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1. REPORT DATE (DD-MM-YYYY) 30-05-2023		2. REPORT TYPE Certificate Essay		3. DATES COVERED (From - To) Aug 2022 - May 2023	
4. TITLE AND SUBTITLE THE QUEST TO ACHIEVE "ONE ACCURATE SHOT": U.S. NAVY TORPEDO DEVELOPMENT AND TESTING, 1896-1917				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Duke, Audrey, L.				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) John B. Hattendorf Center for Maritime Historical Research U.S. Naval War College 686 Cushing Rd. Newport, RI 02884				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Distribution Statement A: Approved for Public Release; Distribution Unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT The invention of the torpedo in the eighteenth century, initially referred to as the naval mine, kicked off decades of challenges in technological and strategic developments. The weapon system altered naval history, impacting countless battles and influencing strategy and decisions throughout the last three centuries. Lessons learned from torpedo development can be applied to better understand the research and development cycle and struggles the United States faced in fielding the complex weapon system. Although the Navy made significant progress in conducting testing, the					
15. SUBJECT TERMS Torpedoes; Torpedo Development; Testing; World War I; Naval Torpedo Station; Goat Island					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 44	19a. NAME OF RESPONSIBLE PERSON Ryan Wadle
a. REPORT U	b. ABSTRACT U	c. THIS PAGE U			19b. TELEPHONE NUMBER (Include area code) 979-739-5775

THE QUEST TO ACHIEVE "ONE ACCURATE SHOT"¹: U.S. NAVY TORPEDO
DEVELOPMENT AND TESTING, 1896-1917

An Essay

Submitted to

The Faculty of the

United States Naval War College

In Partial Fulfillment

of the Requirements for the

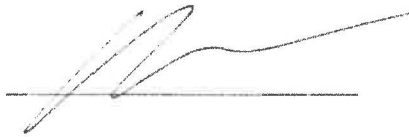
Graduate Certificate in Maritime History

¹Albert Gleaves, *Torpedoes, U.S. Naval War College Lecture* (Naval Torpedo Station Records, MSC-031, Box: July 1906, Newport, RI), 30.

THE QUEST TO ACHIEVE "ONE ACCURATE SHOT"²: U.S. NAVY TORPEDO
DEVELOPMENT AND TESTING, 1896-1917

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²Gleaves, *Torpedoes*, U.S. Naval War College Lecture, 30.

Analyzing the early history of torpedoes' development, testing, and evolution during these dynamic years illustrates the complexity of fielding a novel weapon system during a period of expansion.

From 1896 to 1917, the U.S. struggled to conduct operational tests and exercises consistently. Throughout this time, funding levels for the Navy fluctuated, technical priorities shifted, and the nation oscillated between periods of conflict and peace. The quantitative magnitude of tests, methods, specifications, and requirements of torpedo test reports from this period can be utilized to analyze the U.S. Navy's evolution in understanding the development and fielding of one of its first complex weapon systems. Although the Navy made significant progress in conducting testing, the organization as a whole did not grasp the value of the following three areas: proactive and consistent guidance for required capabilities, repetitive testing and qualification of individual components, and fleet training to build operational experience with the all-up-weapon system. In order to illustrate the Navy's struggle and progression with testing and fielding the torpedo, first, a historical analysis of the weapon system, design iterations, and its shifting battle tactics will be explored. Next, an overview of the organizations and agencies involved with advancing the technology, along with their roles and responsibilities, will be outlined. Finally, an analysis of the testing data and a critique of the testing process will be conducted.

EARLY TORPEDO DEVELOPMENT & BATTLE TACTICS

Torpedoes, also known as naval mines, can be traced back to 1777 with the invention of the Bushnell keg by the American inventor David Bushnell during the American Revolution. The design included a charge of gunpowder in a submerged keg supported by a float on the surface.

In the early years of development, navies perceived the torpedo as a capability that could challenge sea control through denial. While countries with weaker navies viewed the technology optimistically, the British naval establishment, comfortable with being the dominant sea power of the era, was cautious of funding the technology due to the fear of its ability to take away command of the sea.⁶ Fulton leveraged the curiosity and fear surrounding the technology to convince the British, French, and U.S. to conduct tests and fund the development of naval mine technologies, along with submarine trials, under his guidance.⁷ In spite of the strong views on the promises and risks of torpedoes, no navy placed a high priority on its development.

Since the naval mine introduced a new mode of warfare, challenging the honor of traditional battles at sea, many countries were hesitant to leverage the capability fully. For example, the British naval administration was intimidated by its power. It feared this new warfare mode would take away their command and power at sea. Lord St. Vincent of the British Admiralty even remarked that funding this new technology was foolish as it "encouraged a mode of warfare which those that commanded the sea did not want, and which, if successful, would deprive them of it."⁸ Additionally, Sailors felt these new weapons undermined their power and command. To sailors, their honor was their legacy, as demonstrated by Admiral Nelson's message to the fleet before the battle commenced at Trafalgar, "England expects that every man will do his duty,"⁹ and his final words before he died in the same battle, "Thank God I have done my duty."¹⁰ Even before his death, Nelson had regarded torpedo technology as a waste of time,

⁶ Richard Dunley, *Britain and the Mine, 1900–1915: Culture, Strategy, and International Law* (Cham, Switzerland: Palgrave Macmillan, 2018) 17-18.

⁷ Tom Ricci, "Robert Fulton" *The American Society of Mechanical Engineers* (May 14, 2012): 2.

⁸ Hartmann, "NSWC Technical Report: Mine Warfare History and Technology", 8.

⁹ N.A.M. Rodger, *The Command of the Ocean: A Naval History of Britain, 1649–1815* (New York and London: Penguin, 2004), 539.

¹⁰ Davey, *In Nelson's Wake: The Navy and the Napoleonic Wars*, 101.

torpedo.¹⁵ By the war's end, twenty-eight ships on both sides were lost due to spar and stationary torpedoes. Although achieving notable impact in war, the spar torpedo was ultimately replaced by the towed and automobile torpedoes due to its limited range of fewer than 40 feet and risk of injury or death to its executing crew.

