wilkes at Manila. Unfortunately, other submarines on patrol picked up and decoded the radio dispatch and the secret was out. Wilkes ordered the *Sailfish* back home and replaced Mumma with Dick Voge, a captain who had lost his boat in an earlier bombing at Manila.⁴⁶

It is easy to be critical of the United States' attack on the Japanese in Lingayen Gulf and surrounding area from the perspective of today. Viewing the response of these captains and command, knowing what younger, successful sub skippers such as Slade Cutter and Dick O'Kane did later in the war, is not fair. Situations changed rapidly in war. In the words of Admiral and Medal of Honor Recipient Admiral (then Lieutenant Commander) Eugene Fluckey:

⁴⁵ First War Patrol Report of USS *Sailfish* (SS-192) NPPSO Reel H- 108, Roll AR-149, Record Group 76, Keyport, 1-4.

⁴⁶ Blair, *Silent Victory*, 143-144.

At that time- and a lot of their leaders, I could say this, in peacetime, we were handicapped, I thought, very greatly from my own viewpoint by a number of inept senior leaders and commanding officers of submarines who were not aggressive but because of seniority, there was very little selection out and most of the eventually achieved the rank of Submarine skipper. They were also protected by their friends above. This was also the situation that became intolerable and as we learned quite sadly that the age of the skippers, which at that time was roughly between the age 42-age 42 (3?) ... bracket- was a little bit too high and many of them were over-cautious. Part of this may have been due to the fact that there had been a considerable number of operational casualties to submarines and sinkings during peacetime which greatly influenced some of these older skippers. To the point where they were exceeding cautious, even in diving the boat, at angles that were necessary to insure a safe submergence in the face of enemy or planes. In my own experience, I found little interest before the war and in early stages of war in innovation of new tactics or aggressiveness to the point of calculated risk. There seemed to me a general prevailing attitude of let's not upset the applecart or disturb the wigwam. There was a real struggle by many of the junior officers to get their captains to be aggressive. In fact, some of the captains, even in 1942-1943, were of such an age that they had to become fatalistic and had to worry about the fact that this time out they might be sunk. I am certain that many opportunities were missed because of this attitude.⁴⁷

Admiral (then Lieutenant Commander) C.C. Andrews wrote, "Some of our troubles in re-gearing to life as it turned out to be was caused by a backlog and stagnation in S-Force of old timers at the Division and Squadron levels and even in some cases in the Chief of Staff level. There seemed to be a reluctance by the force commanders to move any of these men upstairs or out. Had it been done earlier, younger men would have proceeded with more vision."⁴⁸ This suggests that at this point in the war, there was a lot of weeding out to do, not only of non-aggressive skippers but of area commanders who were not sure what to do. However, having non-aggressive skippers is one thing but

⁴⁷ Fluckey to Blair, Blair Papers, B7 F5.

⁴⁸ Mail Interview C.C. Andrews and Clay Blair, May 16, 1972. Blair Papers, Box 66, File 3

shooting seventeen torpedoes and getting one hit is quite another. As with the *Sargo*, the performance of other ships that had attacked enemy ships off the coast of Indo-China showed that the torpedo failure situation was critical.

Torpedo Issues

The coast of Indo-China and the debacle at Lingayen Gulf was just the beginning of the torpedo problems. The accounts of torpedo problems in the war patrol reports of the submarines that served in the Pacific abound. The first thirty-nine MK XIV/VI torpedoes fired in the war had no hits.⁴⁹ The USS *Skipjack* (SS-182) was a *Gato Class* boat. On January 24, 1942, the *Skipjack* reported a typical instance with her torpedoes:

25 December Position -Long. 130-05E: Lat.-5-52 N. At 2025 sighted ship bearing 260 degrees T., Range Estimated 12,000 yards, angle on the bow 25 degrees' port. At 2027 ship was identified as an aircraft carrier and another ship was sighted acting as a starboard screen- this ship was thought to be a destroyer. C.V. was clocked by sound, which no had a good contact, at 200 rpms. Moon was at altitude of about 15 degrees and ship was picked up a little to the left of the path of the moon, His course was established as 107 degrees and his speed at 17-1/2 knots, by TDC. Kept boat heading at target until setup seemed to be all right and checked with T.D.C. output. At 2035 dived to avoid detection and came to course 197 degrees for ninety-part track. Set-up on T.D. C. checked exactly with bearings from sound. At 2041 fired three torpedoes at 2200 yards range with the following track angles, 89 degrees, 93 degrees and 97 degrees. Only three torpedoes were fired because the other one in the forward tubes was out of the tube and the gyro was out of the torpedo being checked. Torpedoes were fired at depth of 100 feet. Depth setting on torpedoes was 18 feet. Torpedoes were fired at 10 second intervals. After torpedoes were fired rigged ship for depth charge attack and went to 230 feet. No reason can be given for not getting at least one hit...⁵⁰

⁴⁹ US Submarine Attacks, Listed Numerically by Boat and Patrols, based on Task Force Commanders' Assessments, Data from Records of SORG (Submarine Operations Research Group), Office of Strategic Planning ComSubPac, NPPSO Reel H-108, Roll AR-254 Record Group 76, NA.

⁵⁰ War Patrol Report of USS *Skipjack* (SS-184), January 24, 1942, NPPSO Reel, F-108 Roll AR-159 Record Group 78, Keyport, 1.

Submarine captains looked back at the problem with the torpedoes during the first days of the war. Admiral (then Lieutenant Commander) C.C. Andrews of the USS *Gurnard* wrote:

I agree torpedoes were defective - I saw torpedo hit a ship and water splash only up to deck- ship put on more speed. Once forward torpedoes prematured right outside of tubes. If torpedoes were as good as supposed to be, US would have won war lot earlier. There was a torpedo shortage so early skippers fired 1 torpedo at 1 ship.

Yes, several underruns in torpedoes I fired, I had one dud explode against the side of a ship. The crew looked over the side of ship and ship kept going.⁵¹

Rear Admiral (then Lieutenant Commander) Royce L. Gross of USS *Seawolf* mentions, "My first war shot was a premature, and I had very many duds, surface runs, and un-explained misses."⁵² Captain (then Lieutenant Commander) Roland F. Pryce of USS *Spearfish* said, "I have lived with the complete frustration of those three months for over thirty years and even the knowledge we all now have that defective torpedoes were my critical problem doesn't alter the anguish I felt at the end of February 1942. I had failed to sink at least three important Japanese warships after attaining good approach or firing positions."⁵³

Other submarines, the *Pickrel*, *Sturgeon*, *Searaven*, *Snapper*, *Permit*, *Perch* and *Tarpon*, all reported unsuccessful attacks during late 1941 and early 1942.⁵⁴ These reports went to immediate area commanders at the Asiatic station and at Pearl Harbor. After

⁵¹ Admiral C.C. Andrews, Commander, USS *Gurnard* (SS-254), Interview by Mail with Clay Blair, May 16, 1972. Blair Papers, Box 66, File 3.

⁵² Royce L. Gross Letter to Blair January 12, 1972, Blair Papers, Box 68, File 1

⁵³ Letter from Royce Pryce to Clay Blair, October 19, 1972, Blair Papers Box 69, File 2.

⁵⁴ Newpower, *Iron Men*, 66.

endorsement, they went to Fleet Command and BuOrd in Washington, D.C. From there they ended up at Newport. The reports of MK XIV/VI problems were well written and plain. The reports fell upon deaf ears. Command heard the submarine skippers. They just did not believe them.

Initial Response by Command

Springtime in the Pacific was not a happy time for anyone, except perhaps the Japanese. Their Army had made inroads and were pushing down the Bataan Peninsula. The U.S. submarine force pulled back down to Java and then to Australia. Both Withers at Pearl Harbor and Wilkes in Australia were trying to stem the flow of Japanese re-supply. Both were aware that the submarine captains were not confident with their torpedoes. Yet, torpedoes were in short supply, so the magnetic exploder *had* to work. The conflict was demoralizing. For both Wilkes and Withers a change was coming, not just with more torpedoes coming into the conflict but with new people arriving, some with new ideas, some not.

During the first months of 1942, Admiral Thomas Withers commanded the submarines out of Pearl Harbor. Withers, knowing there was a torpedo shortage, could not bring himself to believe that the Mark XIV/VI torpedoes were defective and immediately quashed any mention of trying to improve torpedo performance by modifications performed in the field. Mike Fenno of the USS *Trout*, on a supply mission to Corregidor, met with other skippers who had run combat patrols around the Philippines. Fenno returned to Pearl Harbor convinced that there was a problem with the magnetic exploder. He met with his chief, Admiral Withers, and pleaded with him to

deactivate the magnetic feature and go with the redundant, built-in contact exploder. Withers knew the shortage of torpedoes was severe and demurred. Some skippers deactivated the magnetic feature and did not report it. The situation became more strained when Commander George Crawford assumed command of one of Withers' Submarine Divisions, number 43. As a full commander, Crawford was one step down from a captain. Crawford eventually ordered boats in Division 43 to deactivate the magnetic exploder. When Withers heard about this, he immediately countermanded it and Crawford got a "good old Navy dressing down."⁵⁵

Other skippers tried to disconnect the magnetic feature on their exploders. Rear Admiral (then a Lieutenant Commander) Martin P. Hottel of the USS *Spike* recalls, "...So before my 3rd torpedo run I got my torpedo crew together and we inactivated all of our exploders. Somebody squealed on us however and Fife held (us) up for a day with orders to reactivate and to leave them strictly alone."⁵⁶ Adding to the confusion, sometimes the magnetic feature worked. The same Mike Fenno conducted twelve attacks sinking five enemy vessels in his next patrol in the *Trout*. This helped Withers save face. But to his credit, Withers wrote Blandy at BuOrd asking them to investigate whether the magnetic influence of a ship's hull might detonate a torpedo close to the target without damaging it.

In addition to this, Lt. Commander A.H. Taylor of the USS *Haddock* wrote Blandy directly at BuOrd. Taylor wondered if forces generated on a severe gyro angle

⁵⁵ Blair, *Silent Victory*, 213.

⁵⁶ Admiral Hottel letter to Blair, April 3, 1972, Blair Papers, Box 68, file 2.

could affect the exploder. On a tight turn a torpedo might experience severe buffeting while trying to find its course. This could result in a premature detonation. Taylor also wondered if a “down the throat” shot, a torpedo traveling directly at a target’s stern or a torpedo running parallel to but not under an oncoming ship, might explode harmlessly away from the enemy ship’s hull. If shot from behind at a ship’s stern, in the ship’s wake, might the turbulence trip the exploder there by causing a premature detonation?⁵⁷

Taylor’s letter needed to go through his superior for an endorsement. His immediate boss, Commander O.S. Colclough, noted that he felt the buffeting issue would not affect the exploder and ignored Taylor’s concern concerning the ship’s wake issue.⁵⁸ With this non-supporting endorsement, BuOrd ignored Taylor’s letter.

As for the Asiatic Fleet, its leader, Ralph Christie, both having worked on the development of the Mark VI exploder and having been a driving force on the Mark XIV torpedo, was a true believer in both. He was convinced there was nothing wrong with either the exploder or the torpedo. The problem was with the submarine skippers, fire control parties or torpedomen. He wrote in a letter to Rear Admiral R.S. Edwards USN, Office of Cominch, Navy Department Washington DC: “The torpedo situation is all right. The many failures attributed to torpedoes are, in my opinion, largely due to control

⁵⁷ USS *Haddock* (SS-231) Letter to Bureau of Ordnance. Regards to Mark 6 Mod 1 exploder. Dated April 4, 1942. General Correspondence of the Bureau of Ordnance, Box 136 RG 74 NA.

⁵⁸ First endorsement of letter from USS *Haddock* (SS-231) letter to Bureau of Ordnance dated April 4, 1942. Regards to Mark 6 Mod 1 exploder. Endorsement dated April 17, 1942. General Correspondence of the Bureau of Ordnance, Box 136, RG 74, NA.

failures under the pressure of the enemy. So many made-to-order opportunities have been lost by the inexperience of the commanding officers.”⁵⁹

Changes in Personnel

In late spring, Rear Admiral Robert English was replacing Rear Admiral Thomas Withers. English, aware of the concerns of the crews over the torpedo issue, rejected Commander Crawford’s recommended modifications to the Mark XIV and Mark VI exploder. In a letter to the fleet, English wrote:

3. submarine torpedo misses may be attributed to the following:
 - a. Errors in range estimation
 - b. Errors in speed estimates.
 - c. Errors in course estimates.
 - d. Natural dispersion of torpedoes which is large.
 - d. Inexperience of Torpedo Data Computer Operator.
 - e. Guess and snap decisions by approach officer
 - f. Targets maneuvering to avoid
 - g. Physical condition of the approach officer
4. Commanding Officers will continue to set torpedoes at a depth not less than five feet greater than the maximum draft of the target.⁶⁰

At this point, several people were blaming the crews and the captains. English did not believe that anything was wrong with the weapon and, being a submariner, he should have known. With the change in command at Pearl Harbor there came a change in command with the Asiatic Fleet. Newly-starred Rear Admiral Charles Andrews

⁵⁹ Letter from Ralph Waldo Christie to Admiral R.S. Edwards, dated May 19, 1942, Christie Papers, LOC, 181.

⁶⁰ Letter from The Commander Submarines, Pacific Fleet (English) to Submarines, Pacific Fleet, Subject: USS Grenadier (SS-210)- Report of Second Patrol. June, 18, 1942. Blair Papers, Box 73, File 1.

Lockwood replaced Captain John Wilkes as the newly-created post of Commander Submarines Southwest Pacific.⁶¹

Robert English's title of Submarine Commander Pacific was not necessarily accurate. After a few months, the areas of the Pacific were divided officially. English was responsible for most of the Pacific, certainly he was responsible for all the boats out of Pearl Harbor, but General Douglas MacArthur held sway in the south as supreme Commander Southwest Pacific Area and felt he needed his own Navy. Thus, Lockwood, Christie, and Fife, while technically subordinate to English, did not work for him. They worked for MacArthur's naval commander Vice Admiral Leary. Leary only held the post for a few months until he was replaced by Rear (soon to be Vice) Admiral Arthur S. Carpender.

Both Leary and Carpender came from the Atlantic, Leary as a destroyer man and Carpender as a submariner. Lockwood was respectful towards Carpender but became tired of how they did things in the Atlantic.⁶² Regardless, Lockwood was in command of the submarines of the Asiatic Fleet and had responsibility for his men, their submarines, and their torpedoes.

The stage was set. At this point in the war, in the spring of 1942, torpedo failures abounded. The submarine skippers were demoralized from this alone. Being blamed for what they saw as a technical failure was worse. The torpedo shortage made things even worse because command felt the torpedoes *had* to work. BuOrd was fully invested in the

⁶¹ Letter of Acceptance and Oath of Office dated May 31, 1942. Appointment as Rear Admiral United States Navy for Temporary Service. Lockwood Papers, LOC Box 64.

⁶² Blair, *Silent Victory*, 283-284.

MK XIV/VI, so they were of no help at that moment. In fact, Newport could not produce enough of the torpedoes as it was.

The Depth Issue

As mentioned, Lockwood was close to his crews. Lockwood's first reaction was that the crews were having internal fire control issues. His experience taught him the difficulties involved in shooting a torpedo successfully at an enemy ship. Under pressure, a fire control issue probably became accentuated. Lockwood arrived in Brisbane on April 28, 1942.⁶³ He took over the exhausted John Wilkes job and began poring over every war patrol report, including those from Chappell and Jacobs. On May 6, 1942, Lockwood met with Chappell and other skippers who had experienced torpedo failures on their war patrols. Lockwood spent the rest of the month meeting with sub commanders and their immediate bosses, the division commanders. He inspected their boats, the submarine tenders and collected information on everything relating to the operations of submarines in his area of responsibility, the Southwest Pacific. During this time, Lockwood found that his friend Bob English was now Submarine Commander Pacific, SubComPac.⁶⁴

After hearing from submarine commanders and reading report after report, Lockwood concluded that even though the torpedo crews may have been having fire control issues, the MK XIV was running deeper than its set depth. Lockwood had been briefed on the MK VI exploder. He also knew from his service in London that other

⁶³ Lockwood, *Sink 'Em*, 6.

⁶⁴ Rear Admiral Robert H. English US Navy Deceased, Navy Biographies, OI-023, 5 March 1953, Blair Papers, Box 76, File 4.

Navies had tried the magnetic feature without luck. If the torpedo was running too deep, it could not sense the EMF of the target and would pass harmlessly below the ship.⁶⁵

Lockwood contacted BuOrd and they immediately blamed the crews for the torpedo failures. Lockwood recounted in his autobiography, *Sink 'Em All*, "The whole design was sour. It must have been known in the Department (BuOrd) that both British and the Germans had abandoned this type of unreliable exploder early in the war, yet our experts clung to it 'like grim death to a dead cat' for many months to come."⁶⁶

After BuOrd's negative reaction Lockwood realized he would need to run his own tests. He turned to a good friend and his Chief of Staff, James Fife. Fife immediately looked at the problem and found the largest obstacle was the terrible shortage of torpedoes in the Pacific. The MK XIV had been tested at Newport, but not with live warheads. They had used practice warheads that after a run would float the torpedo to the surface for retrieval. To test the MK XIV, Fife needed conditions as close to actual combat conditions as possible. But three issues prevailed. First, they could not spare to lose a single torpedo. They were too valuable. Second, an exploded torpedo could not be taken apart and examined. Third, running an acceptable test required firing several torpedoes for statistical analysis.

Fife remembered a beach at Frenchman's Bay, Albany, Australia where he had been stationed on the tender USS *Holland*. This area is also known as King George Sound. This beach had white sand that continued low beneath the surface. Fife and

⁶⁵ Lockwood, *Sink 'Em*, 8-9.

⁶⁶ Lockwood, *Sink 'Em*, 9.

Lockwood contracted with local Portuguese Fishermen to construct a special net for testing. The net would stretch across the bay and a submarine would fire torpedoes through it.⁶⁷ The torpedoes would perforate the net and continue to shore. They then could retrieve the torpedoes, easily visible against the white sands of the beach.

On June 20, 1942, the tests began. From 1,000 yards USS *Skipjack* fired a torpedo through the net. Upon examination, the torpedo had run fifteen feet deeper than set. Captain Cassius Rhymes, torpedo officer on the USS *Sargo* and later XO of the USS *Saury*, remembered the test of the second day:

In August (In fact June) 1942 Admiral Lockwood ordered *Skipjack* to fire some torpedoes through a net off Freemantle. The tests revealed that the torpedoes took an initial deep dive, pulled up to their concept of running depth at about 1500 yards, whence they ran 11 or 12 feet deeper than they were set. (Sargo sounded the alarm on this discrepancy about 26 December, 1941.)⁶⁸

Lockwood and crew determined that the MK XIV was running on average eleven feet deeper than set.⁶⁹ The day after conclusion of the tests at Albany, Lockwood radioed BuOrd describing not only the results of the tests, but also how the tests were conducted. On June 30, BuOrd's response was not what Lockwood expected. Lockwood related, "Instead of thanking us they scorned our inaccurate approach to obtain these findings." As we shall see in later chapters, Newport felt that no reliable conclusions could be drawn from the tests.⁷⁰

⁶⁷ Captain William Hockett Hazard response to questions from Clay Blair, February 19, 1972, Blair Papers, Box 68, File 1.

⁶⁸ Captain Cassius D. Rhymes Letter to Clay Blair, November 21, 1972, Blair Papers, Box 70, File 1.

⁶⁹ Official Letter to Rear Admiral R.H. English from Rear Admiral C.A. Lockwood, August 1, 1942, Lockwood Papers LOC, Box 63.

⁷⁰ Lockwood, *Sink 'Em*, 9.

Captain James Fife and Lockwood set up another more scientific field test. Fife had the fishing net restrung and, on July 17, the USS *Saury* fired four MK XIV from 850 to 900 yards. All torpedoes were set to run at ten feet. All three punched holes at twenty-one feet. Like the first tests the torpedoes were running eleven feet deep. This confirmed the previous tests. Lockwood sent the results of the test to BuOrd. Lockwood and BuOrd Admiral Spike Blandy were friends from academy days. Spike was a year younger than Charlie but they had still become friends and had kept their relationship going throughout the years. Lockwood wrote Blandy detailing the Albany tests and asked that Blandy make some backup tests.⁷¹

Admiral Ernest King and his right-hand man, Lockwood's friend, Admiral Dicky Edwards, investigated the torpedo issue. With the help of Roland Pryce Edwards, they poured over all torpedo attacks to date and found that no matter what the issues, there should have been at least 100% more hits. King had received a copy of the radio traffic between Lockwood and BuOrd concerning the Albany tests. In a letter to Blandy, King ordered all tactical torpedo data rechecked. With this pressure, BuOrd ran a series of tests using a submarine instead of a torpedo barge. On August 10, almost two months after the Albany tests, BuOrd conceded that the torpedoes were running ten feet deeper than set.⁷²

Newport investigated and determined the first problem was the depth setting calibration process. During this process, they had used a lighter exercise warhead, not an actual warhead. The practice warhead filled with water, which was lighter than Torpex,

⁷¹ Official Letter to Rear Admiral W.H.P. Blandy from Rear Admiral C.A. Lockwood, July 11, 1942, Lockwood Papers, LOC Box 63.

⁷² Blair, *Silent Victory*, 277-279.

so the depth setting was calibrated for a lighter warhead. The weight of the actual live warhead created a nose-down effect when fired. The second problem was the location of the sensor port on the tapered part of the afterbody. Because of the flow of water on this tapered area the pressure was subjected to the Bernoulli effect, a concept that was well understood because it was the same principle allowing the lift on airplane wings. It meant that the sensor always read a pressure lower than the sea pressure for that depth. To compensate, the torpedo dove deeper until the greater depth minus the Bernoulli's effect equaled the pressure of the original depth setting. Greater speed increased this error. The MK XIV had a fast and slow speed setting. The slower the speed the longer the shot. However, since no submarine captain desired to take a longer shot than fifteen hundred yards the slow speed setting was almost never used.⁷³

Getting BuOrd to agree that the depth setting was off was a victory for the submariners in the Pacific but not all captains were satisfied. Nor should they have been. These were the men who had to face the enemy on a day-to-day basis when on tour. They had hands-on experience when it came to the problems of the torpedoes. They knew how the torpedoes were reacting during their runs and how they did, or in many cases did not, react to the enemy vessel's electromagnetic signatures. There submarine skippers and torpedomen knew that deep runners were not the only problem with the MK XIV/VI. From their experience these skippers knew the magnetic exploder to be faulty. Even though Pacific Command thought they had a torpedo that would be effective against the enemy, they were soon to find that these doubting submarine captains were correct in

⁷³ Fredrick Milford, "US Navy Torpedoes (part two)," *The Submarine Review* (October 1996), 4-5.

their assessment of the magnetic exploder. The repair of the deep running issue was soon to make apparent how faulty the magnetic influence exploder was.

Prematures

For a submarine crew a premature detonation of a torpedo was a disheartening experience. As discussed earlier concerning fire control, finding a target was not a simple affair. After contact it sometimes took hours to set up a shot. Missing a shot was bad enough, but a miss also alerted the enemy to your presence. A MK XIV torpedo had a steam exhaust system that produced a bubble trail to the point of origin, but sometimes these trails were missed by the enemy. A premature explosion would alert destroyer escorts to your presence and the submarine would need to dive low to avoid the inevitable depth charging. If there were no escorts, a Japanese target ship would immediately go to evasive maneuvers. The most disheartening issue with a premature was a wasted shot. Torpedoes were precious during the first two years of the war and a torpedo exploding before it even got to the target sank the morale of the crews and heightened the danger of being a submariner.

After settling the depth control issue, premature torpedo explosions became the most prevalent problem. The USS *Sargo* experienced them within the first days of the war. On April 10, 1942, the USS *Pompano* encountered the Japanese aircraft carrier *Shokaku* and attacked with six torpedoes. Three of the torpedoes exploded prematurely *en route*, two exploded prematurely close to the carrier's hull without damaging it, and one

missed.⁷⁴ On June 19, 1943, the USS *Jack* had perfect position on a Japanese trawler. The skipper, Tom Dykers, fired three torpedoes from 1,000 yards. The first torpedo exploded prematurely thirty seconds into its run.⁷⁵ The list of premature explosions could go on and on.

By August, 1942, BuOrd considered the torpedo issue settled. All proponents believed the new depth settings would make the torpedo work. But there were too many torpedoes not making it to target. Regardless of the reason, these were considered misses, suggesting operator error. The men in the Pacific worried primarily about these prematures. The submarine captains were baffled as to what would make a magnetic influenced exploder detonate prematurely.

Between 1941-1945, few understood completely about the Earth's magnetics, contributing to the complexity of the Mark VI Magnetic exploder. The magnetic exploder problems baffled everyone. Sometimes the magnetic exploder exploded well into a torpedo run. Sometimes the torpedo would detonate on a stern shot in the target ship's wake. At times, one torpedo in a torpedo spread would explode when crossing another torpedo's wake. A high-speed gyro turn could make a torpedo detonate. Some torpedoes would broach the surface and detonate. Sometimes all it took was heavy seas for a torpedo to explode.⁷⁶

⁷⁴ Second War Patrol Report of the USS *Pompano* (SS-181), June 24, 1942, NPPSO Reel Number H-108, Roll AR-63, Record Group 80, Keyport.

⁷⁵ First War Patrol Reports of the USS *Jack* (SS-259), July 15, 1943, NPPSO Reel Number H-108, Reel 183, Record Group 78, Keyport.

⁷⁶ Captain R.D. Risser USS *Seawolf*, USS *Saury* letter to Clay Blair, December 16, 1941, Blair Papers, Box 70, File 1.

The coordinates of the submarine when the torpedo was fired caught BuOrd's attention. Charlie Lockwood wrote his friend in the office of the Chief of Naval Operation, Admiral Dicky Edwards, "We make too many misses with torpedoes... We have had four misses underneath the target. BuOrd wants to know what was the magnetic heading of the target. I hope they don't tell us we have to shoot 'em only on east and west headings."⁷⁷ Admiral Blandy knew that Newport's testing had not been adequate. He called for Newport to conduct testing that approximated real-life fire control shots. To date, the limited number of firings had been conducted mostly on north-south headings and not enough on east-west headings, opposite of what Lockwood feared.⁷⁸

Blandy soon toured submarine and surface bases in the Pacific and what he found appalled him. The men in the field had few, if any, trained torpedo technicians and little equipment. Blandy recommended that the magnetic feature on the Mark XV surface torpedoes (used in planes) be de-activated. The destroyer men had similar problems. Lockwood always feared enemy countermeasures, such as de-magnetizing a ship's hull, a process called degaussing. Lockwood addressed his concerns to Ralph Christie:

I'm getting more worried over the increasing evidence that the Japs have some sort of reverse degaussing which makes our torpedoes premature about 100 meters from the target. It is said, and well confirmed, that Tunny had seen prematures against two carriers in a set-up more beautiful than anyone has had so far. Also, that Pompano had three prematures against one carrier. I hate to inactivate the magnetic feature of the Mark-6 for as you know one can get a premature from rough water or broaching or counter mining with the contact feature as well as with the magnetic feature and most of the evidence leads me to believe that the MK XIV-3A is not running

⁷⁷ Letter from Rear Admiral Charles A. Lockwood to Vice Admiral RS Edwards, August 19, 1942, Lockwood Papers, LOC, Box 12.

⁷⁸ Bureau of Ordnance Letter S75-1 (26), August 19, 1942, General Correspondence of the Bureau of Ordnance, National Archives, Box 136, RG 74.

much shallower then set...⁷⁹ Quick, hard motion seemed to contribute to prematures. When the torpedo was shot at high speed it might result in temporary vertical instability, a condition Newport felt might cause enough magnetic field variation to induce premature explosion.⁸⁰

Blandy continued to prod Newport regarding its investigation into the magnetic exploder's performance. He directed the torpedo station to focus its investigation on air dryers, using silica gel, more secure brush holders, a torque wrench for tightening the base plate screws and better gasket materials.⁸¹ BuOrd, through Blandy, thought moisture getting into the magnetic exploder components could be contributing to the premature issues. The warhead of the MK XIV had a large cavity where the exploder component fit underneath and *into* the warhead of the torpedo, built into and resting atop a metal plate. The plate, with the same curvature of the warhead, bolted to the warhead. There were no O-rings in those days, just gaskets. Liberally covering the gasket with a gel could prevent leaking. If sea water got past the gasket, it could enter the cavity, adversely affecting the electrical pick-up, fuses, or Thyatron. This could create a short, triggering the exploder. If simple moisture was an issue, an air dryer could help ward off the moisture. Because there were multiple bolts to tighten on the plate, a torque wrench could help crews maintain a constant torque on the bolts, preventing warping that could let in seawater.

On January 2, 1943, F.H. Roberts, Newport's Inspector of Ordnance in Charge, provided a detailed report, saying some of the small electrical components inside the

⁷⁹ Official Letter from Admiral Lockwood to Admiral Christie, May 3, 1943, Christie Papers, LOC, Box 18.

⁸⁰ Newpower, *Iron Men*, 137.

⁸¹ Bureau of Ordnance letter S75-1 (26), January 2, 1943, General Correspondence of the Bureau of Ordnance, National Archives, Box 240, RG 74.

magnetic feature were not robust enough. He also felt that smaller ships might not set off the magnetic feature. Newport had conducted several test firings beneath the converted yacht, USS *Niagara*, and some of the exploders failed to trip. Roberts did not elaborate on the size of ships that could or could not trip the exploder. He felt the exploder plate integrity was an issue and promised to attack the gasket problem. Finally, Roberts gave his best theories regarding the ultimate causes of prematures. A lot of them happened early in the run, a time that roughly corresponding to the arming time of the exploder mechanism. Significantly fewer torpedoes exploded well into their runs. Newport felt electrical failure and torpedo instability were the prime culprits for the prematures occurring shortly after arming. Torpedo porpoising occurred early in the run while the depth mechanism sought to find and maintain the depth set. If the device armed before the set depth was achieved, the MK VI, in testing at Newport, tended to fire prematurely. Roberts concluded that the early prematures occurred from electrical problems, presumably the brush rigging issues mentioned earlier. Later prematures he blamed on erratic runs.⁸²

Surprisingly, there was no mention in the documentation, published books or articles, concerning torpedoes running close to the surface, nor mention of the magnetic exploder mechanism being too sensitive to quick movement. It was apparent that heavy seas or a high-torque turn could set off the exploder. There was no mention of attempting to run down the cause of erratic running torpedoes. Some torpedoes fired would take a

⁸² Letter from Newport Naval Station S-75-1 (G1-MLM), January 2, 1943, Correspondence of the Bureau of Ordnance. National Archives, Box 240, RG 74.

hard left and keep going. There was a lot of violence when a torpedo left a tube and it took time for a torpedo to find its depth setting. If the torpedo was fired on a shallow setting, it tended to shoot above and then rapidly below the surface. This violent activity could have resulted in the torpedo prematurely exploding or making an erratic run.

On January 2, 1943 Admiral Robert English, SubComPac, issued an order to the submarines sailing out of Pearl Harbor to fire at depths assuring contact hits.⁸³ Lockwood was still working on the torpedo problems at his headquarters in Perth and did not necessarily have to heed this order as he worked under MacArthur, not Nimitz. Lockwood and Blandy were speaking plainly with one another. At times, the exchange was civilized and friendly, other times it was strained. Still, Blandy was working towards a solution. Although their informal relationship would always remain the same, their professional relationship changed on January 16, 1943, when Robert English died in an airplane accident in California.⁸⁴ Charlie Lockwood succeeded him as SubComPac, headquartered at Pearl Harbor. He became the youngest Vice Admiral in the United States Navy at the age of fifty-three.⁸⁵

As the war continued, some skippers had good combat tours, some had multiple failures. After his January, 1943, successful combat tour on the USS *Wahoo*, Mush

⁸³ Commander Submarine force, Pacific Fleet Bulletin 1-43, January 2, 1943, General correspondence of the Chief of Naval Operations, National Archives, Box 1006, RG 80.

⁸⁴ Rear Admiral Robert H. English US Navy Deceased, Navy Biographies, OI-023, 5 March 1953. Blair Papers, Box 76, File 4.

⁸⁵ Official Letter from the White House, President Franklin Delano Roosevelt to Admiral Charles A. Lockwood, October, 5, 1943 designating Lockwood Commander, Submarine Force, Pacific Fleet, with the rank of Vice Admiral, Lockwood Papers, LOC, Box 74.

Morton sang the praises of the MK VI magnetic exploder. This created confusion as sometimes the MK VI worked as advertised.

But other captains, like Walter G. Ebert on the USS *Scamp*, were not so lucky. In the spring of 1943, Ebert located a target. At the opportune range of 1,000 yards, Ebert fired three stern torpedoes. Within twenty seconds, two torpedoes exploded prematurely, almost simultaneously. Five seconds later the third torpedo touched off. The depth setting on all three torpedoes was set shallow. Ebert had the exploders set for magnetic influence or contact. Within days, *Scamp* ran into a formation of ships. Ebert attacked firing three torpedoes, one premature and two that failed to explode, one of which was sighted porpoising on the surface ahead of the target. The porpoising could have resulted from the explosion of the previous torpedo interrupting and influencing its course. Or the steering and depth control of the torpedo may have been faulty. The *Scamp* turned its attention to the other ship in the formation, a small freighter. Ebert fired the three remaining bow tubes at the ship. The first torpedo exploded fifteen seconds into its run. The other two torpedoes completed their run and exploded on time but because the diving officer lost control of the ship Ebert did not see if the torpedoes hit the target or not. Once they got control of the submarine a destroyer escort arrived and the *Scamp* dived. The destroyer pounded the *Scamp* with ten depth charges. After this, Ebert de-activated the magnetic features on the rest of his torpedoes.

On March 21, *Scamp* contacted a Japanese tanker and took a long shot of over 2,000 yards. This torpedo hit. This tanker was not just filled with fuel, but also armaments. Armed shells started flying in all directions. Ebert moved up on the wounded

ship and fired two torpedoes. The first one ran erratically. The second ran under the target. Ebert observed two explosions and the tanker went dead in the water, yet it did not sink.⁸⁶ The tanker made it to port, was repaired, and went back into service.⁸⁷ When Ebert got back to port he made his report. His division commander concurred with Ebert's feelings that the torpedoes and exploders were defective. The squadron commander felt that the shallow depth settings of the torpedoes probably contributed to many of the torpedoes' failures. When the report got to Lockwood's headquarters, Captain John H. Brown, sitting in for Lockwood, felt that the torpedoes sat too long in flooded tubes, affecting the depth setting control mechanism.⁸⁸ Again, the implication was not that the torpedoes were defective but the men who loaded and fired them were.

Any or all these issues could have affected the torpedoes' performance during the *Scamp*'s patrol. The torpedoes could have been defective. The shallow depth setting could have affected the torpedoes' performance. They could have fired straight to the surface and begun to porpoise. When in transport, torpedoes' depth was often set deep and then reset when loaded, so the depth setting could have snapped back to a previous setting as it sat in the flooded tube. This illustrates how difficult it could be to find the true source of a torpedoes' problem.

Blandy asked for a hulk on which to run tests and ordered four civilian scientists from the Office of Scientific Research and Development to Newport for discussions with

⁸⁶ First War Patrol of USS *Scamp* (SS-277,) March 26, 1943, NPPSO Reel H-108, Keyport, 12-14.

⁸⁷ Newpower, *Iron Men*, 145.

⁸⁸ First War Patrol of USS *Scamp*, endorsements, March 26, 1943, 14-20.

their experts regarding the problems with the MK VI.⁸⁹ Blandy saw problems the MK VI but did not know if the right decision was to deactivate the exploder. There were pressures from CNO King, Lockwood, the skippers on Patrol, and from within. He did not want to admit that BuOrd put out a defective exploder, that they could not determine the causes nor how to repair them. But he knew that if he was to do anything about it he needed an experienced submarine captain at Newport to help. Lockwood did not want to part with any of his experienced sub captains, noting the lack of captains with more than a few tours under their belts. New construction was taking more officers than he wanted to give them. Finally, Lockwood promised to send Herman A. “Pi” Pieczenkowski, an experienced captain and a good engineer, if torpedo failures continued.

On March 26, 1943, BuShips sent a letter from Vice Admiral E.L. Cochrane to Blandy regarding the most effective depth at which to achieve torpedo hits. Cochrane conveyed BuShips’ feeling that, except for ships equipped with armor plating, there was no advantage to an under-keel explosion. BuShips and the Navy’s top ship designers studied torpedo damage on scores of ships, including those of foreign navies. Their conclusion that the MK VI magnetic feature offered no advantage over contact exploders was devastating to BuOrd, who had cited the effectiveness of magnetic influence explosions in defense of charges levied against the MK VI by the submarine commanders fighting in the Pacific.⁹⁰

⁸⁹ BuOrd Letter S75-1 (26), April 26, 1943, “MK VI model 1 Exploder Mechanisms, Investigations of Deficiencies,” General Correspondence of the Bureau of Ordnance, National Archives, Box 241, RG 74.

⁹⁰ Official Letter from Vice Admiral E.L. Cochrane to Admiral W.H. P. Blandy, March 26, 1943, Correspondence of the Office of Chief of Naval Operations, National Archives, RG 38.

On April 6th, Lockwood's torpedo officer, Lt. Commander Henry Maynard submitted a report on torpedo performance. Out of approximately 225 torpedoes fired, twenty detonated prematurely. Maynard noted that was more than twice the figure before the depth settings went into effect. Maynard saw a correlation of prematures at a depth setting of nine feet or fewer.⁹¹

On April 10th, Blandy radioed Lockwood in Pearl Harbor and informed him that at depths of twelve feet or less the MK VI was more likely to be premature, especially in heavy seas. He recommended deactivating the magnetic feature if firing at contact depth settings per English's order. Eighteen months into the war, BuOrd had finally issued a recommendation for the MK VI.⁹² In late May, *the Wahoo* returned to Pearl Harbor after its numerous torpedo problems, as explained before, followed closely by the decision to de-activate the MK VI exploder.

Lt. Cmdr. Ellis A Johnson, a member of Lockwood's staff, obtained a draft copy of a BuOrd letter qualifying the conditions for effective employment of the MK VI exploder. Much of the letter dealt with the scientific principles of the Earth's magnetic field and how it changed in different zones, and what happened to it when large steel ships passed through it on various headings in each of the Zones. Blandy conceded that the Magnetic feature was useless in southern latitudes and admitted that countermeasures

⁹¹ Memorandum from Lieutenant Commander H.C. Maynard to Rear Admiral Lockwood, April 6, 1943. Lockwood Papers LOC, Box 12.

⁹² Bureau of Ordnance Message to ComSubPac, serial number 2723487, NCR 2924, April 27, 1943, General Correspondence of the Bureau of Ordnance, National Archives, Box 241, RG 74.

such as degaussing or a paravane (towed underwater glider) with a current-carrying wire could defeat the MK VI.⁹³

Lockwood finally gave in. He went to Admiral Nimitz for permission to deactivate the magnetic exploder. The next day, Nimitz's order went to all submarines but this did not include Christies' command as he worked under MacArthur.⁹⁴ Christie wrote Lockwood that same day questioning Lockwood's claims regarding the MK VI's flaws. Admiral Christie ignored Admiral Nimitz's order and wrote directly to Nimitz asking why he had sent the order. Nimitz, obviously trying to let Christie down lightly, responded, "Because of probable enemy countermeasures, because of the ineffectiveness of the exploder under certain conditions, and because of the impracticability of selecting the proper conditions under which to fire."⁹⁵ Christie still would not admit defeat. Christie felt that the MK VI at least got some hits and if it was deactivated it would never be improved. After a couple of more attempts to get the exploder reactivated he finally gave in.⁹⁶ Nevertheless, the magnetic feature on the MK VI exploder was finally deactivated.⁹⁷ This meant that crews could now shoot for contact hits. The submarine captains and crews would need to depend on shooting spreads and this would cost more torpedoes. Fortunately, the Mark XIII was entering the theater of combat. The crews now went out with more confidence than they ever had. Unfortunately, even with the magnetic influencer de-activated they still did not have a dependable torpedo.

⁹³ "MK VI mod. 1 Magnetic Exploder Mechanism," Bureau of Ordnance Letter (draft), Number T, General Correspondence of the Bureau of Ordnance, Box 240, RG 74. Anthony Newpower notes this letter as well.

⁹⁴ Newpower, *Iron Men*, 159.

⁹⁵ Blair, *Silent Victory*, 430.

⁹⁶ Admiral Ralph Christie (Retired) letter to Clay Blair, June 20, 1972, Blair Papers, Box 65, File 6.

⁹⁷ Blair, *Silent Victory*, 430-436.

Duds

Statistically, when using several units of any technical device, some will fail. Submarine captains accepted that they would have some torpedo failures. Some torpedoes left the tubes and fell straight to the ocean floor. Some torpedoes made circular runs forcing the captain to use evasive measures to avoid getting hit by his own torpedo. As has been shown, there was a lot of science, technology, and machinery in a MK XIV/VI torpedo. An air flask could rupture in the tube, the engine might not fire, gears could bind, or propellers could spin off. But a torpedo could make a full run and hit the target and still fail to explode. This was called a dud. When that happened there was little chance of deducing the problem. Not only was the torpedo inaccessible, it usually had been destroyed. Several things could have caused the dud. It could have hit and the air flask exploded. This would create a large splash and a loud bang. If the fuel ignited and exploded with the air flask the explosion would be bigger, there would be a flash and smoke. Thus, early duds looked like solid hits, making it even harder to assess the issue.

Not all duds reacted like submarine captains expected. Captain Ralph C. Lynch of the USS *Mingo* recalled:

Each patrol was rather long and plagued also with torpedo troubles (duds, prematures and low-order explosions). Mingo was on patrol with doubtful torpedoes while the suspected torpedo warhead exploders were being tested in Pearl Harbor. The fact that they proved defective must be well documented. Another enigma, Mingo tested, while shaking down in New London Newport area, the first issue of the then new electrical torpedoes. But she went to sea on the first two patrols with the unreliable torpedoes about which serious doubts had already developed. On occasion, I watched a dud torpedo hit a Jap freighter and climb vertically up the side into the air. It could have landed on deck!⁹⁸

⁹⁸ Captain Ralph C. Lynch to Clay Blair, December 7, 1972, Blair Papers, Box 69, File 1.

Reports of duds were commonplace from Captains' reports. The USS *Trout*, with Captain Red Ramage, fired fourteen torpedoes, five of which were duds.⁹⁹ Some of Skipper Tyrell Jacobs' torpedoes were duds. Captain Moke Millican on the USS *Thresher* reported duds as well. On December 29, 1942, *Thresher* sighted a 10,000-ton unescorted ship leaving Surabaya. *Thresher* made three attacks using six torpedoes, all duds.¹⁰⁰

As it was early in the war, Skippers Jacobs and Millican, both highly trained engineers, could not convince Withers, Lockwood, or Christie that there was a problem with the torpedoes. One of the most significant problem with recognizing duds was that submarines would often take shots and then immediately go deep for protection. With the boat a couple hundred feet under the surface, and no distinct, loud explosions occurring, it was difficult for the sound men to tell what was a solid hit and what was not. If there was no sound at all, depth settings on the torpedo could be off, the torpedo could have been fired at the wrong speed, the exploder could have failed or perhaps it was just a lousy shot. If there was a hit, sound gear could often pick it up. But at longer ranges or in heavy seas, sound could not determine anything.

By summer 1943, Naval Command, BuOrd, Naval Command at Pearl Harbor, and Southwest Pacific Command had finally reached the point that they had to admit that the MK XIV/VI was not infallible. They had tested and found the depth setting to be

⁹⁹ Seventh War Patrol Report of USS *Trout* (SS-202), February 25, 1943, NPPSO Reel Number H-108, Roll AR-12, Record Group 80, Keyport.

¹⁰⁰ Sixth War Patrol Report of USS *Thresher* (SS-200), January 10, 1943, NPPSO Reel F-108 Dated 12-15-81, Keyport.

wanting. Because of prematures, Command decided to de-activate the magnetic influenced exploder.

The scientists, like Ralph Christie, had used foresight when they designed MK VI exploder. The design of the MK VI allowed disconnection of the magnetic component such that the contact exploder still operated. However, as mentioned, the exploder would not act like a nose exploder on an artillery shell. The MK was installed inside a cavity on the underside of the warhead and pointed up, essentially sitting perpendicularly. When the warhead contacted a ship's hull, the exploder mechanism released a spring that drove the firing pin *upward* on a set of guide rails. The pin would contact a fulminate cap which would then detonate the warhead. Because of all the duds, Captain Swede Momsen came up with a plan to determine the cause.¹⁰¹

On August 31, 1943, the USS *Muskellunge*, with support vessels *Chalcedony* and *Widgeon*, sailed to Kahoolawe Island, south of Maui, Hawaii. The smallest of the eight Hawaiian archipelagos, Kahoolawe's cliffs extended dozens of feet below the water. The idea was to fire torpedoes from a submarine into the cliff until a dud occurred. The third torpedo failed to explode. Divers from the *Chalcedony* retrieved the torpedo, pulled it to the surface, placed it aboard the *Widgeon* and hauled it back to Pearl Harbor for examination.¹⁰² When technicians disassembled the exploder, they found that the guide rails were distorted. The firing pin would travel only part of the distance on the distorted

¹⁰¹ Description, Adjustment, Care, Operation and Shop Tests of U.S. Navy Torpedo Warhead Attachments, Bureau of Ordnance Pamphlet (OP) 663, November 1942.

¹⁰² Newport, *Iron Men*, 176-177.

guide rails, so it could not contact the fulminated cap. The metal in the guide rails was too soft to withstand the impact.

Lockwood assigned Pi Pieczentkowski and a host of other junior officers and torpedomen to set up drop tests. They used cranes called cherry pickers to drop torpedoes from ninety feet onto a steel plate. The torpedoes, using a cement mixture that mimicked the warhead density, hit at forty-five knots. Seven out of ten torpedoes failed when impacting at the desired ninety-degree angle. The failures decreased by more than half when hitting the plate at an oblique forty-five-degree angle.¹⁰³ Lockwood sent word out to the crews to not take ninety-degree shots and concentrate on oblique shots. Enemy ship sinkings improved. It became clear that the higher speed of the MK XIV caused the impact distortions. The contact part of the MK VI exploder was based on the Mark III exploder used on the air-launched Mark XIII torpedo. The Mark XIII traveled at a top speed of 33.5 knots. The extra thirteen knots almost doubled the inertia of the impact deceleration of the MK XIV.¹⁰⁴ The firing pin guide rails could withstand a deceleration from 33.5 knots, but not 46.5 knots.

War is full of ironies. One of the biggest ironies in the Pacific concerned the search for the right metal to use for the MK VI guide rails. After experimentation, it was found that the torpedomen could fabricate rails using metal from the propellers of Japanese Zeroes that were shot down during the attack on Pearl Harbor.¹⁰⁵

¹⁰³ Official Letter to Admiral Charles A. Lockwood from Captain H.A. Pieczentkowski detailing wartime exploder tests, December 27, 1946, Lockwood Papers, LOC, Box 126.

¹⁰⁴ Milford, *US Navy Torpedoes*, 9.

¹⁰⁵ William Hockett Hazzard USS *Saury*, USS *Blenny*, Blair notes of interview, June 1972, Blair Papers, Box 68, File 1.

On September 25, 1943, when Chief of Naval Operations Admiral Ernest J. King was at Pearl Harbor meeting with Admiral Nimitz, they received Lockwood's report. At his suggestion, they ordered immediate mass production of the modified exploder.¹⁰⁶ On Sept 30, twenty-two months into the war, the USS *Barb* was the first fleet boat to sail from Pearl Harbor with confidence in their weapons. All their torpedoes contained the new, modified exploder.

Conclusion

The U.S. Navy began the war without a fleet. After the Japanese attacked Pearl Harbor, the most powerful weapons carriers they had were three aircraft carriers and a small fleet of submarines that included the S-boats and O-Boats from World War I, the giant V-Boats and smaller P-Boats from the interwar years and the fleet boats. The massive attack at Pearl Harbor and in the Philippines negated War Plan Orange. The Southwest submarine fleet should have made a large impact on the Japanese invasion. The Navy had an assortment of submarines and they had the latest and greatest submarine torpedo that the world had ever seen. But the torpedo did not work. Report after report went into Command alerting them to this fact. Instead of believing the submarine skippers, their officers and the torpedomen Command believed the problem was with fire control issues of the crews.

¹⁰⁶ Lockwood, *Sink 'Em*, 142.

Throughout the years, Naval Command, the BuOrd, and Newport have taken the blame for not believing the submarine captains about the torpedo failures.¹⁰⁷ In retrospect, this was an issue where everyone shared some degree of blame. Older captains, trained during the interwar years, valued not getting sighted by the enemy over aggressiveness. Older subs could not match the newer fleet boats. Fire control procedures were difficult to get right under the best of conditions. But in the end, even though all these issues contributed to low success rates against the Japanese, the MK XIV/VI torpedoes were not working correctly. The torpedoes were running deeper than what they were set, the magnetic influencer was prone to premature explosions, and contact hits would not work because of defective guide pin rails on the contact exploders.

No one wanted the magnetic feature to be disconnected on the MK VI. They wanted it to work. If the magnetic feature worked it would have solved many problems. Foremost, it would have solved the torpedo shortage that was a constant issue during the first twenty-two months of the war. If the magnetic feature would have worked, every torpedo would have had the potential to sink one enemy ship. If not, a second torpedo would certainly do the trick.

Also, the MK XIV/VI would have been an incredible tactical weapon for the sub captains. Had the torpedo worked early on, it could have given the submarines captains greater confidence. More cautious captains, such as Captain Wilkes, might have taken greater risks with their boats, as the younger captains did later in the war. If the magnetic

¹⁰⁷ Pratt, "Torpedoes that Failed.," 25.

feature had worked with the depth control it could have impacted the Japanese landing on Luzon. If the torpedoes had worked, perhaps the Japanese would have been so damaged during the Philippine campaign they might have changed their strategy, giving the American and Filipino Armies more time. If the submarines had been effective enough it could have overextended the Japanese to the point that the Americans and Filipinos could have driven off the attack on the Bataan Peninsula.

BuOrd, Newport, Pacific Command, and Southwest Pacific Submarine Command did not want to admit a problem existed with the MK XIV/VI torpedo. They were too invested in its success. BuOrd and Newport had put years into the scientific, technological, and manufacturing development of the torpedo. Their reputations, as leaders or organizations, depended on it. Also, these men took pride in, and formed their personal identities on, being right. So, they sold themselves and Naval Command on the idea that the weapon was ready.

The only support for the weapon's readiness was that it looked good on paper. There was no testing before it went to the crews in the Pacific. The G-53 test in 1926 fired two torpedoes on a submarine weighing 800 long tons. The first torpedo missed. The second torpedo sank the submarine but its exploder did not have the modern Thyatron. Thus, the actual MK VI exploder that went to the Pacific was never tested. The MK XIV torpedo had been tested multiple times, tracked by aircraft. Many torpedoes went under the target but no one tested how far under.

When the torpedoes failed, Command, BuOrd, and Newport went into denial, blaming the submarine crews for the failures. It took the tenacity of the submarine

captains and Lockwood to conclude that something was wrong with the torpedoes. It took men like Lockwood, Jimmy Fife, Red Coe, Pi Pieczentkowski, Swede Momsen and a host of enlisted and non-commissioned torpedomen to design and conduct the tests needed to discover the problems and solve them.

But just describing the solutions to the problems of the MK XIV/VI was not the point of this dissertation. The following chapters will describe how the U.S. Navy, BuOrd, and Newport Torpedo Station let the MK XIV/VI problems happen in the first place, how they could have prevented them, and why it took them twenty-two months to resolve them.

CHAPTER FOUR

HIGH-RISK SYSTEMS

The USS *Squalus*

A perfect storm of failure ended with the sinking of the U.S. Naval submarine USS *Squalus*¹ on Tuesday, May 23, 1939.² The *Squalus* and her sister ship, the *Sculpin*, were brand new submarines undergoing testing out of Portsmouth, New Hampshire. The *Sculpin* was slated to sail to South America to conduct its shakedown cruise. Fortunately for the *Squalus*, the *Sculpin* had not left yet.

This day the *Squalus* was performing diving tests. A submarine makes for a particularly inviting target to the enemy while on the surface. Diving is central to a submarine's performance and protection. Diving is one of those chores in which many crucial tasks must be done almost simultaneously. Test dives were integral to a submarine's testing and shakedown. The quicker the dive the quicker out of danger it becomes.

In the early days of the USS *Holland* at the turn of the twentieth century, a submarine did not submerge completely. It had no ballast tanks and dove as far under the surface as it could, using propulsion, weight, speed, and diving planes, taking twenty

¹ *History of USS Sailfish (SS-192)* (Formerly the USS *Squalus*), Ships Histories, NPPSO Reel Number H-108, Roll AR-149, Group 76, Keyport.

² Peter Maas, *The Terrible Hours: The Man Behind the Greatest Submarine Rescue in History* (New York: Harper Torch, 1999). Unless otherwise noted the following material is from Maas' excellent account of the sinking and rescue of thirty-two crew members of the USS *Squalus*.

minutes just to get the hull under the surface.³ By World War I, diving fast was essential to protection from enemy airplanes and warships but its contribution to stealth was just as important. If a sub could dive before being seen, it could go on the prowl instead of retreating.

The ideal in a submarine was for the captain to call out the order, “Dive,” twice over the intercom, signal an alarm, in this case a type of klaxon (A-oooh-gah), and to be under water in under one minute. This meant a clearing of the fore and aft deck, upper periscope shears and bridge of men, lowering the four diving planes, closing all apertures, shutting down the diesel engines, engaging the battery propulsion, having everyone at their battle stations and the submarine fifty feet under the surface in fewer than sixty seconds.⁴

There were several apertures on a Fleet Submarine. These including two escape hatches, a conning tower bridge hatch, exhaust valves for the diesel engines, and ten outer torpedo tube doors. There were several small apertures as well. There was even a small flapper that the radio antenna raised while on the surface that would let seawater in if not closed.

The two largest outlets on the ship were called the main inductions. Both were located on the side of the conning tower right below the bridge deck. One of the

³ Morris, *Holland*, 35-49.

⁴ Submarine Air Systems, NavPers, 16164, produced for ComSubLant by Standards and Curriculum Division Training, Bureau of Naval Personnel, 1946, Keyport. 86. This chapter is part of *The Fleet Submarine*, Navpers 16160 which is a large volume that discussed multiple systems on a submarine. Any type of access or holes in the boat that were open to the sea when submerged or to the air when surfaced. They flooded the submarine with fresh air while on the surface. A deck hatch was considered an aperture to submarine sailors.

inductions funneled air to the diesel engines, allowing quick induction of air to the carburetor. The faster the submarine moved, the more air it needed. The other air induction was for the crew. It let fresh air into the submarine and fed the air conditioning system. The main induction for the diesel engines' air intake was large and measured thirty plus inches across in diameter. The other induction was sixteen inches across.

The inductions were open while on the surface but were closed while under the surface. If any aperture was open while the submarine was submerged, seawater could flood into the submarine's interior. The lower the submarine was submerged, the higher the pressure of the surrounding water and the greater the volume and pressure of water blasting into the interior. A large tube led from the intake to the diesel engines, feeding pipes that fed each compartment in the submarine. Each induction valve was a door that opened to let air in and closed to keep seawater out. If left open, the induction for the diesel engines would flood the forward and aft engine rooms rapidly. When the air induction valve was left open, each chamber in the sub would be flooded with the equivalent of a four-to-six-inch hose simultaneously. Closing the induction valves actuated a locking pin to ensure that the door or valve stayed closed.⁵

Every crew separated into three rotating sections, each spelling the others on eight hour shifts. Each crew member had a station to tend or monitor during a dive. For example, officers assured that the outer torpedo doors were closed. Senior electrician's mates monitored the battery group meters and called off readings when ordered. Young electrician's mates took directly to the battery holds and visibly monitored the batteries.

⁵ Navpers 16164, 86.

Torpedomen stood by their stations in the torpedo room, often readying a reload or training. The main concern of all the men during a dive was that all openings to the sea were closed. Leaving any aperture open was a major failure in diving protocol, endangering every man on the submarine. There was no room for failure.

The *Squalus* ran tests off the coast of New England, specifically off the coast of New Hampshire near the *Isle of Shoals*, before being cleared for its shakedown cruise. Previous tests in her berth at Portsmouth and in the Portsmouth harbor had gone well, except that there was an instance of the thirty-one-inch diesel induction valve failing to open properly. The men had taken the valve assembly apart, inspected and re-assembled it, with no further trouble. On May 23, she was to make her nineteenth test dive in the ocean to verify the resolution of some small, commonplace issues that had been observed and repaired, such as an engine bearing and some electrical problems with a torpedo tube.⁶

The crew was attempting to get the submarine to periscope depth within the sixty-second timeframe. They had missed it by five seconds the dive before. To get the sub to periscope depth in sixty seconds was a matter of pride during testing, a matter of life and death in battle. The captain of the *Squalus* was thirty-five-year-old Oliver Naquin, an Academy graduate and seasoned sub skipper.⁷ A few minutes earlier, Naquin told his XO to have the men rig the submarine for diving. At 8:30 AM Naquin instructed the

⁶ War Reports of the USS *Sailfish* (SS-192), NPPSO Reel Number H-108, Roll, AR-149, Record Group 76, Keyport, 1. After the sinking the *Squalus* was renamed the *Sailfish*.

⁷ Carl LaVo, *Back from the Deep: The Strange Story of the Sister ships Squalus and Sculpin* (Annapolis, Maryland: Bluejacket Books, 1994) Kindle Edition LOC 593

radioman to transmit their dive location and ordered, “Standby to dive.” He then gave the order to dive and the klaxon sounded twice.

The men were at their dive and battle stations. Naquin started his stopwatch and slid down the ladder into the control room. He glanced up at the hull opening indicator board, also known as the control board, most commonly called the Christmas tree.⁸ A red light meant that the aperture on the boat represented by that light was open. If the light showed green, that aperture was closed. At this moment, the tree showed eight red lights.

The aperture opening and closing control system was tightly coupled, but not dependent on one another. The light system that told the operators that the aperture was open or closed was an Automatic Safety Device (ASD).⁹ Although the lights did not close the aperture, they indicated to the operators that the aperture was open and must be closed.¹⁰

The eight red lights indicated that four engine exhaust valves, the flapper for the radio antenna, and the hatch above the conning tower were still open. The last two red lights indicated that the two main inductions were still open. The bow and stern planes were angled at a hard dive. The main ballast tanks were open and seawater poured in. The bow buoyancy tank filled, dragging the nose of the sub at a hard, downward angle. The

⁸ USS *Pampanito* Control Room, “Hull Opening Indicator Board,” *Maritime.Org.*, accessed January 16, 2017, <https://maritime.org/tour/cr.php>. This website is interactive and each part of the control room can be viewed by arrow or mouse manipulation.

⁹ Perrow, *Normal Accidents*, 17-23.

¹⁰ Maas, *Terrible Hours*, 28. The Christmas Tree was the most important safety feature on a submarine before submerging. Several eyes were on the board before a submarine submerged, most importantly the captain’s. If even the newest sailor on board saw a red light they would have spoken out as it would be a natural reaction.

trim tanks were filling at a slower rate so that the boat could be trimmed when it reached fifty feet.

Naquin's eyes never left the Christmas tree as, one by one, the eight red lights turned to green. Finally, the two induction lights went from red to green at the same time, as they closed in tandem, both valves being controlled by the same hydraulic lever. Machinists Mate Second Class Al Prien operated the lever that morning as he did on every dive the *Squalus* made. Prien was experienced, as he had the same duty on another submarine before he joined the *Squalus* crew. When Prien pulled the lever for the main inductions, the indicator lights went green.

Naquin saw a full green Christmas tree, as did Al Prien and diving officer Lieutenant Doyle. Machinist's Mate Carrol Pierce bled a small amount of air from one of the pressurized cylinder banks. This affected each sailor's ear drums as the pressure in the boat changed, a naturally-caused, secondary confirmation that the boat was closed to the sea and pressured up for the dive. At that moment, the *Squalus* disappeared under the surface of the Atlantic.

After the second dive klaxon, Chief Petty Officer Campbell glanced at the Christmas tree and saw that it was green. The control room talker, Yeoman Kuney, enjoyed competing with himself by watching the board. Would he get verbal confirmation of an aperture closing before the board showed it? The board always won. Al Prien looked up, once again, and saw that the board was green as his hand came off the hydraulic lever for the main inductions. In addition to these navy men, Harold Preble, who was also in the control room, looked up and saw a green board.

There was not just one operator monitoring the board, there was a redundancy built into this process. Six men, all experienced experts, saw that they had a green board. On top of this, Machinist's Mate Pierce ran a natural check by pressurizing the boat. All the men on the boat felt the pressure build up in their ears as the boat went under the surface.¹¹ As Lieutenant Commander Oliver Naquin's hand grabbed the periscope handles, control room talker, Yeoman Kuney, shouted out, "Sir! The engine rooms! They're flooding!" The *Squalus* went down in 243 feet of water, over three quarters of a football field under the surface.

There can be and have been systems failures with shipping, petrochemical plants, aircraft, dams, space ships, and nuclear power plants. With these, there was usually some buffering, inexactness or wiggle room (slack) concerning the number of first party victims and severity of this damage.¹² First party victims are harmed but often not killed immediately. There are often repercussions down the line, as in the case of radiation exposure, where first party victims may develop cancers and die years later. Yet, there is no slack for a system failure in a submerged submarine. Nor is there slack for the first party victims. The smallest detail usually means total failure resulting in sinking of the boat and certain death for all aboard. The sea is unforgiving.

The water pouring into the *Squalus* from the diesel air intakes flooded the forward and aft engine rooms as well as the maneuvering room and aft torpedo room. However,

¹¹ LaVo, *Deep*, LOC 776, Kindle Edition. This final climb in air pressure was the absolute confirmation that the submarine was closed to the outer environment and pressured up.

¹² Perrow, *Normal Accidents*, 94-96.

one crewman was heroically able close a compartment door forward of the forward engine room and dogged it down, saving thirty-three enlisted men and officers.

Thesis and Organization

The MK XIV/VI torpedo was a high-tech, high-risk armament fired from another high-tech, high-risk piece of equipment, the fleet submarine. Adding in the fact that these systems were being used in the highest risk application known to man – war – the chance of a system failure was assured. The MK XIV/VI torpedo should have undergone extensive testing before it was disbursed to the Fleet, and held to the same level of excellence as the fleet submarines. Even if the MK XIV/VI had been thoroughly tested, it was still bound to have failed, and BuOrd, Newport Torpedo Station, and the U.S. Navy should have had a program in place to handle these failures. Because there was no such program, the submarine crews and torpedomen in the Pacific used their own knowledge and methods to initiate their own solutions to the torpedo problems.

This chapter will show how relationships between men and machines were essential to the success or failure of these submarines in combat. It will discuss how science is a large part of war, and how crews developed their own field laboratories and were methodical in conducting their experimentation on the subs or on the submarine tenders. Most importantly, this chapter shows what high-tech, high-risk technologies were and how the science concerning these applied to the undersea war in the Pacific. It uses concrete examples to define incidents versus accidents, loose coupling versus tight coupling, mental models, visible interactions versus invisible interactions, transformation

processes, degrees of disturbance and operator error. In doing so, it applies high-risk technological analysis to the *Squalus* and the MK XIV/VI torpedo, showing that these were complicated, high-risk systems within the complicated, high-risk system of war.

High-Risk Systems

In his book, *Normal Accidents*, Charles Perrow argues that within all high-risk systems, accidents are inevitable. The more technical and complicated a system, the more risk there is of a major, perhaps catastrophic, problem. Conventional safety devices will never eliminate this risk, as they add to a system's complexity, creating new opportunities for failure.¹³

Perrow proposes that a system consists of four levels.¹⁴ A part is the first level. In a submarine, this might be a fuel valve from the main fuel tank that allows diesel fuel feed to the engines from a reservoir. The second level, a unit, is a collection of parts, such as an engine which consists of a cylinder head, pistons, crankshaft, engine block, valves, injectors, injector rack, fuel injection pump, and magneto. An array of units, the third level or subsystem, might include all four diesel engines as well as the batteries, electric generators, and motors. This subsystem is the propulsion unit. The fourth level, a system, would be the submarine itself.

¹³ Perrow, *Normal Accidents*, 4.

¹⁴ Perrow, *Normal Accidents*, 65.

Incidents and Accidents

Within this arrangement, the term accident refers to failures affecting the third and fourth levels. The term incident refers to level one and two. The transition between accident and incident is where many engineered safety features (ESFs) lie. Some of these are redundant components, emergency shutoffs, emergency supplies, and other things desirable for a system in an emergency.¹⁵

The dividing line between incident and accident, between part two and three, is not clear, as there is no constant between different systems. The *Gato* submarine might be considered a system in one analysis, where in another analysis the submarine service in the Pacific might be considered a system and the *Gato* just a unit. That which is an accident in the first might be a simple incident in the second. With this as a background, Perrow defines an accident as a “failure in a subsystem or the system that damages more than one unit and in doing so disrupts the ongoing or the future output of the system.”¹⁶ An incident includes damage of units or parts, whether the failure disrupts the system or not. Disruption then means that the output halts or declines, requiring timely repairs.

People figure into systems. The crew on a submarine could be considered a subsystem using our definitions, and damage to a human would mean that an accident has occurred. Yet, humans may be only parts of a system. Within a World War II submarine there were seventy-five people, and thus one, two, or perhaps dozens of humans were mere parts. A sailor falling off a periscope shears, could be an incident instead of an

¹⁵ Perrow, *Normal Accidents*, 66-71.

¹⁶ Perrow, *Normal Accidents*, 66.

accident under this definition. In this dissertation, the point is to show how different systems failed within the U.S. Navy and the Mark XIV/VI system, then use that knowledge to save as many lives as possible, to stop or reduce future catastrophic failures.

There are different types of victims. First party victims, the operators of the system, include nuclear plant operators, airline pilots or ships' officers. With submarines, the first-party victims included the captain and perhaps the torpedomen in the torpedo rooms. In the case of the torpedo failures, the operators were the ones deemed responsible and it took a long time for that view to change. Second-party victims are non-operating personnel, such as ship passengers. Third-party victims are innocent bystanders, and fourth-party victims are future generations.¹⁷

Failures

There are different levels of failure. A component failure involves the failure of one or more parts, units, or a subsystem. James R. Chiles speaks of system failures in his book *Inviting Disaster, Lesson from the Edge of Technology*. He argues that system accidents involve the unanticipated interaction of multiple combined, or at times independent, failures. Most component failure accidents involve a series of failures.¹⁸ For example, a jammed torpedo door might cause a torpedo tube to flood, causing seawater to seep into the torpedo, altering its gyro controls, causing it to run erratically when fired.

¹⁷ Perrow, *Normal Accidents*, 66-70.

¹⁸ Chiles, *Inviting Disaster*, Kindle edition LOC 405.

An operator sometimes can recognize and stop a part or a component failure. Often, they cannot if these failures are invisible and it takes time to deduce the cause.

Squalus as a High-Risk System

Systems are very significant when it comes to those who study disasters and failures. Using the guidelines of a systems failure, the task analysis of the *Squalus* episode was obvious. The submarine was a warship designed to travel on the surface of the sea, then submerge to avoid enemy contact and sneak up on the enemy. Yet, in this case the *Squalus* sank at an early phase in its existence, while undergoing testing, so the task analysis changed.

Every modern high-risk system goes through thousands of man-hours of testing. In the case of a nuclear plant, testers pressurize safe water and run it through the system, checking for leaks or faulty valves. Another testing phase concerns the containment area for the fuel rods. This involves extensive stress testing of metal and concrete containment areas. With an airliner, technicians exhaustively test high torque areas while the plane is on the ground, often employing wind tunnels or machines that apply stress in performing these tests. Testing of ships starts in dry docks, first without water then with water. If there are any problems, testers can drain the water in the dry dock and the ship is safe. Most of the time a skeleton crew is on hand to do the testing in case a problem develops. However, a submarine is an incredibly complicated machine that requires testing at dock and then at sea with a full complement of men.

The first tests of the *Squalus* took place at her dock while she calmly sat in the water. From there she backed into the channel of the Piscataquis River, submerged in a safe area and underwent basic underwater tests. Had something happened, the crew could have escaped the ship using the escape hatches and underwater breathing apparatuses called Momsen Lungs.¹⁹

Degree of Disturbance

All Portsmouth submarines went from this point out to sea to run tests. Herein lies the difference between nuclear powerplant testing and the testing of a United States Submarine. If something goes wrong in a powerplant the operators have someplace to run. There was no place to run if there was a problem on a submarine. This was the epitome of risk in the testing of a high-risk system. The degree of disturbance in a situation like this was maximum.²⁰

The sinking of the *Squalus* was a full blown third level (subsystem) failure. It was not as if the engines had failed, or the batteries had exploded or a luxury liner had run into the vessel. The failure was caused by failure of a small subsystem, a vent door failing to close.

Coupling

Coupling comes into this discussion time and again.²¹ Some systems are tightly coupled, meaning the processes happen very quickly and cannot be turned off. However,

¹⁹ Vice Admiral Charles Bowers Momsen, Navy Biographies, Blair Papers, Box 68 File 3.

²⁰ Perrow, *Normal Accidents*, 64.

²¹ Chiles, *Inviting Disaster*, Kindle Edition, LOC 1399.

when developments in a system happen independently from one another, this is a loosely coupled event. Although they may be involved in the same production sequence or system, one has not caused another to fail. Non-coupled is just what it says. The system can continue to run because the operating components are in no way dependent upon the failed one. This is rare in a system.

The intake valve system was considered tightly coupled. There was a lever that actuated a hydraulic system that closed the intake valve. The intake valve had an optical warning system that showed on a control board whether the valve gate, or door in this case, was open or closed.

Linear versus Complex System

Diane Vaughn makes a reference to interactions in her book *The Challenger Launch Decision, Risky Technology, Culture and Deviance at NASA*. Some interactions can be as linear as a Sherlock Holmes investigation.²² Other interactions may be incredibly complex. For example, a linear interaction could be Newport shipping a torpedo through the Panama Canal to Pearl Harbor. The cargo ship receives the torpedo, lifts it off the cargo ship and onto a dolly. The dolly transports it to the submarine dock where it is wrapped in a sling. A cherry picker lowers the torpedo to the torpedomen and they take over. Any breakdown in this system, like a wheel coming off the dolly, the cherry picker breaking down or the equipment failing to arrive would have constituted a breakdown in a linear system.

²² Diane Vaughn, *The Challenger Launch Decision: Risky Technology, Culture and Deviance at NASA* (Chicago: University of Chicago Press, 1996), Kindle Edition, LOC 1394

The *Squalus* was state-of-the-art for its time. Yet, unlike the complex systems of the torpedoes that she carried, the *Squalus* had very linear systems. Although the submarine took a crew full of specialists to operate, the interactions were linear. A notable exception was the single hydraulic handle controlling both major induction valves.

But a part, unit, or subsystem may serve multiple functions. The operation of the valve in the case of the *Squalus* could be confusing. At the time of the sinking, a single valve closed both induction valves. It was confusing enough that the Navy modified the control placement after the incident. The control handle for the intake valve was simply a metal lever, with the grip forged into it but without a rubber cover over the grip. Forged handles are notorious for hand slippage during operation. Another advantage to a simple thing like a rubber grip on a lever is that you can see a noticeable difference and can quickly determine where to grab. The positioning of the lever could have been better as well. The connection from the handle to the valve was hidden from the operators.²³

This was not an automatic system. Closing the induction intake valve took the action of a seaman. There was no sensor telling the valve that the submarine was submerging, engaging a system that caused the valve to close by itself. There was a hydraulic line that ran from the lever to the valve. However, this was a hidden interaction. It was not like a wire line operation where a person could visually trace the wire from handle to valve. The hydraulic lines between the handle and the valve ran against the hull behind cork and other piping. However, if there was a failure in the hydraulic line it

²³ LaVo, *Deep*, Kindle Edition LOC 787.

would become visible as hydraulic fluid would present itself somewhere inside the hull. Even so, crewmen could not observe the failure of the valve before the submarine submerged, if not for safety features.

Engineered Safety Features

Since the assembly line began, many have developed ideas to simplify the system. One way of doing that is to automate as much as possible.²⁴ This is called automating subsidiary interactions. This leaves only the main framework to worry about. But doing so decreases the system's flexibility and operators lose the control to correct small situations or failures. This can lead to some systems having automatic monitors or components that command or monitor other systems. If the monitor misreads information, it can lead to operators shutting down a component at the wrong time or thinking the wrong component has broken down. Apollo13 ran into this problem when the astronauts were depending on instrumentation and alarms instead looking out the window as precious oxygen vented into space.²⁵

There were three official safety systems involved with both air induction systems in the *Squalus*. These features were important in the operation of the boat and became very important in the investigation after the sinking. The first safety feature engineered into this system was a lock. This pin was a small metal rod that slipped into place to hold the valve, in this case a door or gate, after it closed, to assure it stayed closed. Engaging

²⁴ Henry Ford, "My Life and Work," 1929, in *Major Problems in the History of American Technology*, ed., Merritt Roe Smith and Gregory Clancey (Boston, New York: Houghton Mifflin, 1998), 312-328.

²⁵ James Lovell and Jeffrey Kluger, *Lost Moon: The Perilous Voyage of Apollo 13* (New York: Pocket, 1994), 107, 126-127.

this pin was a hidden interaction. The second set of safety features were the hand-operated hull valves, located in the induction and ventilation lines at the inner end of the ventilation shafts, in the engine room. They were notoriously difficult to access and operate. The valves for the forward engine room were especially hard to access. The third safety system was the light on the control board, discussed above. Had a single red light remained lit on the dive, the dive would have been cancelled.

The final safety check was developed by the crews. Once the submarine's Christmas tree was all green, and the sub was buttoned up, a crewman discharged a little pressured oxygen from the pressurized oxygen banks into the boat. The men could physically feel the increased pressure in their ears. Once the crewmen felt pressure they would hit the klaxon and the boat would dive.

Mental Models and No Time for Correction

Engineers and designers create products and have expectation of how these products are supposed to work or not work.²⁶ With linear interactions, there are expected production sequences, a way in which a system is supposed to run, and everyone involved with operation knows what they are supposed to do. The design does not usually call for complex interaction by intention. In the example of the destroyer, no naval architect said, "Let's put the oil tank next to the pump room so there will be an interaction there." Nor did the opposite happen. No one gave any thought to putting the

²⁶ Chiles, *Inviting Disaster*, Kindle Edition LOC 3379.

tank next to the pump room. Complex interactions may be unintended or just unfamiliar ones.

As we have seen, when things go wrong with a high-risk system there is little time to do anything about the situation. In addition to this, when things go wrong, the operators go into a kind of denial because of the mental models that have formed in their brains.²⁷ In the case of the *Squalus*, the largest aperture of the boat was open to the sea. The delay in recognizing and accepting that possibility may have wasted some of the precious, limited time they had to act.

The moment the submarine reached fifty feet and completed the crash dive test, the skipper, Naquin, felt an unfamiliar sensation in the air. This gave him pause but he disregarded it for the moment. The call came in from the engine rooms that they were flooding. The board was green; this crash dive was the last after several successful dives. It took the captain and the other men in the submarine valuable seconds to sort things out in their minds. Naquin, however, put together the emergency call about the flooding and the fluttering sensation he had felt. The flooding from the massive influx of water was driving air forward into the control room. Naquin immediately ordered to blow the bow bouncy tank as the two gunner's mates who operated the stern and bow dive planes put them on hard rise.

The operator on the main induction lever noted that the lever was in the closed position. He tried to pull it down even more. The lever was as far as it would go. He looked up. No red lights showed on the board.

²⁷ Vaughn, *Challenger Launch*, Kindle Edition LOC 4497.

By blowing the bow buoyancy tank the submarine stopped for a second and tilted upward. But the sea water that was running into the rear of the boat was too much and the submarine hit bottom. Fortunately, they settled at a near-level landing. The forward crew took it for granted that the engine rooms were flooded. They hoped that the engine crews, maneuvering room operators, and the aft torpedo men had closed themselves off in the aft torpedo room and were safe. Due to the incredible strength of one crew member, the aft door to the control room was closed and thirty-three men forward of that door were still alive.

The victims of the *Squalus* were first party victims and, as usual, they were the operators of the high-risk system. There were second party victims as well. These were the people on board who were conducting testing for manufacturers the Navy had contracted to make submarine components, like the engines. The U.S. Navy has always known the high-risk nature of submarines. However, until the sinking of the *Squalus*, they did not have any rescue system put together to evacuate a sunken submarine.

One of the most famous submariners in the history is Charles Bowers Momsen, universally known in the submarine world as Swede Momsen. The story of Swede Momsen is a long complicated one.²⁸ Momsen worked his way up in the US Navy to become the expert on undersea diving before the war.

Momsen designed a rescue breather for submariners escaping submarines that had been sunk up to 150 feet. Momson was also responsible for the development of the rescue diving bell. By the time the diving bell had become a viable option for rescuing

²⁸ Vice Admiral Charles Bowers Momsen, Navy Biographies, Blair Papers, Box 68 File 3.

seamen, Momsen was wildly popular in the press. Yet, during the effort it took to develop the diving bell, Momsen had stepped on many toes. Thus, the diving bell was christened *the McCann rescue chamber* after another submariner, Lieutenant Commander Allan McCann, who also had a hand in the rescue chamber's development.²⁹

The rescue of the crew of the *Squalus* and its salvage was naval lore and the topic of many books. Momsen and the crew of the diving ship USS *Falcon* proceeded to the site of the sinking and rescued thirty-three men, including Lieutenant Naquin.

Resolution of the *Squalus* Story

The official Court of Inquiry took statements from all thirty-three surviving crew members. The investigation team boarded the *Squalus* after it had been salvaged and brought back into Portsmouth. The Captain, XO and a member of the Court went into the control room. They fed hydraulic fluid into the system and Lieutenant Doyle pulled the inductions' lever. This should have closed both induction valves, yet it just closed the ventilation valve. After they pumped more fluid in, pulling the lever closed both valves. It is not clear why they did not top off the fluid or why did they not have the system pressured all the way up? This was not a good test. By failing to run the hydraulic system at full pressure, a single successful attempt proved nothing. However, they also found that when the induction valve was closed, the locking pin was not in place.³⁰

One theory, other than the official one, was that the induction valve did close as the submarine went under, allowing the valve to re-open once the sub reached fifty feet.

²⁹ Maas, *Terrible Hours*, 146-165.

³⁰ Maas, *Terrible Hours*, 282.

This would explain why everyone's ears popped after the precautionary blast of air from the compressor, and then later felt a fluttering sensation resulting from water rushing into the engine rooms.

After the official inquiry, the officers and surviving crew members of the *Squalus* received praise. However, a memo reprimanded Lieutenant Naquin because, like most other submariners, he did not follow the practice of closing the redundant hull valves in the induction lines due to the difficulty in reaching the handles. Almost no submarine captains bothered with them as they were very difficult to reach let alone operate, so Naquin was not doing something out of the norm. Yet it cost him. Oliver Naquin never commanded another submarine, though he went on to a highly distinguished, decorated career as a skipper on a destroyer during the war.

Yet, the Board of Inquiry was right. If these redundant valves had been closed, a lot of water would have come through the ventilation system but those ventilation valves could have been closed off and the submarine probably would not have sunk. Certainly, the flooding in the engine induction system would have stopped on the back end toward the aft torpedo room.

Changes came about. Engineers modified the lever to be isolated from other levers and impossible to open by mistake. The new lever had a different, distinctive grip and moved to a different position. Other changes included backup valve trip levers to automatically close large aperture valves that were open to the sea if the main valves did not close.

One last note: The Court of Inquiry mentioned “an electrical failure on the control board” could have been responsible for crewmen failing to recognize the mechanical failure in a timely fashion, though it also noted that the failure could have been the result of a “mistake in reading this indicator by the *operating personnel*.”³¹

Operator Error

This item figures heavily into the story of the MK XIV/VI torpedo. Operator error is always high on any list for causal factors with any system failure. In the story of the MK XIV/VI, operator error came up time and again, as it did in other technological disasters. For example, with the Three Mile Island disaster, the operators took the major part of the blame from the President’s Commission to Investigate the Accident at Three Mile Island.³² In fact, the builders of the equipment in the plant, Babcock and Wilcox, put one hundred percent of the blame on the operators. As mentioned, the Bureau of Ordnance put all the blame on the operators, the officers and crew of the submarines, for the failure of the Mark XIV torpedoes and Mark VI magnetic exploders.

Perrow does not divide operator error into groups but, arguably, there is true operator error (Chernobyl), operators becoming the scapegoat when the system was at fault (MK XIV/VI torpedo debacle) and operators saving the day (Apollo 13).³³ Even when half a dozen officers and men saw that the board on the *Squalus* showed full green, the Court of Inquiry questioned whether they might have mistaken what they saw.

³¹ Vaughn, *Challenger Launch*, Kindle Edition, LOC 8548. As with Perrow and Chiles Vaughn cites that operator error is usually the first error people look to for blame.

³² Perrow, *Normal Accidents*, 7. Even when it became clear that the failure at Three Mile Island was caused by a faulty valve, the investigating commission blamed primarily the operators.

³³ Lovell and Kluger, *Lost Moon*, 363-382.

Perrow's analysis focuses on properties of high-risk systems themselves rather than on the errors of their designers. Problems like faulty designs or faulty equipment, lack of attention to safety features, lack of all-around experience in management, inadequately trained personnel, failure to use the most advanced technology, systems that are too big, underfinanced systems, or just poorly run organizations come to mind when failures occur. Complex systems are going to fail, even in state-of-the-art systems. The sinking of the *Squalus* was a clear example. Yet time and again it was not the designers or the managers that were blamed. It was the operators.

MK XIV Torpedo

The Mark XIV/VI torpedo failed at what it was designed to do, namely exploding while underneath the keel of an enemy ship. There were two main problems that the torpedomen faced with the Mark XIV/VI, depth control and the magnetic influenced exploder.

The Mark XIV torpedo's depth was dependent on a pressure sensing diaphragm, depth engine, and a pendulum. Unlike a clock pendulum, which moved back and forth at a constant rate, in the MK XIV, the two pendulums attempted to stay static. When in motion, during a run, they worked in union, opposing the forward-backward movements of the torpedo traveling through water. The pendulum, acted upon by gravity, worked to limit the angle of inclination at which the torpedo sought depth and at the same time steadied the torpedo at set depth. This means that the pendulum is always fighting to stay straight down. The pendulum unit was connected to the depth control, or immersion,

mechanism. This maintained the torpedo at the desired depth during its run. Two horizontal rudders, acting as one, connected to the rudder yoke in the tail of the torpedo. The rudder yoke was in turn connected to the linkage coming from the depth engine.³⁴

Like everything else on the Mark XIV, the piston of the depth engine was operated by air and was controlled by an extremely sensitive valve located inside the piston. This piston was connected by a system of levers to the pendulum of the depth control mechanism. The pendulum was connected to a diaphragm by interconnected levers and links. Because of these connections, the pendulum, diaphragm, and depth engines valve moved simultaneously.

The pendulum drove the engine valve. When the torpedo was not level, the pendulum moved the engine valve or if not at the desired depth, the hydro diaphragm moved this valve. Regardless, the pendulum and the hydro diaphragm had a modifying effect on each other. This is what is known as the *Uhlán principle* with the weight and valve being dependent. Water pressure acted upon the torpedo's diaphragm when the torpedo was in water. A depth spring, which was connected to the lower depth spring socket held the diaphragm against this seawater pressure. Thus, the depth spring tension controlled the running depth of the torpedo.

The torpedo tube was flooded when the outer door opened or via the use of a valve. Therefore, there was already seawater pressing against the hydro diaphragm. Launching a torpedo required a blast of air and immediate contact with the ocean. Because of the shock and dynamics of initial launching, the pendulum would swing aft.

³⁴ Torpedoes Mark 14 and 23 Types, OP 635, 24 March 1945, 9.

This immediately made the torpedo dive, causing depths to vary during the initial dive. As soon as the pendulum picked up this motion, the pendulum would swing forward and, in combination with the action called for by the pressure on the hydro diaphragm, cause the rudders to gradually adopt their neutral position. The forward momentum carried the torpedo a little above the set depth. After a time, the trajectory would even out and the torpedo ran at the desired depth. The pendulum and the hydro diaphragm controlled the rudders to correct for any deviations in depth.

Hydro Diaphragm

The hydro diaphragm requires additional description, as it played a major role in the failure of the MK XIV depth mechanism. It was made with oil resistant rubberized fabric, clamped on its outer edge between the diaphragm ring and the air chamber. Water entered to exert pressure upon the upper side of the diaphragm through an inlet pipe, the open end of which was in the midship section. This inlet pipe was open to the sea and carried the pressured water to the diaphragm. The higher the pressure, the more force was applied to the diaphragm. This told the depth setting mechanism how deep the torpedo was traveling. A small hole, driven into the diaphragm ring, vented air which may have been trapped in this chamber by incoming water.

Depth setting mechanism

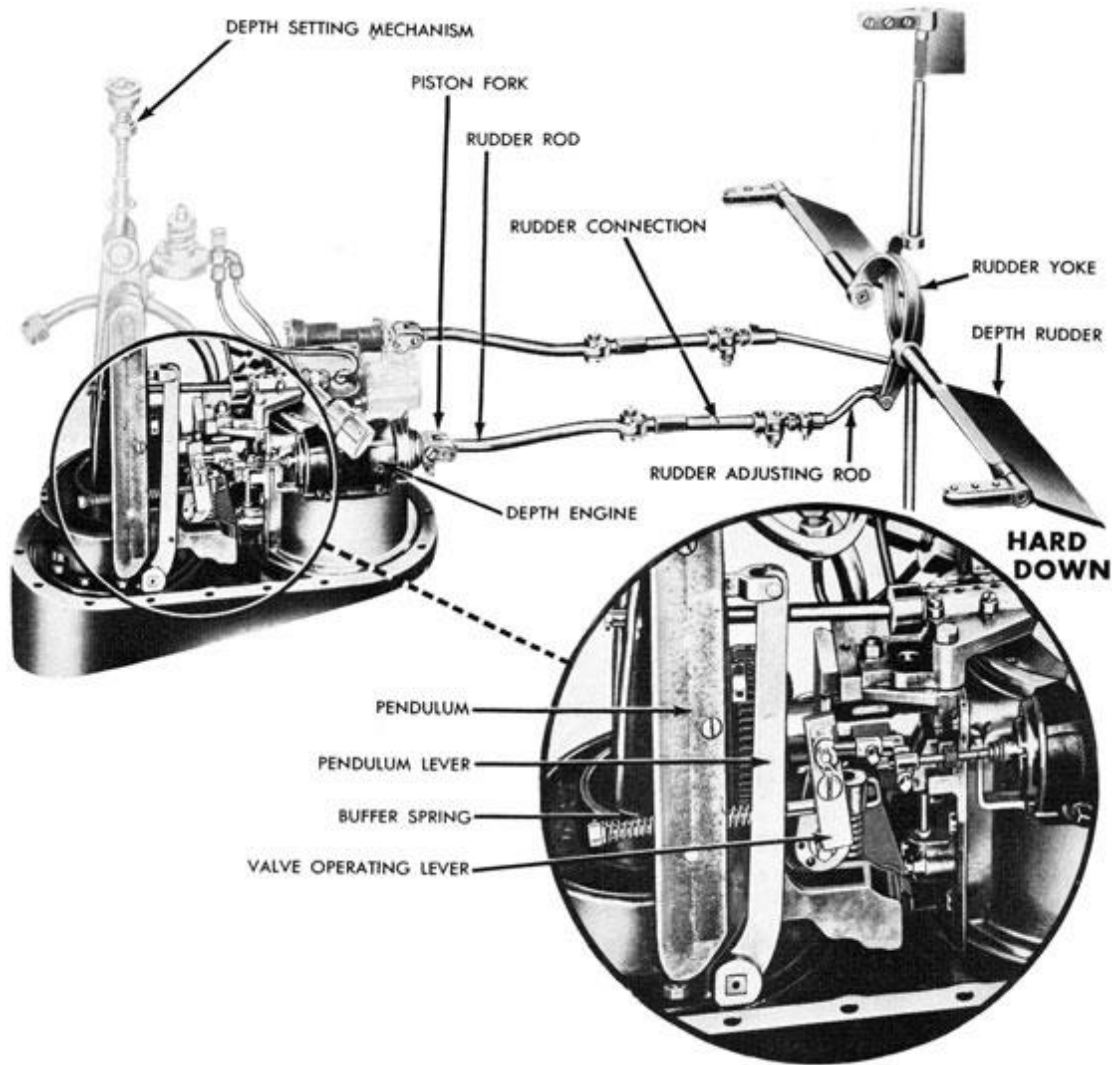


Figure 8. MK XIV Torpedo Depth Mechanism

The depth setting mechanism resided inside the pendulum mechanism. The depth setting mechanism set the tension of the depth spring to correspond with the water pressure at the desired running depth. This setting was indicated on a graduated dial called the depth index wheel. There were two major units in the depth setting mechanism, the depth index flange assembly and the spring socket assembly. The depth index flange

contained all the parts secured to the afterbody shell and, in its center, was the depth index spindle which passed through a stuffing box in the flange. Through spring pressure and linkages, this mechanism manipulated the depth setting engine which in turn controlled the linkages to the depth rudders.

Torpedomen used special tools to calibrate the depth setting so that the torpedo would find a preset depth and remain there. It was important that the depth set for the torpedo be met exactly because of the depth needs of the Mark IV magnetic exploder.

Mark VI Exploder: Electrical Engineering View

As previously described, the MK VI exploder initiated its explosion by the release of a firing pin to strike against a primer cap which initiated a warhead detonation. These exploders were also machined and well-designed to explode only under certain circumstances. This way, the torpedo would not explode while stored aboard or going through the violent process of being fired from the submarine. Yet, the electrical system responsible for initiating firing seemed overly sensitive to the electromagnetic environment and possibly to physical disturbances.

The first exploder drawing below, “Figure 1. Exploder circuit Drawing (Wiring Layout MK VI-2A and 6-2B Exploder),” shows the layout of the circuit components.³⁵

³⁵ Bureau of Ordnance Drawing Number 352833. This drawing was discovered, along with blueprints and other drawings of the Mark XVI torpedo and the Mark VI magnetic exploder by mechanical engineer Charles R. Gunderson, and electrical engineer Jerry E. Armstrong. These men worked for decades at the National Undersea Weapons Center at Keyport, Washington. Mr. Gunderson is a mechanical engineer and Mr. Armstrong, an electrical engineer. These men produced a self-published paper concerning the Mark VI Magnetic Influence Exploder. The paper is named *A Little Premature: A Paper Produced for the Naval Undersea Museum Keyport Washington*. This author met with Mr. Gunderson on multiple occasions and has communicated with him since. Much of the following

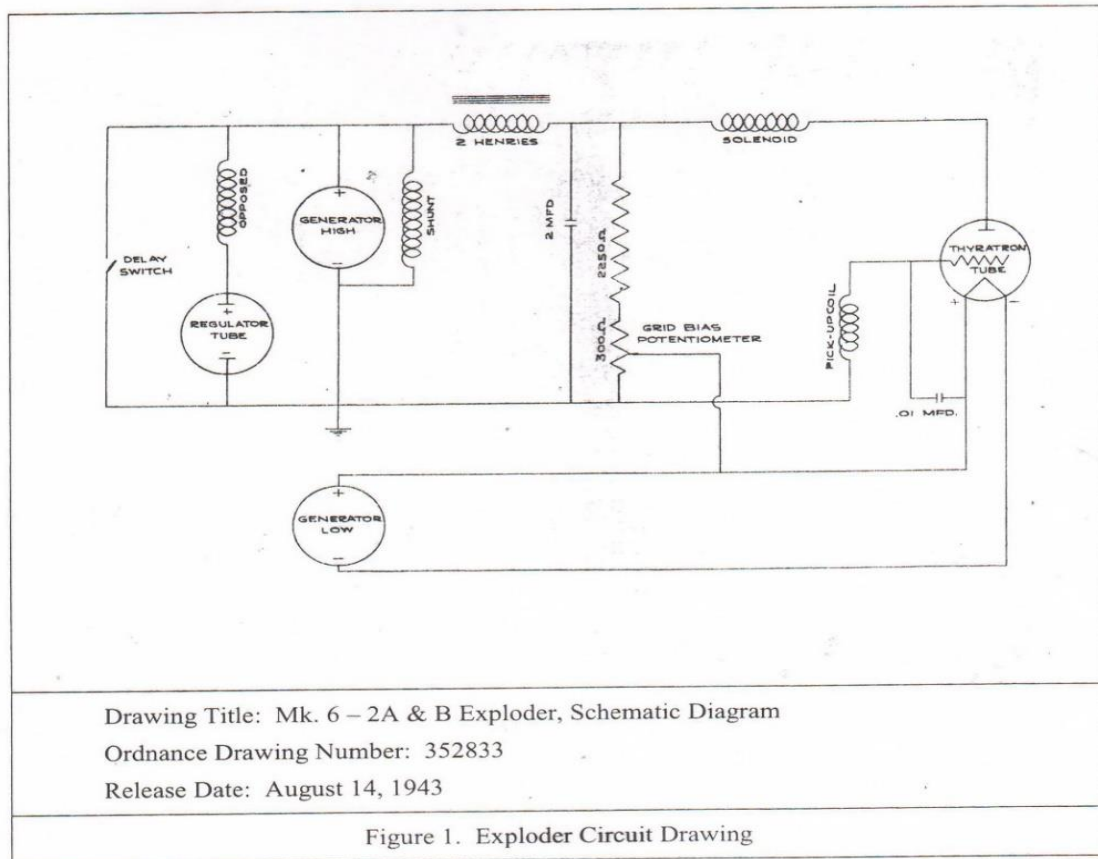


Figure 9. MK VI Exploder Circuit Drawing

The second drawing below, “Fig. 2 – 3, Exploder Mechanism, Schematic,” shows the electric circuit of the exploder.³⁶ Although primarily a magnetic influence exploder, it also could be retrofitted to be a contact (impact) detonator. The magnetic influence part should be looked at first.

information was drawn from this paper and this author is in great debt to Mr. Gunderson for his invaluable help in writing this portion of this dissertation.

³⁶ “Torpedoes Mark 14 and 23 Types,” *OP 635*, 17.

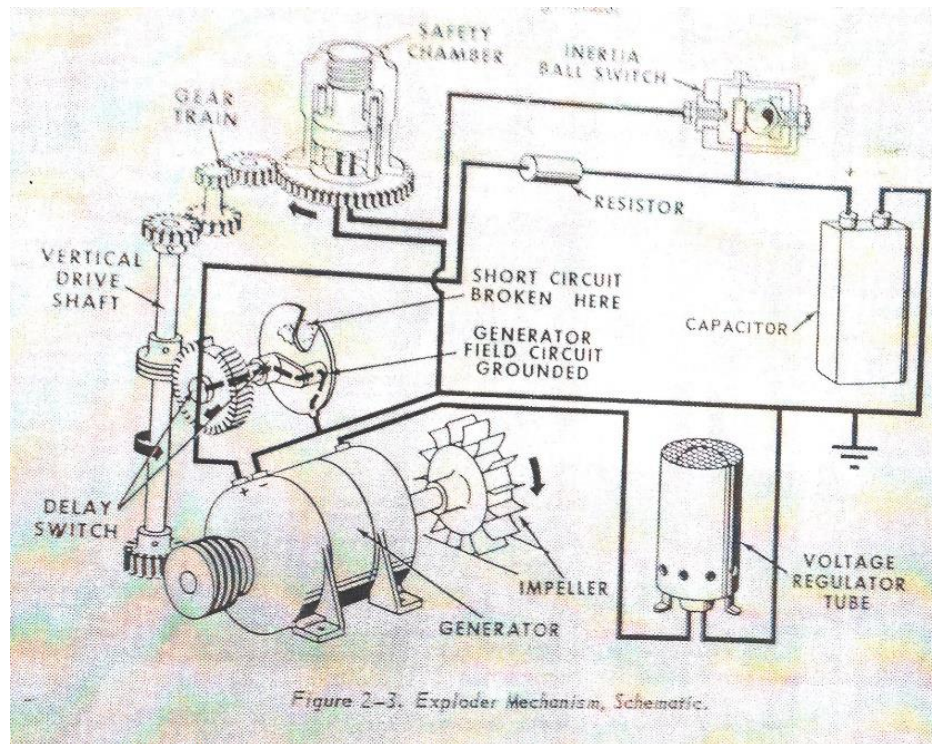


Figure 10. MK VI Exploder Mechanism Schematic

The earth has a magnetic field. There is magnetism everywhere but the power of the magnetism per location on the Earth varies greatly. This important factor will come into play later. The MK VI magnetic exploder continuously monitored the earth's magnetic field looking for significant and abrupt deviations in that field. When that happened, a pulse of electrical energy shot to a solenoid. This was the theory. Reality was an entirely different story.

The last thing any submariner wanted to worry about was a torpedo exploding while leaving the torpedo tube or even a hundred yards out. A MK VI exploder was designed not to arm until it was approximately 450 yards away from the submarine, when

a small propeller at the front of the torpedo head spun off. The MK VI also had an electrical safety feature.

Once armed and operating, a voltage regulator, sent through a Grid Bias Restrictor to a pick-up coil, smoothed the electrical current, which needed to be as close as possible to a constant rate. The voltage also helped keep additional electrical noise from entering the circuit.³⁷ As the torpedo gained speed on its way to the target, the pick-up coil inductor sensed the earth's magnetism through its magnetic flux lines. As it sped through this field, the coil produced a small fluctuating voltage due to the small variations in the earth's magnetic field. Once the exploder reached a point near the target, the combined field would abruptly change in direction and intensity due to the magnetic influence of the ship's iron and steel hull. The ship's EMF helped increase this intensity. The pick-up coil would respond by increasing the amplitude of the output voltage. When the voltage output reached a pre-determined level, the Thyatron tube switched on and current flowed up to the solenoid. Once the solenoid kicked in, a small shaft moved a quarter of an inch touching off the cap that ignited the warhead's 500 pounds of Torpex.

As mentioned in chapter Two, the Mark VI exploder did not fit in the nose of the torpedo. It fit underneath the torpedo, several inches behind and below the nose piece. The exploder could be removed. Indeed, torpedomen often needed to remove the exploder assembly and service it. The exploder weighed ninety pounds, not including the core rod tube that weighed an additional twenty pounds. Taking the electrical system of

³⁷ Noise is excess electricity that is not contained within a component or wire. For example, an overcharged wire may not contain all of the electricity that flows through it and this excess electricity is thrown into the air and can accidentally enter a nearby component like a capacitor or relay.

the MK VI apart and looking at each individual component shows how complicated the science and technology of the exploder was.

The Arming and Delay Switch

The delay switch, shown on both drawings, was one of the torpedo's safety features but also an important part of the arming system. This delay switch prevented the electricity from completing a circuit until the torpedo was a safe distance from the submarine. When launching a torpedo, any type of quick change in speed or course of the submarine, perhaps a depth change or rough sea conditions on a surface shot, could have introduced yaw, side to side, or up and down motions that could have set off the exploder. It was the delay switch's job to prevent the exploder from accidental detonation before it reached a minimum safe distance away from the submarine. Until the torpedo traveled 450 yards into its shot, the delay switch was in a closed position. When in the closed position, there was a direct short circuit to ground from the high end of the generator. This short circuit prevented electric current from flowing to the magnetic influence features of the exploder. Once the torpedo reached the requisite yardage, the delay switch opened, removing the short circuit and re-directing the current and completing the circuit. Following this, the electronic tubes warmed up within seconds to their operating temperature, making the exploder ready to fire. Another major function of the arming mechanism was to align the explosives by moving the detonator into the booster cavity, securing it in place by the time the torpedo reached arming distance.

Generator

The MK VI warhead was totally self-contained, yet it required electricity. It did not depend on outside electricity, such as batteries. MK VI exploder had a trough cut into the underside of the exploder base, contoured to let ocean water flow in and turn the blades of an impeller. The impeller was a small, tightly-machined, watermill-like waterwheel with fifteen convex shaped blades. In Figure 2 – 3 above, this wheel was attached to a shaft that drove the direct current (DC) generator and the warhead arming mechanisms. At the end of the shaft was the delay switch control. The armature of the dual output generator contains two windings and two commutators, one at each end of the armature, with soft or hard brushes, supplying both high and low voltage currents. So, one generator did double duty, a non-linear interaction adding risk.

The low voltage part of the generator was not subject to any action by the delay switch and began to supply low voltage, high current electrical power the minute the torpedo launched. This power went directly to the Thyatron tube amplifier to heat up the cathode filament. The high end of the generator supplied the high voltage necessary to keep the grid element, anode plate, and the cathode filament of the Thyatron tube at their correct voltages. The high end also supplied the biasing voltage that prevented the Thyatron tube from triggering in the absence of the trigger signal. This is highly important, as it is the Thyatron tube that was the last link in the chain before the solenoid fired to engage the exploding cap.

Voltage Regulator and Noise Filter

Of the two tubes in the MK VI, the voltage regulator, was the smaller one. This tube controlled the output voltage of the generator no matter what speed the impeller wheel was running. Thus, there was a constant voltage, a *regulated* voltage, regardless whether the torpedo was running at thirty-five knots or forty-seven knots.

The voltage that the generator produced was held at an almost constant value by an opposed field winding. This opposed field was connected in series with the regulator tube across the high voltage terminals of the generator. When the generator reached a set speed, the regulator tube activated to hold the voltage generated nearly constant even as the speed of the generator increased. The generator had noise filters, used to clean up and filter out the electrical noise from the high generator output. This kept the voltage noise, due to the electrical noise of the arching brushes in the generator, to a value lower than the expected trigger signal of the Thyratron tube, to prevent prematurely setting off the warhead.

Pick-up coil

The Pick-up coil consisted of many turns of fine wire wound on a tubular core inserted into a large cylindrical can twelve inches long and four inches in diameter. The Pick-up coil was the component that was sensitive to the distortions in the pattern of the earth's magnetic field.

The background magnetic flux intensity level constantly varies because of the torpedoes' violent motions and the natural changes in the earth's magnetic field. The

pick-up coil, in passing through such an irregular field, produced a small and variable voltage output. The magnitude of this small voltage followed the changes in the earth's magnetic field. Fortunately, these natural low level signals are not enough to trip the Thyatron tube.

Again, a ship passing through water created an EMF signature. Every large ship had a large amount of magnetic influence due to the large amounts of iron and steel in its hull. As the torpedo neared the ship's hull it encountered the distorted and changing magnetic field that the steel and iron produced. Because of this, the pick-up coil's voltage output increased. When Ralph Christie and the other engineers at Newport were designing the exploder, they attempted to tune the pick-up coil's sensitivity just right so that the voltage increase reached a pre-set value under the enemy ship's hull. At that pre-set level, it increased the positive voltage, reducing the negative potential on the grid element of the Thyatron tube, allowing the Thyatron tube to trigger and draw off the current from the cathode filament.

The core rod was a specialized metal bar, placed last into the warhead through an opening in the nose of the warhead, and fit into a special tube. The cored rod and pick-up coil acted together to sense the changes in direction and intensity of the earth's magnetic field. This thirty-four-inch-long, magnetic bar, or rod, sat in the middle of the pick-up coil. It was made of a highly permeable alloy and increased the magnitude of the magnetic flux passing through the coil windings of the pick-up coil, ultimately increasing the voltage produced.

Thyratron Tube

A Thyratron tube was a gas-filled, electronic tube but not a vacuum tube. The gas inside was either mercury or argon. The Thyratron tube acted as an amplified, electronically-actuated switch like today's Silicon Controlled Rectifier (SCR).³⁸ The tube contained a cathode filament, a central grid element and an anode plate. In the exploder, the control grid was connected to the pick-up coil and the output from the anode plate was directed up to the solenoid. As mentioned, once fired and during the runout to the arming distance, the cathode filament was heated up by the low voltage end of the generator. The rise in temperature caused the thermionic emission of electrons. This was not new to World War II. The Thyratron tube's ability to provide a switching action was a commonly used feature dating back to at least 1929. One of the other many uses during World War II included the proximity fuses used in artillery shells.

To the Target

Once on its way to its target, the torpedo swept through the earth's magnetic field lines. These lines were uniform and constant. The pick-up coil and core rod sensed the subtle magnetic field and only produced a small variation in the output voltage of the pick-up coil. This voltage entered the grid element of the Thyratron tube. Any changes in the lines of the magnetic flux were translated into changes in the voltage of the grid

³⁸ "Early Power Semi-Conductor History at GE" *Semi-Conductor Museum*, Accessed December 16, 2016, http://www.semiconductormuseum.com/Transistors/GE/OralHistories/Gutzwiller/Gutzwiller_Page6.htm. The SCR was a three-terminal switch. It was a black box in that it took years to design, had input (electricity) coming in, energy going out and needed not to be taken apart, just replaced if there was a failure. In the end the SCR could rectify, invert and direct electrical flow. SCR's came in all shapes and sizes.

element. During initial installation and adjustment of the torpedo, crewmen applied a negative voltage to the grid elements to suppress the tendency of negative electrons to flow from the cathode to the anode of the Thyatron tube. The negative charges repelled each other blocking any electrical current.

The position of the contact slider on the grid bias resistor governed the potential of the cathode filament with respect to the grid element and anode plate. The position of the slider varied such that if the filament was neutral, or at zero potential, the anode was at a high positive and a high potential, called the grid bias, and it was this grid bias that prevented the tube from firing until the proper time.

When the MK XIV torpedo traveled through the disturbed magnetic field caused by the sudden appearance of the enemy ship's hull, the pick-up coil produced a large voltage change. This positive voltage change removed the negative bias voltage from the grid that held back the electrons on the cathode. The voltage impressed on the grid from the pick-up coil was positive and of a magnitude greater than that of the bias voltage to fire the Thyatron tube. The voltage depended on both the torpedo velocity relative to the target and the space rate of change of the horizontal magnetic field component in the direction of the torpedo motion. An increase in the speed of the torpedo relative to the target caused the pick-up coil to generate a higher voltage thus the exploder was more sensitive at higher than at lower speeds. In addition to this, the generator delivered a slightly higher voltage at higher impeller speeds and the effect of this was also to increase the sensitivity.

Once the Thyatron tube fired, the ionized gas became a conductor rather than acting as a blocker and the rush of electrons supplied by the high voltage armature windings of the generator made their way up to the solenoid. Once this voltage began to flow, it avalanched into full conduction. A large amount of current began to flow through the Thyatron tube and on through the solenoid to activate it like a switch.

Capacitors

There were two capacitors in the system. The first was a two-microfarad (MFD) capacitor that performed double duty. When combined with the Two-Henry choke,³⁹ it functioned as a low-pass noise filter by choking or blocking the higher frequencies. It also supplied the initial current to the solenoid during the time the two-henry choke was increasing its current to above the bias current level. The capacitor then recharged as it followed the increasing voltage output of the choke. The choke current increased until the voltage drop across the solenoid equaled the high voltage supply value, but by then the explosion was already in process.

The .01 MFD capacitor, in combination with the pick-up coil, formed a low pass noise filter. This filter also introduced a time delay between the time of arrival of the signal from the magnetic influence of the target at the pick-up coil and the time the grid voltage rose to the trigger level. If the pick-up coil detected a short duration signal, the .01 MFD capacitor, with its delaying action, reduced the voltage rise to the grid and reduced the likelihood of having a false trigger. The delaying action allowed the torpedo

³⁹ The Two-Henry Choke is a power supply filter element. It "smooths out" the ripples in the rectified voltage waveform. A Henry is an electrical unit of measurement that relates to inductance.

to advance a toward the target's keel and could have been the reason for its inclusion into the circuit design. The resulting delay time was speed dependent. It also varied with the beam width of the target and the angle of approach.

Solenoid

The solenoid released the firing pin but only after the torpedo reached the arming distance. At this point, an additional safety device on the arming screw unlocked the solenoid lever system. The solenoid converted electrical energy from the Thyatron tube into mechanical energy to lift the solenoid's armature sharply upward only about one quarter of an inch. This action triggered the firing ring of the contact firing mechanism, releasing the firing pin to strike against a primer cap and initiate the detonation of the warhead.

Analysis

Once fired, the torpedo burst from the tube. As it ran into the sea, the seawater spun the impeller, which in turn generated electricity to the electrical circuit. The magnetic influence exploder crossed magnetic flux lines and in doing so created small changes in voltage in the pick-up coil. The grid element in the Thyatron tube opposed the voltage created, so small variations did not trigger detonation. The voltage regulator and noise filters eliminated the noise that could trigger detonation as well. When the exploder entered the ship's magnetic influence, which was of much greater magnitude than the magnetic flux lines, there was a sudden rise in voltage within the unit. This was sufficient to overcome the inhibiting action of the grid element in the Thyatron and allow the voltage from the generator to flow to the solenoid. Here, the capacitors made

sure that the voltage was not in response to noise and created a small delay so that the torpedo could get under the ship. The solenoid then tripped and ignited the tetryl, exploding the Torpex.

Though very complex and detailed, this is still a simplified and abbreviated description of the system. The entire system includes seals, bulkheads, cushions, mounting brackets, and other vital parts too numerous to describe here.

Analysis of the Mark XIV High-Risk System

We have already been through the intricacies of the Mark XIV. Looking at it from the perspective of a high-risk system, it was bound to fail from time to time. A torpedo could be dangerous just sitting in a tube or on a storage rack. This section will examine the MK XIV/VI from the perspective of what it was designed to do.

The torpedo was a fascinating study in the failure of high-risk systems. Unlike a static nuclear plant, a weapon like a torpedo had few constants. Different applications meant different definitions. This meant that shooting a torpedo spread from 1,500 feet, waiting and watching, was different than shooting a Japanese destroyer down the throat as it attacked. In the first application, the submarine was in limited danger and, if the torpedoes did not function as intended, the result was disappointing. The second application meant life or death for the submarine and crew.

Definitions

Definitions changed depending on the fire control setup of the target.⁴⁰ Taking a shot at a static target in a harbor or lagoon was much different than taking a down-the-throat shot with both ships speeding at one another. A sneak attack and an attack to fend off a foe require additional definitions. These definitions are very liquid. Definitions and tasks with firing a torpedo were interchangeable at times.

Task analysis

The task analysis of the Mk XIV/VI was simple. This torpedo was nothing more than a missile that was fired underwater. Like a missile, it had a body which allowed it to travel under its own power and carried a warhead that would explode when it reached its target. Like any other ordnance, it was dangerous even when it was in storage or waiting to be fired. Its task was to reach the enemy and explode, causing death to enemy combatants and to sink, or render harmless, the vehicles the enemy was using to carry troops, munitions, fuel or supplies. While this was happening, the submarine either retired or sat in the water and watched the terrible fruits of its labors. However, the task analysis changed greatly if the submarine was attacked and was attempting to neutralize an attacking ship. This was when a torpedo *needed* to work and, if it did not, it could cost the lives of the men on the submarine.

⁴⁰ Perrow, *Normal Accidents*. Much of the work that Diane Vaughn and James Chiles have done rely on definitions and ideas originated by Charles Perrow's book. The definitions used here also rely on Perrow's definitions unless otherwise noted.

Degree of disturbance

Degree of disturbance in this case went hand in hand with the task analysis. Under normal circumstances, the degree of disturbance when a torpedo failed was not that high to the ones using the weapon. The submarine shot the torpedo at an unsuspecting enemy ship and if the torpedo failed then the target went on to its destination. The submarine made more attempts until the submarine was out of torpedoes. The failure of the torpedoes at that point could be regarded as incidents. The degree of disturbance changed greatly if the torpedo failed when in use against an attacking destroyer, or if the torpedo trails led a destroyer to attack. If the torpedo failed to explode during an attack, then the degree of disturbance reached the highest degree.

Incident versus Accident

These definition, too, depend on the task analysis and the disruption to the system. The failure of a torpedo during normal operation was not an accident. It was an incident. This was a disruption to the system but it rarely meant life or death to the users. If the torpedo made a circular run, as it did with the USS *Tang*, or somehow exploded onboard the submarine, then it became an accident. A torpedo failure in a submarine under attack was also considered a systems accident. If the torpedo failed and attacker sank the submarine, this became a systems accident with first party fatalities.

Engineered Safety Features

The engineered safety system on a torpedo was the propeller that kept the torpedo from detonating under 400 yards from the submarine. Until this propeller detached, the

warhead was not live. There was also an engineered anti-countermining feature that prevented an exploding torpedo from prematurely detonating other torpedoes close by.

Linear versus Complex, Visible versus Invisible

The Mark XIV torpedo was mostly a linear system. The torpedo could be and was taken apart for inspections and servicing. If one part was not working, it was easy to chase down and figure out the issue. This could be done while at port or in one of the two torpedo rooms. However, it was impossible to check the torpedo *while it was in action* and in the *process of the expected production sequence*. Thus, although the system was linear, the interactions within the torpedo were invisible interactions.

Redundancy

Thankfully, there was a redundant system in the Mark VI magnetic exploder. Operators could disable the magnetic part of the exploder and use the contact exploding mechanism. However, during the failures of the torpedoes, in the early and middle stages of this issue, redundancy did not enter the equation. There was no redundant magnetic system nor was there a redundant depth control system.

Mental Models

After the first three or four torpedoes failed to either hit their targets or explode, the mental models of the operators should have changed. However, the theory behind the magnetic exploders was solid. One torpedo for one sinking was imperative. When the torpedoes did not work, the crews came back in and told their stories. Most of the officers

were engineers. Some, like Lieutenant Commander Jacobs, had Master's degrees in mechanical engineering. Not only did higher-ups tell the crewmen that they were wrong, they threatened them with Courts Martial if they insisted they were right by disabling the magnetic mechanism.

Managers or commanders were supposed to know more and be better at their jobs than their subordinates. They had more experience and must have been smart because of their exalted rank. The men knew that something was wrong. But greater minds than theirs created the exploders, so the men began to question themselves. The Bureau of Ordnance was saying the men were doing something wrong.

So, there were crews going out time and again trying to get it right. They were trying to get their approach perfect, conduct the perfect fire control procedures, fine-tune the torpedoes as well as they could, all hoping that if they got it right the torpedoes would work. At first, the crews fell for BuOrd's propaganda. Finally, with continued evidence that the torpedoes were defective, the crews' mental models changed, empowering them to set up their own testing.

Coupling

There was a one-way tight coupling within the MK XIV/VI. This meant that one component was terribly dependent on the other but the dependency was not reciprocal. The Mark VI was dependent on the depth control. Remember that the Mark VI was designed to explode fifteen to eighteen feet under the keel of an enemy ship. If the depth control was not working correctly, the magnetic exploder was not going to work correctly. If the torpedo traveled too deep, then the magnetic exploder could not pick up

the EMF of the ship, would pass underneath the ship and just keep going until its fuel ran out. If it did not travel deep enough it could pick up a ship's electromagnetic signature too soon and explode prematurely.

The dependency between the two was not reciprocal. While the Mark VI was dependent on the depth control, the depth control was influenced in no way by the exploding mechanism.

Transformation Processes and the Environment

Perrow wrote that linear interactions were intuitively constructed because of their simplicity and comprehensibility.⁴¹ Linear interactions overwhelmingly populate all systems, whether they are highly technical or not. However, these linear systems had one source of complex interactions. That was the environment.

A transformation process consists of hidden interactions. As Perrow points out, when processes like chemical reactions, vapors, temperature fluctuations, air turbulence, water turbulence or air and water pressures are involved, a lot of mystery is involved as well. Not only are these processes invisible, most of the time we cannot understand the principles behind them.⁴² Other transformation processes affecting torpedoes might include magnetism, electromagnetic forces (EMF), seawater salinity, plankton density, and debris and wildlife in the sea.

The first example of a transformation process affecting the depth sensor was the Bernoulli Effect. As we have seen, the location of the depth sensor was on the rear of the

⁴¹ Perrow, *Normal Accidents*, 75.

⁴² Perrow, *Normal Accidents*, 10.

main body of the torpedo between body and fin. Because of the flow of water and the Bernoulli Effect, the depth sensor was not giving the depth control mechanism the right information.

Another example was the fact that ships' electromagnetic fields were not constant. The larger the ship, the larger the EMF. Christie suggested that the MK XIV/VI would not be expected to work as well on a ship lacking a reinforced hull because it would have a weaker EMF.⁴³ Also, EMFs change the further one gets away from Newport, where the torpedoes were manufactured. The EMFs at Newport were more hemispherical. The closer a ship came to the equator the more the EMF flattened out to a pancake shape.⁴⁴

Today, the Earth's magnetic field is mapped out. The U.S. Navy is close to having the capability to call up ship position using the Earth's magnetic field. The system is called Geomagnetic Navigation (GMN). Pigeons, bats, sea turtles and a host of other animals use magnetic navigation for long distance homing and migration. This sense is referred to as magnetoreception. GMN works similarly. GMN measures the magnetic field at your present location and then uses a library of magnetic maps to determine that location. The Earth's magnetic field is susceptible to local disruptions and fluctuations because of weather conditions, solar flares, and magnetic noise. Within the last ten years, researchers have developed the technology to overcome these hindrances. GMN uses two components, a map of Earth's magnetic field and magnetic sensor that detects and

⁴³ Official communication to Rear Admiral R.S. Edwards from Rear Admiral Ralph Christie, May 19, 1942, Christie Papers, LOC, Box 181. After torpedo failures were adding up in the first months of the war, Christie first blamed the crews and then mentioned that the "Mark 6 magnetic feature be used only against the type of ship it was designed for—the BB," (Battleship)

⁴⁴ Gunderson and Armstrong, *A Little Premature*, 43-47.

measures the local magnetic field. There is nothing constant about the Earth's magnetism. The National Oceanographic and Atmosphere Administration (NOAA) is trying to create real time models of the magnetic field by combining crowd sourced data with real time solar wind data. The crowd sourced data depends on a free application called CrowdMag. NOAA audits the quality of the magnetic information collected from the apps and then makes that data accessible to the public as accumulated maps and charts. A ship carrying a library of GMN maps could then rely on that information and, along with the sensors, navigate successfully if GPS was inaccessible or shipboard communications systems were down. This technology is hoped to be included on ships within the next few years as it is still not perfected as of 2016.⁴⁵ In 1941-45 few knew much about the Earth's magnetism, contributing to the complexity of Mark VI Magnetic exploder.

The point is that these situations were transformation processes. They could not be seen, and certainly, they were not understood during the time the torpedoes were being used during the war. Other transformation processes like these contributed to the failure of these high-risk systems, the Mark XIV torpedo and Mark VI magnetic exploder.

Materials and Relationships in Action

One of the interesting facets of the torpedo issue during the war was the relationships. These were not just relationships between the people involved, but also relationships between the men and the technologies with which they dealt, fought, and

⁴⁵ Lieutenant Ashley O'Keefe and Lieutenant Junior Grade Shane Halton, USN "Geomagnetic Navigation Can Replace GPS" *U.S. Naval Institute Proceedings: The Independent forum of the Sea Services*, April 2016 Vol. 142/4/1,358, 81-83.

lived. These men were trying to make these torpedoes work while living within the confines of a war machine that transported them to the other side of the largest ocean on Earth.

The first submarines used in the war were a collection of the new and old but the submariners made the most of what they had. As mentioned, the new fleet boats were state-of-the-art, diesel-electric submarines. The world had never seen anything like these machines. The men who sailed them were the most highly-trained men in the Navy. These submarines were the definition of a high-tech, high-risk system. They were using, on a par with proximity fused bombs, the highest tech armament that the world would see until Trinity.⁴⁶

Science in War

The MK XIV/VI torpedo was a high-powered, highly-destructive weapon. This was warfare, with warriors fighting the enemy. There would seem to have been no time for science once shooting began. Yet, science goes on no matter what is happening in the world. In fact, the torpedomen on the submarines were advancing science every day as they attempted to correct the problems with the torpedoes.

The submarine officers were sending the most detailed reports possible to Pearl Harbor to show that the men in the submarines were doing the job right and not making mistakes. Most, if not all, of the submarine commanders in the first year of the war were

⁴⁶ Ralph Belknap Baldwin, *The Proximity Fuze: The Secret Weapon of World War II* (New York: Presidio Press, 1980), 3.

Annapolis graduates with engineering degrees. The enlisted men were held to high standards and were among the most thoroughly-trained personnel in the Navy. The torpedomen were specially trained at what they did. Thus, many sub commanders minutely detailed every shot they took to scientifically spell out the circumstances surrounding and symptoms of the failed shots. If they were to sort out the conditions and symptoms scientifically, then perhaps the people at Newport and at BuOrd could take that information, apply theory to it, and help find and fix the reasons for the failures.

Submarine Reports

Submarine reports were inscriptions that dealt with everything one can imagine concerning serving on a submarine. Issues reported concerned: health issues from colds to appendicitis, morale, food consumption, fuel consumption, fresh water supply, longitude and latitude location throughout the day, submarine machinery performance in heavy or calm seas, training and drilling, top guns, wind speed on surface, thermal density layers under the surface, ocean currents, tidal current, currents caused by estuaries, sounding, engine performance, battery performance, crew moral, discipline problems, sleeping quarters issues, crew health issues, radio reception, cryptography, radar and sonar contacts and equipment performance, and more.

As has been shown, the enemy contact and attack reports were most important. These told command the minutiae of conducting the attacks, how firing parties performed

and how the torpedoes performed. Submarine officers and torpedomen dissected any torpedo failures to the finest detail and let Command know their opinions.⁴⁷

Testing

High-risk technical systems will fail. Most current high-risk systems should be and are thoroughly and extensively tested. Crews undergoing training for sonar and periscope approaches and attacks before the war thoroughly tested the Mark XIV torpedo with frequent, though not live, fire testing.⁴⁸ The Mark VI was live tested exactly once in 1928.⁴⁹ But there was never a live-fire test of either wartime setting, even simulated. Not only was the MK XIV/VI a high-risk system with a high risk of failure, the combined system was not tested live in combat conditions. This, alone, could have ensured failure for the torpedo and magnetic exploder.

Corrective Systems for the MK XIV/VI

This chapter has described the construction parameters concerning the MK XIV/VI. The U.S. Naval Command, BuOrd and Newport should have instituted a plan to handle the failures that were bound to happen. As mentioned, a testing program would have warded off many failures, but economics prohibited this. A failure backup program would have required two components, without which there was no reason to contemplate such a program. The first was the understanding that the weapon could fail. This was

⁴⁷ War Reports of the USS *Trout* (SS-202) NPPSO Reel Number H-108, Roll AR-12, Record Group 80. Keyport, 1-23.

⁴⁸ Newpower, *Iron Men*, 60. Newpower related that he obtained this information from a former crewman of the USS *Sargo*, Cornelius W. Bartholomew.

⁴⁹ Buford Rowland and William B. Boyd, *US Navy Bureau of Ordnance in World War II*, Chapter 6, Torpedoes (Washington DC: Bureau of Ordnance, Department of Navy, 1953), 95-100.

lacking. The second was the capability of admitting that failures did occur. This was something that Naval Command, the Bureau of Ordnance and Newport Torpedo Station did not have.

The United States Bureau of Ordnance, as well as the torpedomen and officers on the boats, had time to deduce what the problem was. Because of issues already discussed it took until October, 1943, to remedy the problems.

The Mark XVIII electric torpedo came into the Pacific about the same time that the MK XIV/VI issues were resolved. This took a lot of pressure off the torpedo shortage. Almost every Mark XVIII torpedo had been tested in a live-fire setting. Since the magnetic/contact issue had been resolved in the Navy and BuOrd's minds, and the Mark XVIII used the same contact exploder as the Mark VI, they did not deem live testing to be necessary. If BuOrd had set up a system to live-fire torpedoes after failures were reported, they probably could have found the problems within the first few months of the war. Alas, the torpedo shortage and the faith in the MK XIV/VI torpedo precluded that.

There was as much risk associated with a twenty-one-foot torpedo as with the boat that carried it. Torpedoes did not need to be in the sea to explode. They could explode while on board a submarine or sitting on the dock. And since a Mark XIV could blow a Japanese destroyer in two it would have no problem blowing a *Gato* class submarine to pieces, especially if it detonated in a torpedo tube and sympathetically detonated the rest of the torpedoes in that torpedo room.

Fifty-two U.S. Navy submarines sank during the war. The problem with the sinking of a submarine was that a distress call could not go out explaining the situation.

After the war, JANAC records matched some of the sinkings with probable causes. In the case of the USS *Wahoo*, after-war records list a Japanese airplane bombing a submarine in the area where the *Wahoo* supposedly went down.⁵⁰ In situations such as the sinking of the *Tang*, survivors could tell the world the reasons behind the sinking of the boat. In the *Tang*'s case, it was a new Mark XVIII electric torpedo circling around and hitting the *Tang* in the after half of the boat.⁵¹ Not only were most sinkings unexplained but the submarines' final resting places remain unknown.

Some of these submarines could have been lost from systems failures just like the *Squalus*. Others could have been lost from torpedo explosions on board. Robert Gannon found in his research a little-known problem with Torpex. As previously mentioned, Torpex replaced TNT in warheads as it created larger explosions. Not long after Torpex was introduced, a mysterious explosion leveled a section of a storage building at the Naval Mine Depot at Alameda, California. Shortly after this, another explosion occurred at a storage facility at Hawthorn, Nevada. Another explosion leveled a cooling warehouse at the Naval Mine Depot in Yorktown, Virginia. Of course, investigating officers blamed the operators, claiming that the problem lay with careless handling of Torpex-loaded munitions. But then a BuOrd officer. Lt. Commander William Freeman, who oversaw BuOrd's torpedo-maintenance desk, received a call from a maintenance clerk at one of

⁵⁰ "Navy Says Wreck Found Off Japan is Legendary Sub USS *Wahoo*." *America's Navy*, http://www.navy.mil/submit/display.asp?story_id=26378, Accessed July 8, 2015. The *Wahoo* was found in the Soya (Le Perouse) Strait between Hokkaido and Sakhalin Islands in 2006. And aerial bomb had hit it in the middle of the conning tower.

⁵¹ "USS *Tang*," *Subsowespac*, http://www.subsowespac.org/world_war_ii_submarines/uss_tang_ss_306.shtml, Accessed October 12, 2016.

the mine depots. The clerk had been told to call by the officer in charge, who told him that sometimes when he removed the filler plug from a torpedo's warhead he would hear the "hiss" of escaping gas. Freeman reported to BuOrd research desk and they, at first, did not believe it. But they ran tests and found that the torpedo was developing hydrogen. All that was needed to set off a warhead was a spark. BuOrd experimented and found that adding additional beeswax to the Torpex cured the problem. Later, they found a petroleum additive that did the same trick. Freeman's superior was the heavily-experienced submarine captain Charles Triebel (USS *Snook*, SS-279). Triebel was convinced that some of the submarines that did not make it back to port were not casualties of the Japanese but of torpedo hydrogen explosions. The only question Freeman had was whether the hydrogen came from the Torpex or the submarine batteries.⁵²

Former Chicago bureau chief for Newsweek, novelist, and qualified World War II submariner, Harry Homewood, wrote of a torpedo incident in his book *Silent Sea*.⁵³ It is the story of a submarine running silent when a torpedo engine in an aft tube fired, running at full speed with the outer door closed. The torpedo was running hot inside the non-flooded tube, expelling hot steam in the closed, confined space with the propellers spinning at full speed. The temperature coming from the steam exhausts was hundreds of degrees Fahrenheit. The captain gave the senior chief torpedoman full reign to stop the torpedo's actions. The scream from the torpedo's screws and steam engine revealed the

⁵² Gannon, *Hellions*, 185.

⁵³ Homewood, *Silent Sea*, 81-84.

submarine's position to a Japanese tin can and the destroyer set up for more depth charging.

The chief and his torpedomen formulated a plan. They gathered a flexible cable and tied it into a loose figure eight. The chief opened the inner door of the tube and threw the cable at the torpedoes' propellers. Steam was billowing out as the cable grabbed the torpedo screws. The drive gears came to a screeching and grinding halt.

Because of the noise, the Japanese destroyer found the sub and began to depth charge them. A depth charge exploded over the top of the bow of the submarine, pushing it downward and making the boat slant at a sharp angle. The torpedo slid backward out of the tube. Fortunately, the crew had a reload skid in place. The torpedo slid onto the reload skid. Torpedo and skid rolled across the aft torpedo room crashing into the far bulkhead.

Suddenly, a twenty-four-inch diameter stream of water shot into the room from the torpedo tube. The outer door had somehow opened. The chief tried to close the inner door but the torpedo warhead blocked final closure. Being an experienced torpedoman, the chief realized that, although the torpedo was static as it sat in the tube, the rock-hard onrushing stream of water had spun the arming propeller from the warhead. The warhead was live.

The chief of the boat ordered that air pressure be blasted into the room from the maneuvering room, hoping that sufficient pressure inside the torpedo room would slow the stream of water. With muscle, the chief and a young ensign closed the inside torpedo door and dogged it down. They found the situation was worse than they thought. Not only did they have a live warhead, the warhead was split open. Sea water mixed with

Torpex created a sticky semi-liquid called exudate. Exudate was highly explosive. But the armed warhead was a bigger problem. If something were to hit the warhead with at least four pounds of impact it would detonate. Also, the warhead was set for magnetic explosion. With the inconsistencies of the Mark VI, no one knew what magnetic anomaly might set it off. The captain and torpedomen determined that they needed to remove the exploder mechanism. This they did. They stored the exploder and dropped the damaged warhead and torpedo body over the side, sinking them to the depth of the sea.

These examples show how highly technical, and more importantly, how risky a submarine and torpedo were. It also shows how prone a war ship like a submarine was to having unseen problems arise. There were many different things that could go wrong. Due to superior training, the U.S. Navy had the men who could solve problems on the go. A torpedo was a highly technical and dangerous system. They were fired, not to mention stored and moved about, inside a submarine, another highly technical system that was also a dangerous environment. There were many ways that these systems could fail because of interior or exterior influences. As with many other modern systems, designers could not have anticipated and prepared for all contingencies using their wildest imaginations. Yet, all high-risk systems, including the MK XIV/VI, must fail.

Torpedo Failure Response Program

The Navy could have set up a program to handle the certain-to-happen torpedo failures based on the system already in place for the submarines. The Navy knew the fleet submarines were going to have battle damage as well as normal, day-to-day component failures. To handle the normal, wear-and-tear failures the Navy had specialized training

for repair technicians. These technicians trained in New London and Portsmouth and then went directly to suppliers who manufactured special items like sonar or radar. The men learned how to repair all the electrical, optical, plumbing, hydraulic and diesel engine systems. Furthermore, the Navy had special ratings for particular crewmen. There were electrician's mates who were trained to work on the generators, switchboards, battery room, electrical motors and total grid systems inside the vessel. Machinist's mates worked propulsion equipment (diesel engines), auxiliary equipment (periscopes), steering machinery, hoisting, food, refrigeration, air conditioning or laundry equipment. On top of this were gunner's mates, sonarmen, radarmen and torpedomen.

All this training did not do any good unless these men could work on the boats in the Pacific. This was where the submarine tenders came in to play. Ships like the USS *Holland* (below) were commissioned U.S. Naval Ships that were sent into remote areas of a combat theater provide potable water, parts, fuel, food and repair of submarine equipment. Specialists supplied and refurbished submarines after combat cruises.

Photo # 80-G-63334 USS Holland with seven submarines alongside, off San Diego, 24 Dec. 1934

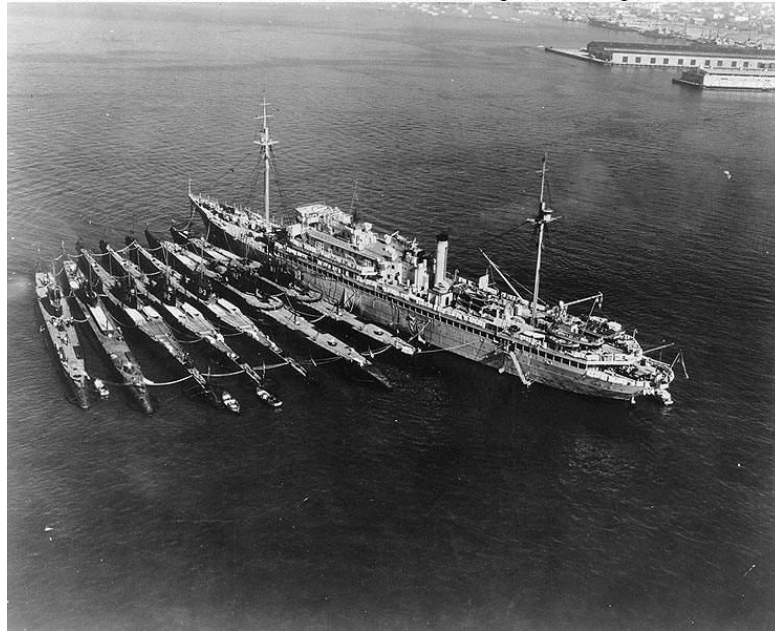


Figure 11. Submarine Tender

The repair specialists also worked on torpedoes. But because of the top-secret designation and tight security on the Mark VI magnetic exploder, no one had the ability or the technical manuals to work on them with any confidence. Periodically, torpedo specialists would come out and work with some crews. They were not exactly impressive. Captain Cassius D, Rhymes, XO of the USS Sargo recalled:

Another sidelight: When Sargo arrived Soerabaja (sp), Java from our first patrol the Bureau of Ordnance flew a LCDR Walker all the way out from Washington to investigate Sargo's torpedo problems. He put us through rigorous drills in preparing torpedoes for firing and in routine maintenance procedures. Near the end of our check list in getting one of the torpedoes ready, Walker interrupted the proceedings, made a couple of checks, then directed me to lock the gyro in place. I looked into the well and noted that he had turned the gyro backwards. (a MK14 gyro could be locked in a reverse position and result in an erratic run.) I turned the gyro to the correct alignment, locked it in place and told Walker that we preferred to attack enemy ships instead of our own, His face fell half a foot.

During his investigation Walker did not point out a single fault in our preparation and maintenance procedures. Nevertheless, Walker's

report, in summary, placed all the blame for Sargo torpedo problems on Sargo personnel. As a result, the Bureau of Ordnance reaffirmed their positions that MK14 torpedoes ran at their set depth.⁵⁴

Regardless, there was no set system to back up the Mark XIV/VI. Indeed, there was no thought given to them failing, which was bound to happen. Such was the unpreparedness of the U.S. Navy for war where the torpedoes were concerned.

Conclusion

This chapter has shown that the MK XIV/VI torpedo was a high-tech, high-risk armament. This torpedo was fired from another high-tech, high-risk piece of equipment, the fleet submarine. The systems were manufactured and operated by highly-trained men. The submarines these men sailed on were put through rigorous testing. Similarly, the torpedo should have undergone extensive testing before it was disbursed to the Fleet, and held to the same level of excellence as the fleet submarines. Even if the MK XIV/VI had been thoroughly tested, it was still bound to have failed and BuOrd, Newport Torpedo Station and the U.S. Navy should have had a program in place to handle these failures. Because there was no such program, the submarine crews and torpedomen in the Pacific used their own knowledge and methods to initiate their own solutions to the torpedo problems.

This chapter showed how relationships between men and machines were essential to the success or failure of these submarines in combat. It discussed how science was a

⁵⁴ Captain Cassius D. Rhymes Executive Officer, USS *Sargo*, Letter to Clay Blair, December 6, 1972, Blair Papers, Box,70 File 1.

large part of war and how crews developed their own field laboratories, with methodical experimentation on the submarines or submarine tenders. Most importantly, this chapter showed what high-risk technologies were and how the science concerning these applied to the undersea war in the Pacific. It answered the question as to why the torpedo failures happened, which was that torpedoes were high-risk systems and so failures were inevitable.

This chapter ends with a solution that the Navy could have implemented a program of testing, monitoring, maintaining and improving torpedoes that mirrored the system already in place for submarines. There first needed to be a complete live-fire testing program. This was not done. There should have been specialists sent to the Pacific that knew everything about the Mark VI magnetic exploder. Robert Gannon's book *Hellion's of the Deep's* concerns torpedoes but it also concerns "The Gathering" of graduate students of different sciences at Harvard University to work on undersea weapons. That included research into fluid dynamics, sound transmission in the ocean, explosives, torpedo statics and dynamics.⁵⁵ Young men like these could have researched the Earth's magnetism and how it interplayed with the Mark VI magnetic feature. This was not done. So, the failures continued. Chapter Five will answer why the failures continued for nearly two years before the underlying issues were addressed.

⁵⁵ Gannon, *Hellions*, 1-73.

CHAPTER FIVE

BLACK BOXES

The USS *Sculpin*

During early March 1942, Lieutenant Commander Lucius Chappell and the crew of the USS *Sculpin* were on their third war patrol north of Australia. Codebreakers at Pearl Harbor picked up a transmission that Japanese Carrier Division Five was to arrive on March 24, 1942 at the Japanese port at Kenadari on the island of Celebes. The *Sculpin* was radioed about the Task Force and arrived soon on his way. Two days later, on March 26, the six Japanese carriers, screened by two battleships got underway from the port. *Sculpin* missed the Task Force but on the way picked up a freighter and fired three torpedoes. They all ran hot, straight and true but none hit. During the next six days Chappell and crew encountered two more Japanese freighters, fired three torpedoes apiece and scored no hits.

All the shots that Chappell had taken were east set-ups and he had perfect firing solutions. Chappell was meticulous in his contact and fire control reports. Few submarine captains went to the length of drawing maps of each of his attacks. In his report dated April 27, 1942 Chappell concluded that a.) the torpedoes exploder mechanism failed to function properly, and b.) the torpedoes ran too deep.¹ As with all submarine war reports, this report eventually landed at the Chief of Naval Operations

¹ *War Reports of the USS Sculpin (SS-191)*, Third War Patrol Report, April 27, 1942, NPPSO Reel Number F-108, Roll AR-86, Record Group 79, 3-4.

office, which then sent it to BuOrd who forwarded it to the Newport Torpedo Station. Not one of these organizations felt that anything was wrong with the *Sculpin's* torpedoes. The failure rested on the shoulders of its crew. Command in both Washington DC and at Pearl Harbor were so invested in the success of the Mark XIV torpedo and the Mark VI magnetic exploder that it took over 18 months and the determination of the submarine crews in the Pacific in their testing to prove that the Mark XIV/VI was a faulty weapon.

Thesis and Organization

The question of why it took over a year and a half of torpedo failures during combat to solve the torpedo issue has resonated since the war. This chapter argues that that the actions that the Navy, BuOrd, and Newport took concerning the MK XIV/VI issue can be explained using current theories on the construction of scientific knowledge. Specifically, Bruno Latour's theories predict that in attempting to open black boxes, including the MK VI exploder and the depth mechanism of the MK XIV, critics of the torpedo brought about denial, opposition, and delays.

This chapter will show the cultural and professional differences between naval command and the men in the field. It will examine recent theories in the history of science and technology, beginning with the Strong Program, Latour's the Actor-Network Theory, Materialism, and the concept of black boxes. Included are primary reports from U.S. Naval Command, Bureau of Ordnance, and the U.S. Submarine Service in the Pacific. Applying Latour's theories to the Mark XIV/VI torpedo failures demonstrates how the type and degree of opposition and delay becomes completely predictable.

Command Structure

Naval command was far removed from the men in combat. Between the wars, Naval Command had been responsible for the design and building of materials of war, the best battleships, destroyers, aircraft carriers and submarines in the world. Though these ships were few during the first year of the war, these men took great pride in these war machines. Also, these officers were responsible for giving the American fighting sailor the best equipment, weapons and ammunition available to fight the enemy. A good part of their reputations and self-pride were centered on this. For example, if navy destroyers had a bad batch of five-inch shells it reflected poorly on command, the Washington Naval Yard and everyone in between.

The torpedo was the main armament of the U.S. submarine. This torpedo took years of design and development. If Naval Command said it was good enough to go to the fleet in the Pacific, then it was. Naval Command had developed a relationship with the Mark XIV/VI torpedo. In protecting the torpedo, they were protecting themselves and their fellow, senior officers.

Senior commanders had their social hierarchies, as did the submarine commanders; the enlisted men were on the bottom rung of the social scale. Enlisted men did not question anyone senior in rank. Because of this alone, alliances were formed. When the question of faulty torpedoes became an issue, the senior commanders not only had their reputations on the line they were being questioned by men who had no business questioning them about this or anything else. These groups of men worked within normal

military and professional alliances. When the torpedo issue presented itself, command's alliances grew stronger.

History of Science

Strong Programme

There were natural forces that influenced the failure of the MK XIV torpedo and MK VI magnetic exploder. For example, as previously discussed, the magnetic differences in different regions of the Earth influenced the settings of the pickup coil in the MK VI exploder. The Bernoulli effect's influence on the MK XIV depth setting components was another example. However, the MK XIV/VI torpedo's issues involved social factors in addition to natural law.

In the 1970s, a group of historians, sociologists, and philosophers of science sought to understand the organization and content of scientific knowledge in sociological terms. The Strong Programme helped examine the historical and sociological aspects of science.² There were four tenets to the Strong Programme: causality -- examining the conditions, such as cultural, social and psychological, that bring about claims towards a certain kind of knowledge; impartiality -- examining successful and unsuccessful claims of knowledge; symmetry -- the same types of explanations used for successful and unsuccessful claims of knowledge; and reflexivity -- in principle, its patterns of explanation would be applicable to sociology itself.

² David Bloor, *Knowledge and Social Imagery* (Chicago: University of Chicago Press, 1976, 1991), 5-18.

The history of science contains many examples of scientific theories being proven false. Sociologists explained failed theories by showing researchers' and scientists' influences such as blatant economic, prejudicial, or social biases. Successful scientific theories, on the other hand, were obviously true because they had revealed a fact of nature. The Strong Programme argued that both false and true theories should be seen and treated the same way. Both were caused by social factors and conditions whether they were driven by culture or personal self-interest. All knowledge that involved humans must have contained some social components in its development. This meant that beliefs were treated as objects and had causality. It was the job of the historian or sociologist to understand these reasons or causes. Since beliefs were objects, beliefs judging these beliefs as true or false, rational or irrational, were also objects. Rationality or irrationality itself became the object of study. The rationality and irrationality of the response to the torpedo issue needed to be studied, as it was part of the scientific equation. With the Strong Programme, sociologists, historians and scientists became concerned with how much of science and technology arose from personal and professional interests or other social influences.³

Materialism, Actor Network Theory and Black Boxes

There were many different people involved with the MK XIV torpedo and MK VI magnetic exploder. However, the submarine, MK XIV/VI components, inventions and completed weapons contributed to the story as much as the scientists who designed and

³ Sismondo, *Intro STS*, 47-56.

built them, and later the military technicians who used them. This ability of objects to impact history, to be active agents in change or to have agency, is called Materialism.

In the late 1980s, Open University sociology professor, John Law, École des Mines de Paris Professor of Sociology, Michel Callon and Sciences Po Paris sociologist of science, Bruno Latour, originated the Actor Network Theory (ANT).⁴ Out of these three, Bruno Latour made a name for himself as an influential theorist in the field of Science and Technology Studies (STS). He is known for such works as *We Have Never Been Modern*⁵ (1991), *Laboratory Life*⁶ (with Steve Woolgar, 1979), and *The Pasteurization of France*⁷ (1988). Arguably his biggest impact came in 1987 with *Science in Action*.⁸ *Science in Action* takes precedence in this chapter's discussion of the MK XIV/VI.

By viewing the undersea war in the Pacific through the lens of actor network theory, materialism, and black boxes, we can see how the development of the MK XIV torpedo and MK VI magnetic exploder was scientific knowledge in the process of being constructed. The controversy should not be viewed solely through the lens of the participating people. It also included non-human actors, in this case the torpedo and the submarine. The resolution of the torpedo and exploder problems were scientific

⁴ Sismondo, *Intro STS*, 81. This page included the concise definition of Actor-Network-Theory.

⁵ Bruno Latour, *We Have Never Been Modern*. Translated by Catherine Porter (Cambridge: Harvard University Press, 1991)

⁶ Bruno Latour and Steve Woolgar, *Laboratory Life: The Construction of Scientific Facts* (Princeton, Princeton, 1979)

⁷ Bruno Latour, *The Pasteurization of France*. Translated by Alan Sheridan and John Law (Cambridge and London: Harvard University Press, 1988)

⁸ Latour, *Action*. The following information concerning Latour's theories come from this volume except where stated.

knowledge in the process of being further constructed, or reconstructed, under very difficult wartime circumstances.

Networks

The best way to explain materialism and the actor network theory is to tie them to the MK VI magnetic exploder. ANT sees what Latour terms “technoscience” as the creation of larger and stronger networks.⁹ Imagine a navy admiral who was vying for a promotion to the Joint Chiefs of Staff. This admiral assembled alliances with senior officers, congressmen and senators, perhaps the President of the United States. These alliances allowed the admiral to build and then maintain power. Scientists and engineers did the same. However, the actors of ANT were all mixed together in a heterogeneous way. In the matter of the MK XIV/VI, the network included the naval commanders, submarine commanders, enlisted seamen, BuOrd scientists and sometimes engineers, but the actors were not just human. The network included both human and non-human entities. Using the ANT methodology, these entities had no significant distinction between them. Both humans and non-humans formed associations linking with other actors forming networks. These actors are called actants.¹⁰ These actants had interests that caused them to act, interests that need to be accommodated and that could be managed and used.

For example, in 1922, Project 63 was formed within BuOrd for a magnetic exploder. The Newport scientists, engineers, technicians, Lieutenant Ralph Christie and

⁹ Latour, *Action*, 175-175. This page contains Latour’s definition of technoscience.

¹⁰ Latour, *Action*, 84.

the magnetic exploder itself were all actants in a network and they all were involved in alliances.¹¹ What made this story fascinating was that as the depth issue, magnetic exploder issue and then finally, the contact exploder issues continued, alliances changed, black boxes had to be opened, and networks reformed.

When the order for a magnetic exploder came from BuOrd, Ralph Christie was a young lieutenant who attended graduate school at the Massachusetts Institute of Technology (MIT) and left the university with a Masters in Electrical Engineering. In the late 1920s, Christie and the Newport Torpedo Station personnel put years into the design and production of the magnetic exploder. As the design process went on, the people created design drawings, descriptions and written information that explained their invention. In Latour's lexicon, these are referred to as inscriptions.¹² These inscriptions backed up the reason this invention was needed, how it worked, and why it was the best alternative for the job it had to do. Inscriptions can go both ways, though. If an invention is questioned, those who are questioning it will have inscriptions of their own to support their viewpoint. The point of inscriptions is that they can be a powerful ally when the time comes.

These men had time, effort, and reputations invested in the success of the exploder. As time went on, Christie went back to sea and gained in rank. BuOrd decided to replace the aging MK X torpedo. In 1931, Christie returned for a second tour of duty and found himself involved in the development of the MK XIV torpedo. By 1938,

¹¹ Newpower, *Iron Men*, 27.

¹² Latour, *Action*, 218.

Christie had graduated to the head of the torpedo section at BuOrd. He thus saw the final development of both the MK XIV and MK VI as they were deployed to the fleet. His investiture in the total torpedo package for the World War II submarines was complete. Again, Christie formed various networks and indeed networked and formed relationships with the MK XIV torpedo and MK VI magnetic exploder. Top engineers had designed and top craftsmen had built the torpedo and exploder, so that by the time the United States went to war, the U.S. Navy and BuOrd felt that there was no reason to question the performance of any of them.

Black Boxes

As mentioned in Chapter One, a black box was a scientific metaphor denoting a component, device, system, theory, or object that was valued by the simplicity and infallibility of the output gained by the information that went into it (input). There was no thought given to the internal processes of the black box.¹³ The inner working was taken for granted. Information went into it and information came out of it. No one knew how this worked and no one cared.



Figure 12. Black Box

¹³ Latour, *Action*, 2. This page contains Latour's definition of a Black Box.

In the case of a component or invention, years went into the theorizing, construction, and working out the bugs of the black box. During the time that the black box was being built, there was a lot of uncertainty as to whether it would work. Yet, once the black box was finished, there was no need to open it to see how it was constructed.

As an example of a Latour black box, one could look at a laptop computer's central processing unit, or CPU, as an example. The CPU took years to develop, millions of dollars went into inventing and perfecting it and it was highly technical. The only characteristic of concern was that if a person inputs certain data, the person expected to get certain data in return. No one cared how long the CPU took to be invented, how much stress, heartache, sleeplessness, controversy, grant money or infighting the developers might have endured in its development. Again, the only thing that mattered was that it worked. Indeed, the fact that it worked was taken for granted, resulting in an aura of infallibility.

Yet there is always a history behind every component or scientific theory that has been black boxed. Latour opens *Science in Action* with a discussion that includes Watson and Crick's development of DNA strand theory.¹⁴ The battles, stress, doubts, competition with Linus Pauling, interworking of different scientists, scientific supervisors, other departmental individuals, and happenstance of the right people being in the right place to assist was a fascinating look at the early days of the development of a theory that is now black boxed. Today, society takes for granted the use of DNA in science, health, child

¹⁴ Latour, *Action*, 1-17.

paternity, and law enforcement. Today, the DNA helix just is and no one is concerned about its history. It has been black boxed.

MK XIV Torpedo Depth Control as a Black Box

As has been shown, the MK XIV torpedo was filled with black boxes. The air flask, fuel system, main engine system, gyroscopes, and depth control system were all black boxed systems. The MK VI magnetic exploder was an important black box, as was the contact exploder contained within this assembly. This chapter is concerned mainly with the exploders and the depth control system as black boxes. To see the complex nature of the MK XIV depth control system and MK VI exploder, it is necessary to compare them to their original designs. Designers did not consider the depth control on a torpedo important at first. Remember that an automobile torpedo was nothing more than a mine that could travel under its own power, and because a ship rode on the surface of the sea, depth did not appear to be an issue. The thinking was to just fire a torpedo at a ship, the torpedo cruised on top of or just under the surface of the water and ran into the ship's hull, triggering the warhead's exploder and then the warhead.¹⁵

When the dynamics of ship sinking became more of a science, it became clear that a torpedo that ran deeper would be of benefit. The hull of a warship could extend feet or yards under the water. In the case of a capital ship, depending on how heavily it is loaded, the hull could rest up to ten yards under the surface. Again, a torpedo exploding

¹⁵ Gannon, *Hellions*, 16. As had been shown the early spar torpedo sinkings concerned ships that were at anchor. It appears that the first automobile torpedoes were meant to complete the same mission while shooting from shore. Only later was thought given to firing a torpedo from a moving vessel.

at the base of a ship's hull, well under the surface of the sea, could make the difference of a ship going down with one torpedo vs. six, or not at all. Because of this, a depth setting became important for contact hits. The depth setting became crucial when the magnetic exploder came into being. The depth control could exist without the magnetic exploder. However, the magnetic exploder could not exist without the depth control. When the torpedoes began to malfunction, all the focus went into attempting to figure out the exploder. Little thought went into the depth control. This was the motivation for the reconstruction of the science behind the system: to correct the problems with depth control and torpedo exploders.

Science is prodded onward by many different motivations. Some of these motivations include personal desire to do something for humanity, curiosity, interest, enchantment with design, desire for fame, the challenge of problem solving, war, ego, personal advancement, national advancement, desire for riches and plain old altruism.

Ironically, the first depth control mechanism was invented by a man who abhorred war, Robert Whitehead. As mentioned, Whitehead met and visited with a retired officer of the Austrian Navy who had built a model of a small craft able to explode at a target location. The officer, Giovanni de Luppis, had built the small working model from papers of an officer of the Austrian Marine Artillery. Luppis and Whitehead combined ideas and built a full-size, working model but could not overcome mechanical difficulties so they eventually gave up. Yet, Whitehead could not get the idea out of his mind and felt that if he could build a weapon so appalling it could help preserve the peace. He was not

the first man with that false assumption nor would he be the last.¹⁶ Whitehead found that his dreams of peace hinged on a dependable weapon. In the early days, Whitehead's torpedoes could not hold depth. Some would skim on top of the water. Others would dive down to the depths, burying themselves in silt. Creating a working depth control system included design and experimentation. Like any other inventor, Whitehead wanted to prove that he could produce a working weapon just for the sake of inventing it. However, dependable designs arose from a different motivator: the desire to possess the best weaponry in a current war or have it ready for the next war.

It took two years and a lot of experimentation to develop the first depth control. Unfortunately, Whitehead kept no records. The first depth control came from a simple elastic hydrostatic disc that flexed in with higher water pressure and out with lower water pressure. The disc was connected to levers controlling the elevator fins that would control depth if the torpedo was moving forward. This original torpedo depth control mechanism design contributed to the depth component that future torpedoes used.¹⁷

MK VI Magnetic Influence Exploder as a Black Box

The history of the exploders for U.S. Navy torpedoes was simple. A torpedo was fired from a vessel, ran under its own power and then, once the torpedo contacted the hull of the vessel, it was supposed to explode. The first exploders ran parallel to the body of the torpedo, meaning that the firing pin pointed towards the head of the weapon. These exploders had a hammer and anvil design. The inertia of contact made a pin hit a cap.

¹⁶ Gannon, *Hellions*, 23.

¹⁷ Gannon, *Hellions*, 25-26.

With enough explosive in the warhead, it could sink an aircraft carrier.¹⁸ The issue with firing that size of warhead was that it required a larger torpedo. The early U.S. submarines could handle only small torpedoes.

Warheads did not explode on their own but, like a bullet, needed an exploder to explode on contact. A bullet would not fire unless there was an exploding mechanism to ignite the powder contained within the shell or cartridge body. The hammer of the gun struck the cap in the cartridge and the cap exploded igniting the powder. The same idea applied to the exploder on a torpedo. As a closer example, a 155 Howitzer shell needed an exploder for the shell to explode. The exploder was screwed into the nose of the shell. This insured the shell would not detonate in transit or any other time the artillerymen did not want it to explode. The exploder on the 155 shell, the fuse, was a simple contact exploder like the MK III discussed below. As with the 155 Howitzer artillery shell, care was taken so a torpedo would not explode in transport or storage.¹⁹ Another large concern for a torpedo was that detonating within twenty yards of a torpedo tube could tear the bow from a fleet submarine. There was a lot of commotion and bouncing around after firing a torpedo, causing the fear that jostling, unseen debris, or solid bodies might contact a torpedo head a few feet from a submarine and an explosion might result.

¹⁸ Battleship USS North Carolina, <http://www.battleshipnc.com/about-the-ship/history/torpedo-strikes/>. accessed January 2, 2017. The MK 93 Japanese Long Lance torpedo held almost 1,100 pounds of explosives in the warhead. The torpedo that hit the *North Carolina* during the Battle of Savo Island blew a hole so big into the port side of the ship that two semi-trucks, one sitting on top of the other could literally be driven through the void with room to spare. Because of superior damage control and sealing off the ship's bulkheads the North Carolina was able to be sail back to Pearl Harbor and then to Bremerton, Washington for repairs.

¹⁹ Westwell, *The Illustrated History of the Weapons of World War One*, 46.

A main priority was to keep a torpedo from exploding accidentally or prematurely. Torpedoes had a safety arming system that usually involved an arming impeller spinning off the contact exploder a set distance from the tube. Once the impeller had spun off, the firing pin was armed. The firing pin stuck out from the warhead, restrained by a transverse shear pin. If the firing pin should hit with sufficient force it would shear the shear pin allowing the firing pin to come all the way back and hit the percussion cap. This exploder sat inside the nose of the warhead with the fulminated percussion cap open to the warhead's TNT. These systems were used for years and, though rudimentary, were simple black boxes in and of themselves.

The U.S. Submarine Service had relied on the MK X torpedo equipped with the MK III contact exploder since World War I. The MK X/III was the staple of the submarine service between wars. Because of the new enemy ship sinking theories, the MK VI magnetic exploder work began with Project G-63 in 1922. Work on the MK XIV torpedo body began in 1931. The new Fleet submarines carried the MK XIV/VI going into the war. This top-secret weapon was touted by the BuOrd and Naval Command as revolutionary and dependable. So destructive was this weapon, they claimed, it would only take one torpedo to sink one ship.

Production Science

The torpedoes that the men in the Pacific used were manufactured with such care and to such tight specifications that there was no way to produce them quickly, in the huge quantities the Navy required a year and a half into the war. As the war progressed,

production went up and by mid-1943 the MK XVIII electric torpedoes manufactured by Westinghouse were coming off the line.²⁰ This helped to alleviate this pressure.

Thus, for the first year and a half of the war, there was a torpedo shortage. Clay Blair points out:

There were only 101 reserve torpedoes left in Pearl Harbor. According to the prewar production schedules, he (Admiral Withers) was to receive 192 more by July-about 36 a month. However, his quota had recently been cut to 24 a month. At the rate his boats were expending torpedoes, he would need more than 500 to reach July. There was no way the production rate could be drastically increased to meet this demand. Unless his skippers were more conservation, Pearl Harbor would soon run out of torpedoes.²¹

Losing 233 torpedoes in the Philippines to the Japanese onslaught made the situation grave. The MK XIV/VI had been advertised as a one torpedo, one ship weapon. With the torpedo shortage Command *needed* them to meet that standard so badly they went into denial about torpedo failures. The fact that the MK XIV/VI did work, periodically, complicated the situation.

Several submarine captains received reprimands for using more than two torpedoes per target. After Pearl Harbor, as submarines came back from their first sorties into Japanese-controlled waters, they found that the torpedo supply issue was severe. After the attack on Pearl Harbor, on January 4, Joe Grenfell in the Gudgeon had fired two torpedoes at a small freighter. On January 9, Grenfell fired three torpedoes on a 5,000-ton freighter. His Commanding Officer, Admiral Withers, felt that this was excessive. "Until

²⁰ Official letter from Vice Admiral C.A. Lockwood to Vice Admiral R.A. Edwards, Headquarters of Commander in Chief, Navy Department, Washington D. C., Lockwood Papers, LOC, Box 72.

²¹ Blair, *Silent Victory*, 120.

the supply of torpedoes is augmented it is essential to conserve torpedoes for more appropriate targets.”²²

Production pressures can affect any industry. As mentioned, production pressures with high tech systems can lead to disaster. Author Charles Perrow looked at the high-tech, high-risk situation primarily from a manufacturing and operating perspective.²³ With the MK XIV/VI, the disaster did not affect the manufacturer. Newport went along happily producing torpedoes that did not work. The people affected most by the MK XIV/VI were the customers, Pacific Command, and the operators, the submarine crews. Demands for volume led to the manufacturer failing to slow production to check quality. The main problem was the expectation of the customer hoping and believing that, if they pressured the operators hard enough, the product would miraculously work. They became blind to the inherent problems of the MK XIV/VI.

This blindness was cultural and has a sociological and scientific explanation. Columbia professor Diane Vaughn looked at this culture in her book *The Challenger Launch Decision: Risky Technology, Culture and Deviance at NASA*. Vaughn’s book made the argument that there was a sociological explanation for the *Challenger* disaster. Because of a failed booster O-ring, caused by launching in too cold a temperature, the booster and *Challenger* exploded seventy-three seconds after lift-off. Vaughn described a work group culture where deviance became a norm. A fear of funding scarcity, along with lack of competing production, resulted in the evolution of a culture where

²² Blair, *Silent Victory*, 122.

²³ Perrow, *Normal Accidents*, 18. Unless stated the following information concerning high-risk technologies comes from this volume.

production pressure became institutionalized. Vaughn showed how and why NASA managers, when repeatedly faced with evidence that something was wrong, normalized the deviance until it became acceptable to them.²⁴

There were parallels to the torpedo situation. There was a fear of shortage, not only of funding, coming out of the Great Depression, but of the torpedoes themselves, as they could not be produced quickly enough. There was also a scarcity of competition. The only group producing MK XIV/VI torpedoes was Newport Torpedo Center, a civilian supplier. The Navy was dependent on whatever Newport could get them. These factors led to a culture within the Navy that could accept a situation that, under different circumstances, would be totally unacceptable. Very little Japanese shipping was sunk in the first months of the war. Taking only one shot per ship contributed to this, as did the unreliability of the MK XIV/VI. Keeping the production question in mind, there were two solutions to sinking more Japanese ships. The first was firing more torpedoes at targets. This was proven effective later in the war. The second was to fall back and use the MK X/III torpedo more. These were steam driven like the MK XIV and used a contact exploder. Although smaller, the MK X had shown their reliability earlier in the war. The MK X/III had been designed for the old S-boats but could be used on the Fleet boats with some adaptation. Several older S-boats were used in the first stages of the war and then retired for training purposes. Their armaments could have been used and it might have made a difference.²⁵

²⁴ Vaughn, *Challenger Launch*, Kindle Edition, LOC 1771-1867.

²⁵ S-11 (SS-116) Ships Histories, Vol, V, 1976, NPPSO Reel Number G-108, Roll AR-45, Record Group 80, 1-3. Keyport.

Opening a Black Box

The submarine commanders went into World War II, on December 8, 1942, with confidence. This confidence was short lived as the first thirty-nine MK XIV/VI torpedoes shot failed to inflict any damage on the enemy.²⁶ There were significant defects with the black boxes inside of the MK XIV/VI. Although there were other types of failures, like leaky air flasks or flooding, the main causes of failure were the depth setting system and the magnetic exploder, black boxes in every sense.

Although a lot of work, money, blood, sweat and tears went into building the torpedo's black boxes, the submariners in the Pacific during the war found that it was even more difficult opening them up for examination. These men of the silent service found that they were going to have to commit to a new battlefield: technoscience.

The Technoscience Battlefield

Latour looked at the development of technoscience as a battlefield from which only the strong walk away.²⁷ Yet instead of actual war, which was a means to an end and was rarely considered worth the cost, science and technology were productive. They produced facts and machines. This was a war within the scientific community but also within a heavily structured military community. Often, in a scientific community, scientists of all ages would gather, discuss and combine ideas. This did not happen in a top secret military situation. For example, during World War II, the Alamogordo security

²⁶ See Graph in Dissertation Conclusion.

²⁷ Latour, *Action*, 175-175.

detail had a difficult time keeping the civilian scientists from all sitting around a large table in the mess area “kicking around ideas” about an implosion detonator versus a gun detonator for the atomic bomb.²⁸ This would never happen with a top-secret project in a military community. The military community was very structured by rank, a caste system. A vice admiral would not socialize with a lieutenant JG and ensign, lightly discussing the design flaws of a torpedo or anything else for that matter.

Statements and Facts

If a scientist made a statement, the fact of the statement was not determined by right and wrong in Latour’s world, but by how much support it had and from whom. Fact-making was a collective business. Statements could only become facts if they were noticed and used without modification by others. “The fact of a statement depends on later statements.”²⁹ In this instance, the statement was that the torpedo worked as advertised, one torpedo one ship sunk. The collective senior officers in Washington and Newport believed this, so to them that was fact and the end of story. However, there were younger officers in the Pacific who were beginning to question the statement. This was one of the issues that led to opening the black boxes.

The statement of fact by the collective senior officers in Washington DC and the first commanders in the Pacific was backed by science. As mentioned, the original magnetic torpedo project G-63 began in 1922 and continued into the 1930s. Ralph Christie received his Master’s at MIT in mechanical engineering and eventually joined

²⁸ Ray Monk, *Inside the Centre: The Life of J. Robert Oppenheimer* (London: Vintage, 2012), 338- 389.

²⁹ Latour, *Action*, 27.

the program, becoming one of the main architects of the magnetic exploder. Designing a device that was self-powered, could read the Earth's magnetic signature, and then trip when passing underneath a ship was unprecedented.

In 1928, work began on the MK XIV torpedo body. Thousands of man-hours went into the design, bench testing, fitting of components, testing of fuel, air and exhaust systems, development and manufacturing of gyroscopic components, depth control components as well as propeller design. Although the magnetic exploder was not properly tested, the MK XIV body underwent testing with pneumatic practice warheads hundreds of times. Because of the time, money, scientific and technological design that went into this weapon, Naval Command, BuOrd, and Newport were highly invested in the science behind and production of the MK XIV/VI. This weapon looked good on paper. Command had faith in it in their minds. There was no reason it should not work as advertised in the field.

After a year and a half, report after report of torpedo failures came in. BuOrd responded with their own numbers. On August 11, 1943 Blandy wrote Lockwood:

You still make me just a little weary when you say, "If we can get certain things quickly, such as dependable torpedoes, etc.," I will admit that they are not perfect, but they are a damn sight closer to perfection than some of the work your people do with them. Here are *some*³⁰ data taken from your own reports:

Total torpedoes fired by Subpac since beginning of war up to June 30, 1943.

	Number: 1811/ Percentage: 100%
Total number hits:	Number: 633/ Percentage: 35%
Total number of misses, including failures	Number 1178/ Percentage: 65%

³⁰ Author's italics.

Total number of dud's prematures, erratics, (sp) and magnetic failures, including some "Uncertain" and some "very certain" failures as follows: Number: 124/ Percentage: 7%

Duds 10 .5%

Premature 52 2.8%

Erratics (sp) 36 1.9%

Magnetic Failure 25 1.4%

Certain failure only Number 75/ Percentage 4.4%

Total number of torpedoes which ran hot, straight and otherwise normal, (Except for deep running in early months of war) Number 1687/ Percentage 93% (95.6% including uncertain failures)

From the above table it may be seen that excluding "uncertain" and "very uncertain" torpedo failures, torpedoes fired by Subpac submarines the performance is 93.1%. It also shows that of the total 1178 torpedoes which either missed the target or otherwise failed to produce effective hits, 1054 or 89% of these were due to control errors or to the use of spreads, in which some misses are deliberately accepted, and only 124 or 11% of the total misses, were due to torpedo failures, even including the "*Uncertain*" cases.

While the Bureau of Ordnance is in no way complacent about torpedo quality and intends to keep plugging until the percentage of failures is reduced to zero we do derive some consolation from the fact that the torpedoes themselves are apparently responsible for only 11% of the failures to hit or hit effectively.³¹

This is Admiral Blandy's statement of fact. He is protecting his organization, his reputation, and the reputation of the weapon they have produced for the U.S. Submarine Service.³²

³¹ Author's italics.

³² Navy Department Bureau of Ordnance letter from Admiral William H.P. Blandy to Rear Admiral C.A. Lockwood, August 11, 1943. Lockwood Papers, LOC, Box 72. This letter was sent after the decision to deactivate the Magnetic Exploder but it is a good example of a statement of fact.

Conflicting Statements from the Pacific

There are scores of examples of torpedo failures in the individual submarine war patrol files from the National Archives. Perhaps the most heartbreaking episode of torpedo failure occurred on the USS *Sargo* under the command of Lieutenant Commander Tyrell D. Jacobs. Jacobs was an academy graduate, class of 1927.³³ He earned a Master's degree in Ordnance Engineering and was known as one of the torpedo experts.³⁴ Jacobs was known as a sailor's skipper. The men felt that he was approachable, competent, a professional.³⁵ The *Sargo* was among the first boats that fired upon the Japanese after December 7th. As has been shown, the *Sargo* had torpedo failure after torpedo failure.

Submarine captains handled any success or failure on their boats in any way they chose. A commander could run a failed attack through his mind. Some ran the attack past their executive officer. Jacobs sat his officers down in the wardroom and they dissected each attack. Jacobs and officers considered two potential causes of torpedo failure: the magnetic exploder was defective or the Japanese had developed a countermeasure to the magnetic exploder. This showed that these men included all possible causes of failure, no matter how implausible. No one believed that the Japanese could possess a

³³ Pacific Submarine War Historian Clay Blair and MK XIV Torpedo Historian Anthony Newpower have both devoted a few pages about Jacobs. Because of his expertise as an ordnance, torpedo expert and his ability to set his submarine up for almost perfect shots in his engagements with the Japanese merchant and combat fleet he is used here. This is also the first report concerning defective torpedoes in my research.

³⁴ Naval History Division, Captain Tyrell D. Jacob, Navy Biographies, 01-450 15 November 1955, Blair Papers, Box 68, File 3, 1.

³⁵ Newpower. *Iron Men*, 61. Newpower corresponded with Cornelius W. Bartholomew in 2004. Bartholomew was a Gunner's Mate on the USS *Sargo* and served under Jacobs.

countermeasure to an unknown, top-secret weapon this early into the war, so Jacobs and crew settled on the exploder being defective.

After more failed attacks, Jacobs ordered the magnetic influenced exploder deactivated. Jacobs became the first submarine skipper in the war to do this. Many were to follow. Jacobs radioed his commanders Admirals Hart and Wilkes. They ordered the *Sargo* home.

Jacobs's patrol reports are complete and detailed. Jacobs shows that he is looking for any other causation than torpedo failure and is methodical in checking the TDC, periscopes and gyro angles for problems. In his report in the section *Major Defects and Casualties* Jacobs writes:

The Commanding officer is of the opinion that the MK XIV Mod.1 torpedoes are faulty in two respects. First that the influence exploder mechanism cannot be relied on to function as designed, second that the depth is not being obtained within 2000 yards. That set depth is not being obtained in 2000 yards is clearly borne out by the attacks conducted under ideal conditions with depth settings of ten feet, which resulted in not only misses, but failure of the ships fired upon to sight the wakes of the torpedo. In more than one instance, ships fired upon in daylight gave no indication of sighting the wakes of the two torpedoes fired across their course.

In every instance of the firing of thirteen torpedoes, the inertia starters were tripped by hand through the hand hole plate, prior to loading the torpedoes into the tubes. The removal of the pawl, which is the mechanical linkage between the influence mechanism armature and the firing ring, inactivated only the magnetic feature of the exploder mechanism. It is submitted that this change could not have affected the functioning of the mechanical feature of the exploder mechanism.

In these sentences Jacobs showed his knowledge of torpedoes and that he had made a methodical check to make sure that, even though his magnetic feature was turned off, it would not affect the contact exploder mechanism. Still, after eight attacks and firing a total of thirteen torpedoes the *Sargo* made no hits on its intended targets. Thus,

less than a month into the war, Asiatic Command had evidence of problems with the MK XIV and particularly the MK VI magnetic influence exploder. This report would soon find its way to Pearl Harbor and then to BuOrd and Newport. Jacobs had the expertise and knowledge to flesh out the situation with the torpedo failures. If there was anyone Command should have listened to it was Tyrell D. Jacobs. But Jacobs was talking about opening black boxes. Not only was that not going to happen, the powers he was opposing were going to retaliate, per Latour's theories.

Admirals Hart and Wilkes were unhappy about Jacobs's opinion. They were less happy that he deactivated the magnetic feature on his exploders after his first failures. Hardly disguising their disapproval, they assigned the *Sargo* to transport duty. Their next mission was to deliver a load of ammunition to U.S. Army Forces on Mindanao and to retrieve twenty-four enlisted ground crew from the Army Air Force's 14th Bombardment Squadron. Although vital to the MacArthur's war effort in the Philippines, Jacobs and the *Sargo* were top-of-the-line commander and crew, needed to sink enemy ships. Jacobs resigned after this mission.

In a 1972 letter to author Clay Blair, Jacobs related:

I asked to be relieved of command for two reasons, First I felt very badly for having had such splendid opportunities to sink Japanese ships, only to have my torpedoes run 8-10 feet deeper than set. Also the torpedo was very apt to premature, the first torpedo I fired prematured about halfway to the target, I had a beautiful set-up not over 800-1000 yards from the target, good track angle and I believe if I had had a good torpedo, I would have been the first to torpedo a ship (Japanese) in WWII. After this experience I deactivated my remaining torpedoes, but they were still running deep, as I stated in a dispatch sent while on patrol (1st) in spite of radio silence restrictions. The second reason- I was sent on my next patrol on a deliver 1 million rounds small caliber ammo to Mindanao. Rightfully or wrongly I felt this reflected a distrust in my abilities as a sub C.O. and a lack of

“Confidence” in me by the higher Command. So I asked to be relieved- Now I know it was a big mistake, for it shoved me out of the sub service forever more.³⁶

Latour, in speaking of literature, talks of the stresses that go back and forth. There is stress on the people making contradictory statements as well as those who attempt to hold the party line, if only for self-preservation. Within this interaction, fraud, or falsifying data, could occur.³⁷

Jacobs explained:

Also, I believe some C.O.’s reported hits and sinkings which were not exactly the fact. The high Command knew these erroneous reports were not true since they received information from breaking the Jap code. For Instance, in discussing my 1st patrol report with Commander (Sunshine) Murray, I reported an attack off Indo-China. He said “what was the Lat & Long of the attack”, I gave him my position-he said “your Lat is correct, but your Long is off 1 ½ miles.” Either Murray was telling Tyrell that he knew his absolute position of the attack and Tyrell’s measurements were wrong or he was adjusting Tyrell’s position to meet his needs.³⁸

Either way, Jacobs knew about the falsifying of enemy contact data because his next position was to join the staff of Commander Submarines Southwest Pacific as staff secretary. Here he read report after report, mixed with crews and commanders and was exposed to Japanese intelligence and codes. This had to be an unsatisfying position for a true sea captain and ordnance man like Jacobs.

Latour explained that if someone went against a statement and persisted in his resistance, the debate became more technical and social. It became more technical in to

³⁶ Letter from Jacobs to Blair, February 7, 1972, Blair Papers, Box 68, File 3.

³⁷ Latour, *Action*, 49.

³⁸ Jacobs to Blair, Blair Papers, 68/3.

confuse doubters.³⁹ One tactic was when the establishment showed the doubter that, by calling one premise into doubt, he was also calling into doubt many associated claims that had general acceptance. When the first reports came in about the torpedoes failing, the sub commanders thought they would be credible because they were the commanders on the boats, the experts on all things in undersea warfare. The original submarine commanders were in their late thirties and most ranked at lieutenant commander. Later in the war, submarine command went to younger men with longer service. The officers in their late thirties were full commanders. Some had obtained the rank of captain. Command was competitive, so the best men were awarded the top positions. Trained through the interwar years, they knew every bolt and valve in their boats.

These commanders also felt they could rely on the reputations they had built through years of service. More than that, these officers had built relationships within this very small community. They were known to everyone as honorable, hard-working, smart men. Granted, there was a buildup of military personnel in the United States after Hitler invaded Poland in 1939. By December of 1941, many American people expected a war, they just did not know when. Even with this buildup, there were only 35,760 officers in the U.S. Navy in December 1941 and only an elite two percent of the men in the navy served as submariners.⁴⁰ Almost every sub commander at the outset of the war was educated at the U.S. Naval Academy. This was a small professional organization where

³⁹ Latour, *Action*, 74-79, 123.

⁴⁰ "U.S. Naval Personnel in World War II," *National Archives*, accessed December 12, 2016, <https://www.history.navy.mil/research/library/online-reading-room/title-list-alphabetically/u/us-navy-personnel-in-world-war-ii-service-and-casualty-statistics.html>. A little over 3900 navy officers served during the war.

everyone knew one another or at least each other's reputation.⁴¹ Commanding a submarine at the outset of the war earned the respect of command and enlisted men. It took both hard work and intelligence to get to the top. Almost all commanders had engineering degrees. In fact, several, like Jacobs of the *Sargo*, had graduate degrees in engineering. Many of them have asked, both during and after the war, why no one listened to them. The answer: they were talking about opening a black box.

Latour continued his argument that the act of opening a black box made science become more social, because allies were mobilized and enemies were isolated. This occurred at the outset of a scientific finding and was present when someone desired to open a black box. When the reports of torpedo failures came in, each side formed and mobilized alliances. The minute the reports of torpedo failures arrived at BuOrd, conflicts arose. Latour was speaking about the fact that science is not black and white, right and wrong. It is a social construct.

Social Constructs in a Military Setting

Going into the war, all submarine officers were convinced that the MK XIV/VI was a finely-tuned piece of scientific and technological hardware, a modern marvel. Years had gone into developing the exploder and other mechanisms. This was faith in a weapon with which they had no personal experience. Unfortunately for the men in the field, the powers that had originally developed the exploder and other components now had superior rank, more experience in the navy, much more developed and greater social

⁴¹ Tuohy, *Bravest Man*, 1-13.

networks. They were also still in the United States, closer to torpedo manufacturers and the overall command center for the war. For example, Rear Admiral, soon-to-become Vice Admiral, Lockwood answered to the Chief of Naval Operations Ernest J. King. But it was not just King who held power. Vice Admiral Blandy at BuOrd was in Washington as well. Blandy was a year junior to Lockwood but, because of his position within the Bureaucracy he headed, Blandy held more power than Lockwood when it came to resolving the torpedo issues. Lockwood, the supreme submarine commander at Pearl Harbor, along with his combat staff, was dependent on Blandy and his allies.

Almost all the lesser ranked and civilian “technical experts” were in the United States. Along with Blandy and his staff, they had reputations built around these weapons. They were sold on the science behind them and none of them was going to take a mid-level naval officer’s word that their designs and theories did not hold up in combat. These East Coast men were not ready to listen to men half a world away and they certainly were not going to listen to anything that would tarnish their scientific, technological, social or professional reputations.

Latour spoke of the literature surrounding the opinion being challenged, in this case the exploder or depth control system, becoming hard to read and analyze. This was done to occupy all the opposition’s time refuting scientific calculations, algebraic equations, chemical formulas and whatever else was available, and to build an impenetrable wall of uninterpretable information.⁴² The officers in the United States worked this analytical game in two directions. BuOrd threw facts and figures to the

⁴² Latour, *Action*, 30-45. “When controversies flare up the literature becomes technical.”

Pacific Command supporting their position. BuOrd interpreted these data in a manner that supported their position.⁴³ BuOrd also challenged the detailed facts and figures from the submariners' experiments, claiming that information obtained in wartime conditions, without laboratories in which to work, was unreliable.

The next response in Latour's model involved social circles supporting the original claim mobilizing against any person who was challenging the current science. Social circles in this instance meant job politics and cliques at work. A person endured job politics whether they were in politics, the U.S. Postal service or working on the back of a garbage truck. There were cliques within the Navy during the war. The Naval battleship officers were continually going up against the Naval aviators until the aircraft carrier proved its worth during Midway. Yet, in the instance of the BuOrd and Newport, the mobilization against the submarine officers at sea was extreme.

Latour mentioned that, at each stage of doubt, the cost of resistance increased.⁴⁴ BuOrd and Newport wrote off the submarine officers' reports, citing poor performance as the reason for failing to sink any enemy ships. The men in the United States questioned the sub commanders' training and their competence, telling them they were getting too excited when setting up their shots and they were making mistakes. Here were men who were sitting at desks in Washington, DC, and Newport, Rhode Island, questioning the decisions and abilities of men behind the periscopes who were in the actual fighting. This was an ugly instance in the war, yet understandable per Latour.

⁴³ See above letter from Blandy to Lockwood defending the MK XIV torpedo.

⁴⁴ Latour, *Action*, 77, 133.

In addition to civilian scientists, Newport and BuOrd officers questioned the submarine commanders. For the first year of the war, Naval Command in the Pacific questioned them. Admirals Hart, Wilkes, and English were the major doubters. At the outbreak of the war, Hart was overall Naval Commander in the southwest Pacific. Wilkes was his submarine commander. At Pearl Harbor, Admiral Withers and his Chief of Staff, Captain Styer, were believers in the MK XIV/VI. After the first month of the war, English became overall commander at Pearl Harbor. Lockwood, assigned to relieve Wilkes, came into the war and initially was a believer as well. Most of all there was Captain, soon to be Rear Admiral, Ralph Christie who had the most vested interest in the torpedo and exploder, as he was one of its main creators.

These officers had their own social circle. Each had an interest in the torpedoes working well. There was a torpedo shortage and money was tight, so one torpedo sinking one boat was what they desired most. There was no reason for them to doubt that the torpedoes worked. They had better access than anyone else in the Navy when it came to top secret information, like the information concerning the MK XIV/VI, and this colored their views.

Admiral Ralph Christie knew that reports of torpedo failures increased, but was too invested in the MK XIV/VI. In November, 1942, Christie wrote a letter to Lockwood stating:

Grayback had many opportunities and fired 24 torpedoes. The results were to say the least, disappointing. My analysis is that the fault lay principally in the lack of coordination in the torpedo control part particularly between the commanding officer and the TDC operator. My frank opinion is that the CO, Stephan is not well suited for the responsible job of Commanding Officer. You may well ask then, why not take the steps to relieve (sp) him.

The answer to that is a pusillanimous one. My diplomacy is unequal to the task. I am not permitted the freedom I think I should have to take administrative action in the task force. If it were a clearer cut case, I would not hesitate but this is a matter of opinion, I frankly told Admiral Carpenter⁴⁵ in the presence of the Division Comdr. (Shorty) before the patrol that Stephan was not in my opinion suited for the job but that I had previously so stated officially and had been overruled. Now except for the fact that Shorty agrees (sp) with me there is no change. I am the only one who has known him before, He fired 24 torpedoes and sank one 8000-ton transport and possible damaged two auxiliaries. Five of eight attacks were failures. He has no doubt learned a lot.⁴⁶

Stephan's reports were by the book, to the point and meticulous, mentioning attack coordinates, TDC settings, firing set up, yardage to target and torpedo performance. The *Grayback* endured aerial bombing and depth charging by the enemy. What stood out was Stephan's honesty about equipment problems. The *Grayback* had several gyro issues with the torpedoes. Making no attempt to look good at the expense of the crew or his equipment, he took responsibility for the gyro issues that were caused by his torpedomen.⁴⁷

Stephan probably knew by this time that blaming failures on the torpedoes would only be seen by Christie as an excuse and would bring more trouble than it was worth. By war's end Edward Clark Stephan (Annapolis 1929) was a young officer and earned the Navy's highest decoration, the Navy Cross which is second only to the Medal of Honor. He was also awarded the Silver Star three times for action against the enemy. Stephan

⁴⁵ Blair, *Silent Victory*, 302-304. Admiral Carpenter worked for Douglas MacArthur as MacArthur felt he rated his own Navy. Carpenter was Christie's direct boss as Christie was working out of Brisbane Australia. As a direct subordinate to Carpenter and not Lockwood Christie got away with not deactivating the magnetic feature of the Mark 6. It took a letter from Nimitz to make him do it.

⁴⁶ Official Communication from Admiral Ralph Christie to Admiral C.A. Lockwood, November 23, 1942, Lockwood Papers, LOC, Box 69.

⁴⁷ Fourth War Patrol Report of USS *Grayback*, NPPSO Reel Number H-108. Operator L. Frey, Date 11-6-80, 52-55.

went on to become the Navy's chief Oceanographer after the war.⁴⁸ Stephan, although not a top-scoring commander, knew what he was doing when it came to commanding a submarine in combat.

Christie's letter was sent in November, 1942. By this time, torpedo failures were adding up and Christie was feeling the pressure. But in the case of the *Grayback*, he still would not blame the science and technology but allowed Stephan to take the blame. His resistance was so strong that he was willing to sacrifice the career of a competent officer rather than give in. Latour speaks of increased resistance. This shows the resolve of Christie's resistance.

Laboratories

The Bureau of Ordnance was not an organization to take lightly. One submariner recalled, "... you must remember that the Bureau of Ordnance was a mighty bureaucracy. A naval officer, conditioned to believe the bureau's word was infallible in matters of ordnance, did not lightly challenge it. They could snow you with technical data, incomprehensible to the average line officer."⁴⁹ This speaks to Latour's observation that it becomes too difficult socially and economically to continue opposing the status quo. BuOrd and Newport were the status quo when it came to weapons and ammunition within the U.S. Navy. Eventually, the opponent needed to build his own laboratory to

⁴⁸ "Edward Clark Stephan Obituary," *Washington Post*, September 7, 1990, Accessed December 27, 2016, <https://www.washingtonpost.com/archive/local/1990/09/07/decorated-wwii-vet-edward-stephan-dies/904de4c9-4418-4398-be71-3e850363a61a/>.

⁴⁹ Blair, *Silent Victory*, 275.

contest the claim, impugning the reputations of those he chose to disprove.⁵⁰ The opponent was the U.S. Submarine Service in the Pacific.

Laboratories were often envisioned as enclosed, pristine places where men and women, wearing white jackets, worked on some scientific endeavor. Professor Robert E. Kohler approached this image in his book *Landscapes and Labscapes*.⁵¹ Kohler wrote that there were differences in the field and laboratory, but there were also parallels. Kohler's discussion primarily involved biology, but it applies here as well. Science in laboratories was not questioned like work in the field. Kohler fell on Steven Shapin's argument that, "laboratories help solve the great problem of trust in science: making knowledge that is produced locally - as all knowledge is - acceptable anywhere."⁵² No one was going to question work done at Newport. The men who worked on the Mark VI Exploder were specially-trained ordnance men working within a closed, controlled setting. They even had people working in General Electric and Carnegie Institute laboratories helping them develop components like the Thyatron.⁵³ Kohler writes about laboratories before the 20th Century, "The credibility of experiments was guaranteed by the particular places where the work was done and by the social qualities of the people known to live there."⁵⁴ This was true with the Pacific testing of the Mark XIV/VI. BuOrd

⁵⁰ Latour, *Action*, 63-100. Latour's chapter on laboratories is dense but enlightening. His points concerning laboratories, as they apply to this argument, are shown here.

⁵¹ Robert E. Kohler, *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology* (Chicago & London: University of Chicago Press, 2002), 2.

⁵² Kohler, *Labscapes*, 7. Kohler cites: Shapin's "Pump and Circumstance: Robert Boyle's literary technology." *Social Studies of Science* 14 (1984): 481-520.

⁵³ Powel, *Newport Administrative History*, 136-138. Blair Papers, Box 73, File 1.

⁵⁴ Kohler, *Labscapes*, 8.

questioned the work of mid-ranked officers and enlisted men conducting experiments outside of a formal laboratory. There was an issue of credibility there.

Yet, a laboratory did not have to be inside and run by scientists. There had to be field work as well. Kohler saw a permeable border. He spoke of the laboratory and field as two parts of one thing, as linked opposites, mutually supporting and defining, neither one viable or even conceivable without the other.⁵⁵ And so it was with the submarines in the Pacific and Newport. Newport never fired a torpedo from a submarine, they used a torpedo barge, a floating building that fired torpedoes from the surface into the water. This was a different firing application than firing from a flooded torpedo tube fifty feet below the surface. The torpedo was what Kohler calls a boundary object, a thing whose meanings are pliable enough that people from different subcultures can view them as embodying a shared cause.⁵⁶ Indeed, the boundary between lab and field could not be demarcated by a line, rather it was a zone of mixed practices and ambiguous identities.⁵⁷ Laboratory and field could work in unison. This applied as the men in the Pacific finally resorted to creating their own laboratories in the field. They did field testing under the tightest laboratory conditions that they could achieve within the available environment. The first laboratory was off the coast at Albany Bay.

Bruno Latour and Steve Woolgar studied laboratories and laboratory life as it happened, including Roger Guillemin's scientific laboratory at the Salk Institute.⁵⁸ This

⁵⁵ Kohler, *Labscales*, 13.

⁵⁶ Kohler, *Labscales*, 13.

⁵⁷ Kohler, *Labscales*, 18.

⁵⁸ Latour and Woolgar, *Lab Life*, 108-152, 206-241.

was the stereotypical laboratory, an antiseptic facility where scientists wearing white coats work with microscopes. They described an “anthropological strangeness” where the laboratory was a tribe foreign to the researcher.⁵⁹ The Submarine Service was also a tribe within a tribe. Many of Latour and Woolgar’s experiences related to the U.S. Submarine Service’s experimentation in the Pacific during the war. However, the time, place, subject, focus, and methodology differed from those of the Salk Institute. A laboratory did not need to be inside of a building or hospital. A laboratory could be the torpedo room of a *Gato* class submarine or a beach on the coast of the ocean.

Laboratory One: Albany

After touring his new area of command, Lockwood met with division commanders and individual submarine captains, such as Red Coe of the *Skipjack*. Lockwood’s first official action was to address the torpedo question. Within proper channels, he asked BuOrd if there was any information or if they had run any recent tests of the MK XIV. He also asked if they had found any defects with the magnetic feature of the MK VI exploder. BuOrd promptly told him that their torpedoes were fine. In effect, BuOrd accused the submarine commanders of using torpedo defects as an excuse for their poor performance. To Lockwood’s credit he was exasperated. He elected to run his own tests. In a June 4, 1942, letter to Vice Admiral H.F. Leary, the overall submarine commander of Allied Naval Forces in the Southwest Pacific Area, Lockwood wrote:

Incidentally, I am very much encouraged over recent patrol reports for not only do the C.O.’s show better head work but they are also doing better shooting, The China Sea has provided our best hunting. The remaining fly in the ointment is the

⁵⁹ Latour and Woolgar, *Lab Life*, 40.

number of misses at five and 600 yards which we can ascribe to nothing but the incorrect functioning of the anti-counter mining device or the failure of the magnetic pistol. We are convinced also that they run much deeper than the set depth even though BuOrd (sp) assures us this difference is only four feet, However, I am obtaining some fish net at which we will do some shooting off Albany in order to satisfy ourselves as to just how much deeper they really are running.⁶⁰

Lockwood contacted Captain James Fife who was on the USS *Fulton*, a submarine tender based in Albany, Australia. Jimmy Fife and Lockwood engaged Portuguese fishermen from Frenchman's Bay, Albany, to build a special net in which to fire torpedoes for testing. By this time over 800 torpedoes had been fired during the war, but not one had been fired in a controlled setting. On June 20, 1942, in Frenchmen's Bay, from 850 to 1,500 yards, the USS *Skipjack* fired numerous torpedoes over two days. The results determined that the torpedoes were running deep by up to eleven feet.⁶¹ Here the officers and men of the submarine service had what they believed to be indisputable proof that there was something wrong with the depth setting on the MK XIV. Lockwood radioed a message describing the test and the results.

The response from BuOrd four days later was blistering. They disputed the report, primarily citing that the crews and skippers were at fault. Lockwood wrote, "They scorned our inaccurate approach to obtain these findings."⁶² To make matters more confusing, BuOrd claimed that no reliable conclusions were possible from Lockwood's tests because of improper torpedo trim conditions introduced. This showed that BuOrd

⁶⁰ Official letter from Rear Admiral Charles A. Lockwood to Vice Admiral H.F. Leary, June 4, 1942, Lockwood Papers, LOC, Box 62.

⁶¹ Official letter from Rear Admiral C.A. Lockwood to Rear Admiral R.H. English, August 1, 1942, Lockwood Papers, LOC, Folder 63.

⁶² Official letter from Bureau of Ordnance to Rear Admiral C.A. Lockwood, June 30, 1942, Lockwood Papers, LOC, Box 63.

was searching for something that was not there, as this statement made no sense. Trim improves for a torpedo fired under the surface from a submarine rather than above the surface from a torpedo test barge. Regardless, BuOrd went out of their way to impugn the submarine service's approach, laboratory conditions, testing parameters and procedures. They questioned the effect the environment had on the testing. Thus, BuOrd responded immediately, disregarding the testing at Albany.⁶³

In the civilian world, the financial cost of opposing the established point of view would become almost impossible to bear and the social cost was alienation and retaliation. Increasingly powerful allies mobilized and drew together to go up against the forces challenging the established belief system. In principle, this battle may have continued indefinitely. In practice, doubters often gave up. Yet, with life and death on the line, not everyone gave up. The men who sailed and fought in the submarines knew something was wrong with the torpedoes. Some of these men included scathing reports to their commanding officers. With the testing at Albany, Lockwood showed that the welfare of his men, as well as defeating the Japanese, were higher priorities than following the dictates of the social construct of which he was once a part.

Because the issue with the torpedoes took place within a military organization, events differed somewhat from those Latour had described. Some of the influences from the military structure complicated things. Others simplified them. Despite certain

⁶³ Personal Correspondence from Admiral C.A. Lockwood to Vice Admiral H.F. Leary, June 4, 1942, Lockwood Papers, LOC, Box 64.

individuals in the United States' reluctance to believe the Albany testing, the Navy had an advantage that civilian science lacked: military friendships.

Friendships made in the military were among the closest relationships possible, short of marriage. People whose lives depended on each other developed tight bonds. In addition to this, military officers climbing in the military hierarchy shared experiences that civilians advancing through civilian hierarchies did not. As we have seen, the thing that the Submarine Service had going for it during World War II was Charles Lockwood, the commander of all submarines in the Pacific. Lockwood had a strong relationship and friendship with the commander of BuOrd, Bill Blandy. Although the two butted heads throughout the war, they could talk to one another and, more importantly, hear what the other one was saying. Lockwood, having a very close relationship with his subordinate, James Fife, calling him 'Dear Jimmy' in all their correspondences, put into motion the tests in Albany. Fife was an expert on everything related to submarines. Shortly before the war, Fife commanded the submarine school at New Haven. He intimidated most of his subordinates but they respected him.⁶⁴ Lockwood could depend on Fife to do a thorough job testing the depth settings on the torpedoes. The relationship of Fife through Lockwood to Blandy was key in reducing the infighting and disbelief between men in the Pacific and the stateside commanders.

⁶⁴ Captain George William Grider, USS *Wahoo*, *Pollock*, *Hawkbill*, and *Flasher*, Letter to Clay Blair, June 8, 1971, Blair Papers, Box 67, File 6. "Fife had the sub school when I was there. I was terrified of him." After the war Grider and Fife were next door neighbors and Grider felt that Fife had become "One of the warmest, friendliest, most outgoing people I've known."

The people at BuOrd and Newport did not just decide to accept or even respect the testing at Albany, but criticized Fife's testing procedures and parameters. Lockwood communicated with Blandy and the people at Newport ran their own tests. Although Newport grudgingly admitted that the depth setting was off, they were still unable to bring themselves to confirm the findings of the Albany tests. Yet, because of the tests, the unbelievable happened: the opening of the black boxes of the depth setting mechanism and depth finder. Official testing found both to be defective and undependable.

The word went out to the submarines in port and on station. The submarine commanders felt vindicated. Due to the testing at Albany, and then at Newport, the sub commanders and torpedomen altered their depth settings before loading a torpedo into a tube. This did not fix the black box, but bypassed it. This was where the torpedo's first black box came into play. Thousands of man-hours had gone into the design and construction of the depth control mechanism. The component was built like a Swiss Watch. A torpedo was a long cylindrical body tapering down to a tail with rudders and propellers. The depth control had an opening on the taper. This aperture led to a tunnel which channeled water to the depth reading mechanism. Because of the location on the taper of the torpedo body, the flow of water created a Bernoulli effect.⁶⁵ In simple terms, this meant that an increase in the speed of a fluid occurred simultaneously with and created a decrease in fluid pressure. The MK XIV had two speed settings. It was rare that any crew ran the torpedo on low setting. This meant that the faster the torpedo ran, the

⁶⁵ "What is the Bernoulli Equation?" *Kahn Academy*, accessed December 23, 2016, <https://www.khanacademy.org/science/physics/fluids/fluid-dynamics/a/what-is-bernoullis-equation>.

less pressure there was on the depth reading mechanism, causing the depth reading to be falsely shallow. This led to deeper running torpedoes.

This black box was opened but not corrected. The simpler cure to the problem was to dial down the depth setting, a work-around that, though imprecise, led to better results. But knowing that the torpedoes were running eleven feet deeper on average made any adjustment challenging.

With the depth issue behind them, the submarine captains relied on the magnetic exploders and felt confident that they would obtain hit after hit. Yet, premature detonations, a problem since the beginning of the war, increased dramatically. Some captains wanted to inactivate the magnetic influence mechanism and use the contact part of the exploder but to do so was risking court martial. Some skippers did not care what command said and turned the magnetic influencer off. Some skippers turned them off and told their commanders otherwise.⁶⁶ All of this created more problems, especially with determining what worked and what did not.

There was still a black box to open: the magnetic exploder. This was a much bigger problem than with the depth mechanism, as the main person behind the design and production of the MK VI magnetic exploder was now a combat admiral, and a good one at that. Ralph Christie commanded a substantial part of the submarine forces in the Pacific. In addition, BuOrd and Newport reverted protecting their decisions and reputations, as Latour's theories would have predicted. The opening of this black box became difficult, as this alliance was holding together.

⁶⁶ Harry Homewood, *Silent Sea* (New York, Toronto: Bantam Books, 1981), 108.

Christie, who held a lot of sway in the Pacific, both by rank and by reputation, had military power in addition to being the chief inventor and scientist of the exploder. This complicated the networking and alliance issue. Christie had an alliance that included Newport and command. Yet Christie had the power, by himself, to put a hold on opening the black box of the exploder. Because of his rank, submarine commanders needed to win command officers with ranks of rear admiral and higher over to their alliance.

Just the word from the submarine commanders, or rumors within the Submarine Service were not enough to sway anyone's opinion concerning the prematures. There had to be what Latour calls inscriptions.⁶⁷ Inscriptions enabled people to compare and judge so that they could act from a distance, like Newport or Washington, to view the activities and intervene or coordinate in the name of better management. Newport and BuOrd went into the war with plenty of inscriptions. But there were inscriptions from the Pacific to the East Coast after the war began. These inscriptions were the detailed reports from the submarine commanders to their division commanders, then theater commanders like Lockwood and Christie and finally Naval Command, BuOrd in Washington and Newport.

From a scientific standpoint inscriptions are extremely important. Callon wrote, "an inscription is the result of the translation of one's interest into material form."⁶⁸ "In general, any component of the heterogeneous network of skills, practices, artifacts, institutional arrangements, texts and contracts establishing a social order may be the

⁶⁷ Latour, *Action*, 218.

⁶⁸ Latour and Callon, *Lab Life*, 143.

material for inscriptions.”⁶⁹ There are four interesting aspects of the notion of inscriptions:

- 1) what is inscribed: which anticipations of use are envisioned
- 2) who inscribes them
- 3) how are they inscribed: what is the material for the inscriptions
- 4) how powerful are the inscriptions: how much effort does it take to oppose an inscription.⁷⁰

Latour wrote that scientific knowledge was embedded in the procedures of inscription. Inscriptions were the rendering of what is still contested and not agreed upon. They were the outcome of effective organization and technology and they made it possible to circulate information in the form of formulas or visual representations. As the War Patrol Reports and Action Reports from submarine commanders and torpedomen kept reporting torpedo failures, the alliance of senior level naval commanders began to turn away from Christie and BuOrd to the men in combat. In the end, inscriptions helped save the day for the men in the field. Tyrell Jacobs of the *Sargo* wrote one of the first inscriptions of the war warning against faulty exploders. In 1943, Captain Mush Morton of the USS *Wahoo* wrote the following inscription:

Fourth War Patrol August 15, 1943
Attack No. 1
 0035; Fired one torpedo at medium sized freighter course 205
 degrees, speed 7 knots, torpedo run 950 yards, track 90 degrees

⁶⁹ Ole Hanseth and Eric Monteiro, *Understanding Information Infrastructure*, Manuscript, 27, August, 1998, 110.

⁷⁰ Michel Callon, John Law and Rip Arie, *Mapping the Dynamics of Science and Technology: Sociology of Science in the Real World* (Basingstoke, England: MacMillan, 1991), 143.

starboard, torpedo depth setting ten feet, gyro angle 21 degree right. Miss no explosion.

0055; Surfaced, and commenced tracking for another attack.

0143; Sighted another ship on northerly course. It looked like another ship and he was heading for us. Broke off the chase on the other freighters and commenced tracking on surface on new target.

0206; Dived for a submerged attack.

Attack No. 2

0222; Fired one torpedo at a medium to large freighter course 030 degrees speed 11.5 knots, torpedo run 1,150 yards., track 80, stbd, torpedo depth setting 6 feet, gyro angle 180 degrees. Hit at point of aim, but torpedo was a DUD and did not explode.

0245; surfaced and commenced tracking for another attack.

0415; Dived for submerged approach. The moon was out, but just setting and dawn had no quite arrived so went in on sharp track to expedite attack while light enough to see.

Attack No. 3

0418: Fired two torpedoes at same target as in attack no. 2. Course 025 degrees, speed 11 knots, torpedo run 700 yards., track 60 degrees starboard, torpedo setting 6 feet, gyro angle 345 degrees and 343 degrees. Both missed.

0423; One torpedo exploded at end of run.

In the meantime, swung ship and headed directly for target. At the completion of swing, target presented a good, up-the-stern, shot.

Attack No. 4

0424; Fired one torpedo at same target course 025 degrees, speed 11.5 knots, torpedo run 1,600 yds., track 176, torpedo depth setting 6 feet, gyro angle 355 $\frac{3}{4}$ degrees. Missed.

0427; Torpedo must have broached and exploded before reaching end of run.

This is bad as it is daylight now and we cannot clear the scene of action and the target will disclose our presence. Damn the torpedoes. 0930; Echo-ranging heard over sound. Soon sighted OTORI Class Torpedo Boat. Commenced evading. Heard second ship echo-ranging, but did not sight it.

1220; Lost sight of anti-submarine ships.

1930; While making preparations to surface, sound picked up echo-ranging. Soon sighted another OTORI Class Torpedo Boat, Commenced evading. Heard second ship echo-ranging but did not sight it,

2044; Surfaced in cloudless night and with a full moon. Headed on course 315 degrees, which was directly down moon and cleared the coast. No good hunting to-night with visibility so good. Decided to

move over on the HOOKAIDO-KOREA ship route and spend the night and tomorrow.⁷¹

In January, 1943, Morton and the *Wahoo* had conducted a brilliant attack against the Japanese. After sinking several ships, Morton touted the efficiency and deadliness of the MK XIV/VI torpedo. Yet, between January and mid-August, numerous other submarine commanders wrote time and again about faulty torpedoes. Because of Morton's January successes, command still had some, if waning, faith in the torpedo. The above report of the *Wahoo* was instrumental in turning the opinion of command. Morton was one of the best submarine commanders in the war with a reputation as an aggressive, brilliant commander. These inscriptions resulted in a heated exchange between Morton and Lockwood but, backed by Morton's reputation, led directly to disconnecting the magnetic part of the MK VI exploder.

Most of the submarine commanders, torpedo officers and torpedomen were conducting their own experiments in the vast laboratory of the Pacific. They recorded their findings in highly detailed combat reports, inscriptions that found their way to the command positions that they needed to find. They produced monthly reports of tonnage sighted, tonnage fired upon, tonnage sunk and tonnage not sunk. As mentioned previously, early in the war there had been ninety-eight shots made and three ships sunk. It should immediately have been obvious that something was wrong with the torpedoes but the only alliances in place included BuOrd, command, and perhaps Captain, later Admiral, Ralph Christie. The submarine commanders not only had no alliance at this

⁷¹ Sixth War Patrol Report of USS *Wahoo* (SS-238) August 29, 1943, NPPSO Reel Number F-108, Roll AR-159, Record Group 78, NA, 4-7.

point, they were not totally sure of what was going on. After the attack on Pearl Harbor, and the Japanese drive to Java, too much was happening too fast.

Finally, Pacific Command added up all the information coming in from the field. This, along with influence from Charles Lockwood and some prominent submarine combat commanders, like Mush Morton, Swede Momsen and Pi Pieczenkowski, brought about changes in alliances. However, the black box of the magnetic exploder was just set aside, never opened and corrected. Since the magnetic exploder could be switched to a contact exploder, that is just what Pacific command, Lockwood and BuOrd recommended the submarine crews do. At Lockwood's request, Admiral Nimitz sent word out to the submarine commanders to disconnect the magnetic feature on the exploders on June 24, 1943.⁷²

Laboratory Two: Individual Torpedo Rooms and Submarine Tenders

The men who served on the submarines did their own experimentation in the laboratory they knew best, their submarines' torpedo rooms, to find the problems. When at sea, the men had to conduct maintenance on the torpedoes fueling them with alcohol, making sure the air was up to running pressure, installing the gyroscopes, tuning the engines, removing the exploder mechanisms for inspection, servicing and electrical testing. These weapons, being highly technical, were fragile. Torpedoman Bob Hunt on the *Tambor* had opinions on the MK XIV/VI:

We found out early on that those damned torpedoes weren't doing what they were supposed to do.... We all sent back lots of reports, but it was hard to

⁷² Newpower, *Iron Men*, 158.

convince the brass... They were highly tuned pieces of equipment, and they couldn't take the bouncing around at sea.⁷³

When in port, the submarine tenders, floating repair vessels, serviced submarines as well as torpedoes. Both old-time sailors and young men coming out of the depression knew how to work on everything from farm tractors to the family car. Since replacement often was not a possibility, these young men knew how to repair home radios, tools, bicycles, motorbikes, stoves, heating plates and other day-to-day things. So, there was little fear about fixing anything. Thousands of these men, once enlisted or drafted, went to the Pacific. Sometimes, these men had an officer supervising, sometimes not. Regardless, these are the men, some regular navy, most Depression-era kids, who serviced and repaired the MK XIV/VI. These also were the men who experimented with the failed torpedoes. The submariners' laboratories were rudimentary and makeshift, but sufficient. Although they did not resolve the magnetic influencer problem, they helped immensely with the contact exploder issues.

Laboratory Three: Kahoolawe Cliffs

With the magnetic part of the MK VI disengaged and the contact exploder in use, there were still frequent reports of torpedoes hitting the target and not exploding (duds). When a torpedo hit the side of a target at 46.5 knots, acceleration stopped suddenly causing a significant impact. The 3,200-pound mass of the torpedo was concentrated in a twenty-one-inch circular area, with the weight and the drive of twenty feet of torpedo

⁷³ Robert Schultz & James Shell, *We Were Pirates: A Torpedoman's Pacific War* (Annapolis: Naval Institute Press, 2009), 58.

coming in right behind it. This was unlike a 3,000-pound automobile hitting a wall, where the impact of the vehicle spread out. The concentrated impact created a loud noise that could be heard by the sonarmen on a submarine. Through a periscope, the hit created a sizable splash of water which, with the crushing of the large air tank holding 2,000 PSI of air pressure and ignition of the remains of high test alcohol fuel, resulted in a sizable explosion.⁷⁴ But by mid-1943 submariners knew the sight and sound of a dud hitting a target. At times, a dud would penetrate the hull of a target ship and slow her or make her list. But a dud was rarely going to sink a ship. This was demoralizing or maddening.

Dan Daspit on the USS *Tinosa* came back into Pearl Harbor after firing twelve torpedoes at perfect setups.⁷⁵ After four hits on the *Tonan Maru*, a 19,000-ton whale factory, he recorded no explosions.⁷⁶ After eight more hits, he was chased off by a Japanese Destroyer. When he returned to Pearl Harbor, a furious Daspit met with Lockwood. Adding this report from the *Tinosa* with other failures, Lockwood, his staff and submarine captains like Daspit realized that there was yet another defect, this time with the MK VI contact exploder. Lockwood decided to investigate the situation. The young officers and torpedomen all participated, including officers Babe Brown, Pi Pieczenkowski and the legendary Swede Momsen.⁷⁷ Momsen, like the scientist he was, had the great idea to use nature to advance their scientific endeavors.

⁷⁴ See Chapter Three MK XIV Torpedo specifications.

⁷⁵ Second War Patrol Report of USS *Tinosa* (SS-283) July 24, 1943 NPPSO Reel Number 1, Roll AR-57, Record Group 74.

⁷⁶ This was considered a ship of large tonnage and a valuable prize as whale oil was utilized in Japan due to petroleum shortages.

⁷⁷ See Chapter Four and the *Squalus* rescue.

On nearby Kahoolawe Island, cliffs extended under the surface of the sea. On August 31, 1943, per Momsen's proposal and with some reluctance from Lockwood and others, the USS *Muskellunge* shot torpedoes into the cliff face and recovered the first dud. In fifty-five feet of water, Boatswain's Mate John Kelly found the torpedo, hooked on a retrieving line and lifted it out of the water onto the USS *Chalcedony* for inspection.⁷⁸

Lockwood related to Blandy:

You would certainly have enjoyed seeing us recover this particular dud down at Kahoolawe. Swede Momsen and I went down with the aid of 3 white native Hawaiians-who in fact did all the diving and most of the goggle work-located and recovered the torpedo. The most remarkable part of it all was seeing this youngster swim down 50 to 60 feet and shackle a 5" line into a wire strap on the tail of the torpedo.⁷⁹

As has been shown, the MK VI used an odd design with their exploder. This was not like the MK III exploder, which was placed in the nose of the warhead. The MK VI sat perpendicularly inside the warhead and could be removed from under the nose of the torpedo.⁸⁰ Officers and men found that the guide rails upon which the firing pin rode became distorted and the pin failed to engage or hit the fulminate cap. The force of the impact was too much for the metal used. But one test does not a scientific investigation make. This was a pilot study.

⁷⁸ "John Kelly," *Surfrider O'ahu Presents: The John Kelly Awards*, accessed January 7, 2016, <http://www.johnkellyawards.com/who-is-john-kelly/>. Shockingly Kelly did not use salvage diving gear to do this. Growing up in Hawaii John Kelly free dove 55 feet under the surface to the torpedo using nothing but goggles and rope. He earned the Navy-Marine Diving medal for this incredible feat of courage.

⁷⁹ Official Letter to Admiral William Blandy from Admiral Charles Lockwood, September 9, 1943. Lockwood Papers, LOC, Box 73.

⁸⁰ This exploder is explained in detail in Chapter Four.

Laboratory Four: Pearl Harbor

Drop testing took place at Pearl Harbor under Pi Pieczenkowski. Now BuOrd joined in with advice and enthusiasm. The torpedomen removed the Torpex in the warheads and replaced it with a cement mixture of similar density. The exploder remained in place. A cherry picker or mobile crane dropped the torpedoes from ninety feet up. The torpedoes hit a steel plate at close to forty-five knots, just short of the top speed of the MK XIV. Each experiment, or drop, required engineering to determine how high to raise the torpedoes on the cherry picker given the weight, length, width, shape and desired speed of the torpedo. Wires guided the torpedoes to the ground to ensure that the torpedo hit the steel plate in the same orientation as a live shot.

Torpedomen, with their hands-on expertise and experience, worked hand in hand with the officers testing, analyzing and offering suggestions. The young men who oftentimes grew up with very little, showed their expertise in fixing things. Lockwood wrote to Blandy:

My entire corps of experts, and in fact practically every submariner present, is kibitzing this show, trying to pick flaws in it, but I believe we will arrive at a fair representation of what happens when a torpedo strikes a ship's side without resorting to the more inexact representation achieved by firing against the cliffs, where recovery of duds is a difficult and dangerous proposition.⁸¹

The men found that when the warhead hit the plate at a perfect ninety-degree angle the exploder rails distorted. However, when dropped at a forty-five-degree angle, the rails distorted only half the time. The message went out immediately for skippers on

⁸¹ Lockwood to Blandy, September 9, 1943, Lockwood Papers, LOC, Box 73.

war patrols to change their tactics and shoot for oblique shots.⁸² This was just a temporary solution.

First, the top speed of the MK X/III, on which the contact portion of the MK VI was based, was only 33.5 knots. The additional thirteen knots between the two torpedo types almost doubled the force of inertia of the deceleration from impact against the hull of a Japanese ship.⁸³ Second, the steel used in the exploder guide rails was too weak. A reservist ordnance expert concentrated on making a stronger lighter pin and guide arrangement. The toughest, lightest metal that the ordnance people found came from the propellers of Japanese Zeroes that had been shot down on December 7, 1941. Bill Hazard, the executive officer of the USS *Saury*, noted the irony, “We gave them scrap metal to build their ships. Now they were providing us with scrap metal which would be used to sink those same ships.”⁸⁴ Trying Japanese airplane propellers for metal showed excellent scientific thinking, diligence and imagination. With the rebuilding of the guide rails, the U.S. Submarine Service now had a reliable torpedo.

Conclusion

Alliances had changed, there was no longer any opposition from BuOrd. They showed that they had been won over by giving their expertise and advice for the drop tests. So, the combination of the alliance change, the fact that this black box was not as

⁸² Official Letter to Admiral Christie from Admiral Lockwood, September 29, 1943. Lockwood Papers, LOC, Box 78.

⁸³ Milford, “US Navy Torpedoes (Part Two).” 9.

⁸⁴ Blair, *Silent Victory*, 438.

controversial as the magnetic influenced exploder, and the overwhelming evidence that there was a problem, the repair of the contact exploder went more smoothly than anyone would have expected. It had taken almost two years but now the U.S. Navy had a torpedo that was safer and more consistent. The MK XVIII and MK XXIII torpedoes came into full production at the same time, and became the major torpedoes used through the rest of World War II.

Author and former submariner, Clay Blair, made the well-known statement that the submarine command structure was “incomprehensibly stubborn and stupid” in not believing the reports from commanders in the field.⁸⁵ This whole debacle was much more complicated than stubborn people refusing to admit they were wrong. There was too much science behind the MK XIV torpedo and MK VI magnetic exploder. Too many people had too much time invested and reputations riding on this. As Bruno Latour argued, opening a black box was almost impossible. It took dedicated torpedomen and naval officers and a lot of work to bring these changes about.

Since the war, many have questioned how these torpedoes could have failed. Chapter Four explained how, as with other highly-technical, high-risk systems, they were bound to fail. This was compounded by the Navy’s refusal to test the torpedoes before going into action. Still it seems incredible that these failures could have continued for so long without being corrected. The reason was that opening black boxes inevitably results in difficulties and delays.

⁸⁵ Blair, *Silent Victory*, 216.

CONCLUSION

The Space Shuttle *Columbia*

On February 1, 2003, after a successful fifteen-day mission, the National Aeronautics and Space Administration's (NASA's) Space Shuttle *Columbia* was re-entering the Earth's atmosphere when a problem arose.¹ Telemetry indicated that hydraulic fluid temperatures on four sensors in the aft part of the *Columbia*'s left wing began reading off-scale low, which usually meant that the sensor had stopped working. Soon after, additional telemetry on the tire pressure in the two left side tires bottomed out. Additional sensor responses indicated hydraulic pressure was lost and the shuttle would not be controllable once it descended into the atmosphere. Although expecting patchy communication during re-entry, Flight Control lost total contact with the crew. Radar did not spot anything along the shuttle's flight path. The last two factors pointed to one thing, the *Columbia* had disintegrated upon re-entry. Observers on the ground confirmed this.

After the shock of the tragedy had settled, an accident investigation board scrutinized the mechanics of the mishap as well as NASA's organization and culture to find the cause of the catastrophe. A large piece of insulation from the external fuel tank had detached during launch and struck the leading edge of the left wing at a velocity up

¹ Ramasamy Venugopal, "The Space Shuttle Columbia Disaster," *Space Safety Magazine*, <http://www.spacesafetymagazine.com/space-disasters/columbia-disaster/>, accessed March 6, 2017. Unless noted the information concerning the *Columbia* disaster comes from this thorough article.

to 572 miles per hour.² Although the incident had been discovered two days after launch, managers at NASA viewed it as inconsequential. Unfortunately, the debris had blown a hole in the wing, affecting its thermal protection and allowing super-heated air to penetrate. The heat from re-entry destroyed the left wing, resulting in a structural breakdown rather than an instantaneous failure. During disintegration, the crew module separated from the fuselage causing instant depressurization, probably rendering the crew immediately unconscious. The module spinning in the air caused both lethal rotational forces and battery of crewmembers by loose objects within the cabin. Shuttle wreckage and the bodies of the seven crew members showered over Arkansas, Texas and Louisiana.

The Space Shuttle's main fuel tank was covered in thermal insulation foam to prevent ice from forming when the tank was full of liquid hydrogen and oxygen. Shedding ice on liftoff could damage the shuttle. Though not structural, the foam did need to bear some aerodynamic load. About eighty-two seconds after launch a suitcase-sized piece broke off striking the left wing of the *Columbia*. The first people blamed were the ones who applied the foam. Later investigation showed that temperatures of the fuel made the tank flex and that foam strikes had occurred in almost every shuttle launch. NASA management even gave it a name, foam shedding. This showed that they had become complacent about this phenomenon as no serious consequences resulted from earlier launches.³ They proceeded with the launch. The investigation severely criticized

² The relative velocity of impact was rated at between 670 and 922 km/h.

³ Vaughn, *Challenger Launch*, Kindle Edition, LOC 86. Using Vaughn's definition this is classic Normalization of Deviance, meaning, precedent became the basis for accepting it again and again.

NASA Management and the culture within the organization that valued mission success over engineering insight and suppressed anyone with a different opinion.

Engineers knew there was a possibility of damage from foam strikes. After viewing the video of this strike, they were very concerned about this flight. The Photo Working Group and the Debris Assessment Team requested On-Orbit photographs from the Department of Defense to assess possible damage from the foam debris. Shuttle management said no. If something happened to the thermal protection, they felt nothing could be done about it. After the disaster, NASA enacted remedies concerning the foam, in-space repair, in-space rescue procedures and NASA management practices.

Space exploration and space science is a high-tech, high-risk business. Not only is there a small margin for failure from a mechanical perspective, people's lives are often at stake. In the *Columbia's* case, complacency had set in. Hope had become a strategy and tactic. Because of past success, management did not want to hear what they did not want to hear. Managers felt their reputations were at stake and any new procedures might put these reputations into a bad light. Because of questionable management, construction practices and operational practices, lives were lost. Fortunately, the construction of knowledge from this disaster went on to protect future crews from the same fate of the Space Shuttle *Columbia*.

This story shows the current impact of high-tech, high-risk systems in the world in which we live today. It has become more highly technical as each year goes by.

Engineers and managers have become more reliant upon computers, digital components and automatic safety devices to do their thinking for them. These black boxes, though reliable, can fail. Management and organizational practices have also become black boxed.

The Mark XIV/VI Torpedo

The story of the Mark XIV/VI torpedo failure is a parallel to the story of the *Columbia*. In this dissertation, I have told the story of the torpedo failure through a narrative arc that began with the idea of a seemingly impossible weapons system, an invisible ship firing an invisible weapon. I showed the history of submarine development and its impact on the world. Unlike ocean liners, such as the *Titanic* and *Britannic*, the submarine was built for one application and that was war. The submarine began as a human propelled undersea craft that could not completely submerge. It went from this to a craft that could totally submerge but was not reliable for long distances. The torpedoes were what we today refer to as mines. As the Industrial Revolution came, the submarine could depend on gasoline engines that supplied the power for propulsion and the air systems it needed for total submergence. By World War I, countries like Germany had improved the submarine and torpedo to where they were a formidable strategic weapon.

Once the submarine and torpedo became viable weapons systems, their very natures came under question. Using submarines during war was considered ungentlemanlike at its best. Attempts were made to outlaw them, but the genie was out of

the bottle. The United States and other countries used Germany's submarine template and went on a campaign to develop their own effective submarine and torpedo.

The U.S. Navy invested heavily in the science and technological progress that went into building the submarines and torpedoes of World War II. These were scientific and technological marvels for their time. The *Gato* Class submarine could run on the surface up to twenty-two knots, dive to over 500 feet deep, run for 12,000 miles and carry a complement of up to seventy-five men and twenty-four torpedoes. The Mark XIV torpedo was a self-contained, steam-powered undersea vessel that could automatically steer itself in three dimensions. The Mark VI exploder could, in theory, explode beneath a target ship breaking its back, by using the magnetic signature of the enemy ship. The commanders of the submarines were well-trained officers, most of them degreed engineers and the crews of the submarines specially selected and trained sailors. Once the war began, these men and their machines went to work. Unfortunately, the peacetime tactics, the over-cautious captains, and the torpedoes that they fired at the enemy were not up to the job. The main issue was the torpedo. It did not work as designed. The submarine captains complained but the powers on the East Coast were not listening. They were adamant that if there was a problem with sinking enemy ship, it could not be the armament. The men in the submarines were obviously not up to the task. It was going to take a man like Admiral Charles Lockwood and his Pacific Organization to go up against the Newport Naval Torpedo Station, the Bureau of Ordnance, and Naval Command in Washington DC.

The new, top-secret Mark XIV/VI exploder emerged on the scene in the summer of 1941 and was touted to be a one shot, one ship sunk torpedo. When the crews found their torpedoes were not doing the job, they complained but Command did not listen. The crews in the Pacific then had to prove the inadequacies of the Mark XIV/VI themselves. From shooting torpedoes into a Portuguese Fisherman's net at Albany Bay, Australia, then shooting at undersea cliffs at Kahoolawe, Hawaii, to drop tests at Pearl Harbor, the submarine crews took responsibility for solving the torpedo issues they were facing on their combat tours.

The question of how the U.S. Navy could have put a weapon into service that did as poorly as the Mark XIV/VI has resonated since the war. Using the ideas originally set forth by Charles Perrow and expanded by Jim Chiles and Diane Vaughn, it is apparent that the Mark XIV/VI was a high-tech, high-risk weapon and it was bound to fail. This weapon was so highly technical that it deserved a rigorous testing program that it never received. It should have undergone the shakedown testing that every ship in the Navy received. It should have received the same basic testing as sixteen-inch battleship rounds. But it did not. Regardless, as high tech as it was, the torpedo and exploder required a failure program to back up the inevitable failures.

Another question that comes up is why it took almost two years to correct the situation. Using theories and arguments of sociologists like Bruno Latour, it is clear the depth mechanism of the MK XIV torpedo and the magnetic feature of the MK VI exploder were black boxes, so challenging these would meet with strong opposition. The Mark VI magnetic influenced exploder worked using the Earth's magnetic field in

combination with the electromagnetic signature from the target vessel. In combination, the magnetic impact of the two should have tripped the exploder when it was underneath the target vessel. To do this, the torpedo had to be within a set number of feet under the hull. This meant the exploder was dependent on the torpedoes' depth control working correctly. The Mark VI was also dependent on the intricate interworking of the electronics within the exploder itself. Both black boxes were faulty and it took the men in the Pacific to open them up and prove it.

When Command decided to deactivate the magnetic feature and use the Mark VI as a contact exploder, this presented yet another black box to open. Because the torpedo was hitting ships but not exploding, the men had to experiment once more to determine that the metal in the exploder proper was not strong enough to take the impact of a forty-three-knot impact. As mentioned, the Mark XIV's depth control and the Mark VI's magnetic component were black boxes. Opening a black box was an invitation to conflict. It took the work of the men in the Pacific to set up their own field laboratories, and experiment to prove that they were faulty. Once Command, BuOrd, and Newport saw that there were issues with the depth control and the exploder itself, alliances changed and progress was swift.

Although only a small clique of people know the history of the Mark XIV/VI, anyone can access the story in naval or military magazines, books, or the internet. The reader is almost always left with the questions of how this could happen and why it took so long to correct the problems. This dissertation answers those questions. But it does more than that. We are used to nuclear submarines today that can fire intercontinental

ballistic missiles. This had become the norm in our lives. But the idea of a ship that can sail under the surface of the sea was fantastic, the stuff of Science Fiction. This dissertation shows the science that went into building these undersea vessels. It also shows the science behind a weapon that could be aimed, fired, and could run under the surface of the sea, surprising an enemy ship to the point that the attacker could sail away undetected.

This dissertation speaks of the bravery of the men who served in the submarines during the war. The submarine service was the smallest, most elite section of the Navy and sunk more enemy ships than any other group of warships involved in the war. But there was a price they paid. Fifty-two submarines, three hundred seventy-four officers and 3,131 men perished during the war.⁴ It can be argued that a more dependable weapon during the war could have reduced these losses and shortened the war. It is almost certain that protocols for better testing, monitoring and correcting of weapon failures could have improved the outcome. The cost would have been great, but arguably no more so than the cost the US Submarine Service ultimately paid.

⁴ Lockwood, *Sink 'Em*, 5.

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APPENDIX A

ORIGINAL GRAPHS

Unable to find existing graphics to show the progress made with the torpedo problems, this author went back to the original data from the Submarine Operations Research Group (SORG) to create his own. At first, the data seemed to undermine the thesis of this dissertation. Further analysis showed the results were consistent with this dissertation's arguments, but certainly raised more questions. The most perplexing finding was that, although the MK XIV/VI did finally become safer and more reliable, torpedo effectiveness improved very little throughout the war. Official torpedo data shows only about a one percent improvement in the number of ships sunk per torpedo fired, from only twelve percent to thirteen. Remember, the MK XIV/VI was supposed to sink a ship with every torpedo (100%).

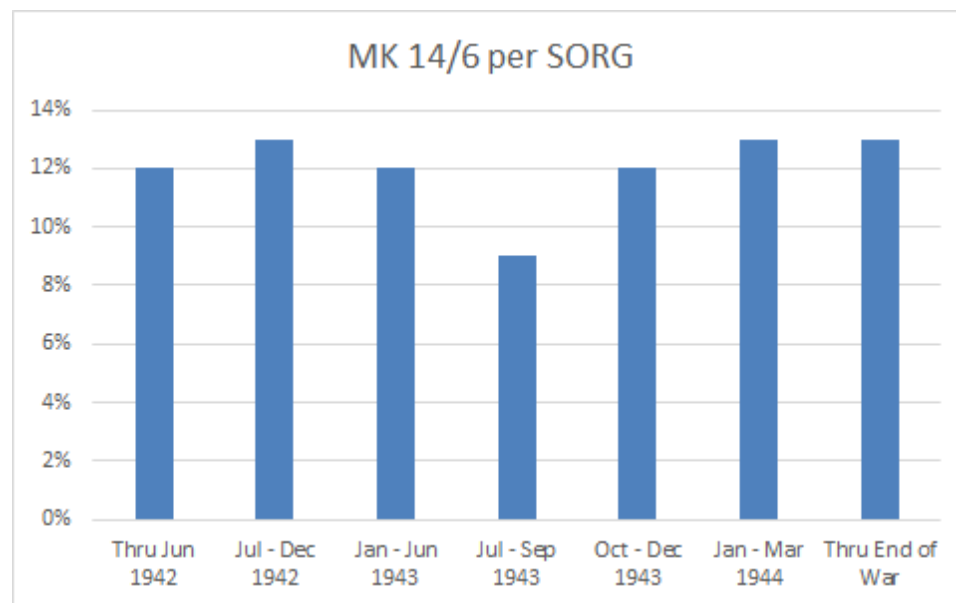


Figure A.1. Ships sunk per MK XIV/VI Torpedo

The second and third bars indicate torpedo performance after the depth issue resolved. The lack of progress was due to an increase in premature detonations. The fourth bar represents the time when the magnetic feature was turned off and the torpedoes fired on contact. Duds increased and performance decreased. After reinforcing the firing pin rails, performance improved, but never exceeded thirteen percent! This was far from the expected 100 percent. But after the navy recommended deactivation of the magnetic feature, June 1943, the strategy was no longer breaking the enemy ship's back. It reverted to punching as many holes in enemy vessel hulls as it took to sink them. The torpedoes and exploders were never improved. Rather, the high-tech features were inactivated or bypassed, reducing complexity and the risk of failures.

So, why did the men stop complaining? Certainly, they were experiencing fewer, scary mishaps such as premature detonations. But that doesn't explain why they felt more successful. So, it was time to look at success through the eyes of the submariners. Success meant sinking identified targets. To do this it was necessary to look at individual attacks. This next graph shows the percent of attacks on a vessel resulting in sinking or significant damage. The same time periods are used as for the first graph for comparison.

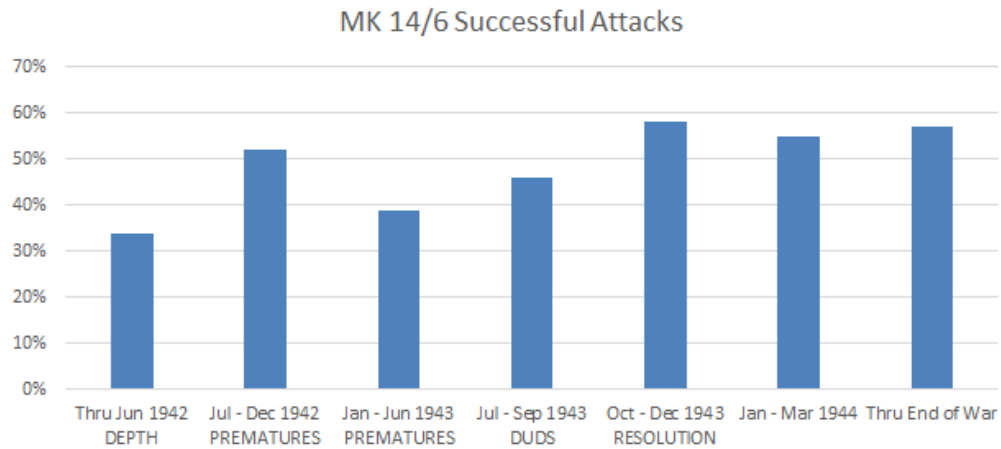


Figure A.2. Attacks Resulting in Sinking or Significant Damage

Since the improvements in the MK XIV/VI did not explain why attacks on enemy ships were more successful, the logical conclusion was that the navy now understood that the only way to sink more ships was to fire more torpedoes per attack. This was the very thing the MK XIV/VI was designed to avoid.

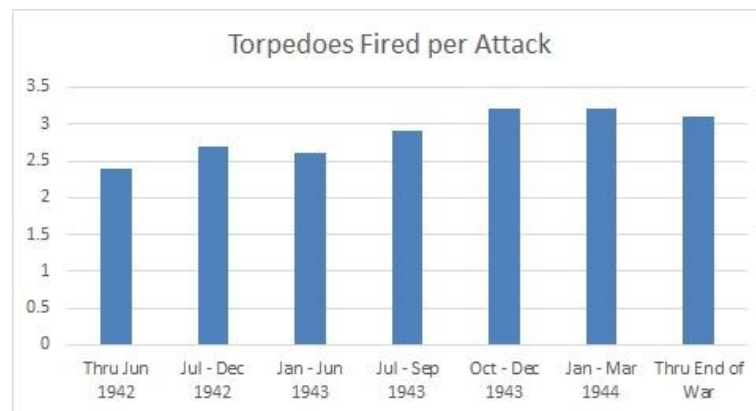


Figure A.3. Number of Torpedoes Fired per Enemy Ship

Still, successful attacks never exceeded sixty percent with any type of torpedo. The common problem, regardless of torpedo type, was getting the torpedo to hit the enemy ship. Only twenty-five to forty percent of torpedoes of any type ever made it to target.

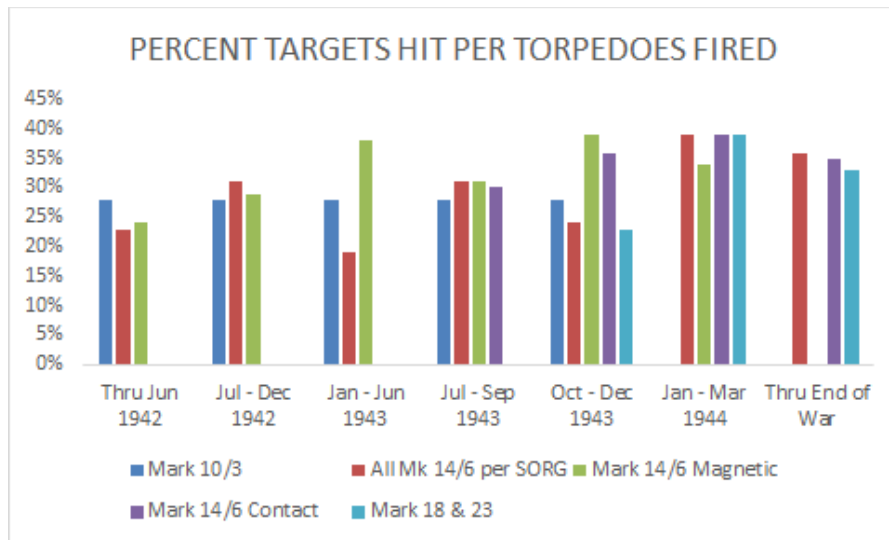


Figure A.4. Number of Torpedoes Hitting Enemy Targets

Future researchers may want to examine the reasons why torpedoes in general have such a low yield. The Fire Control process was very complicated and current technology has removed much of the complexity, perhaps improving outcomes. Data on today's torpedoes is still classified, so no comparison can be made. At the end of World War II the ideal of an invisible vessel was met, but the invisible weapon still needed work. But compare the performance of the MK XIV/VI to the performance of deck guns throughout World War II. Deck guns were lower-technology weapons with projectiles moving through the less complex medium of air and direct, visual control of their

trajectory by the men at the guns. There was no Fire Control, just aim and shoot. Yet, to use the guns, the submarine needed to surface. Again, this is what torpedoes were designed to avoid. The submariners learned to avoid being spotted so, going against the directives in place at the beginning of the war, spent more and more time on the surface battling the enemy with guns. At the end of the war there were more gun battles than torpedo battles. This graph shows why: the success of gun battles was around eighty percent (green line).

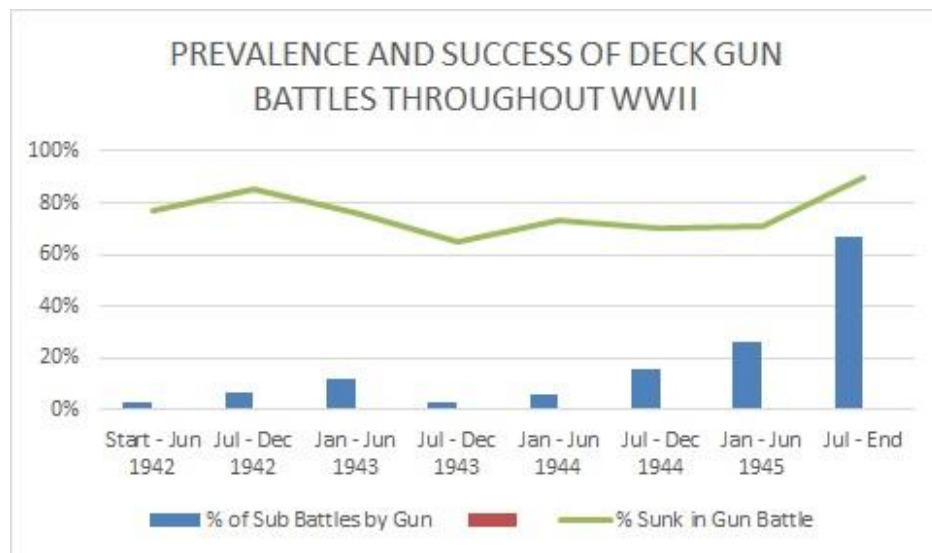


Figure A.5. Percent and Success of Attacks with Deck Guns

All graphs were based solely on official U.S. Navy data from SORG except Figure A.4. SORG did not contain information about which Mark XIV/VI torpedoes were set to magnetic influence and which were set to contact. For this information, the author relied upon all available War Patrol Reports, Action Reports and official endorsements from U.S. Naval Command from all submarines firing Mark XIV/VI torpedoes.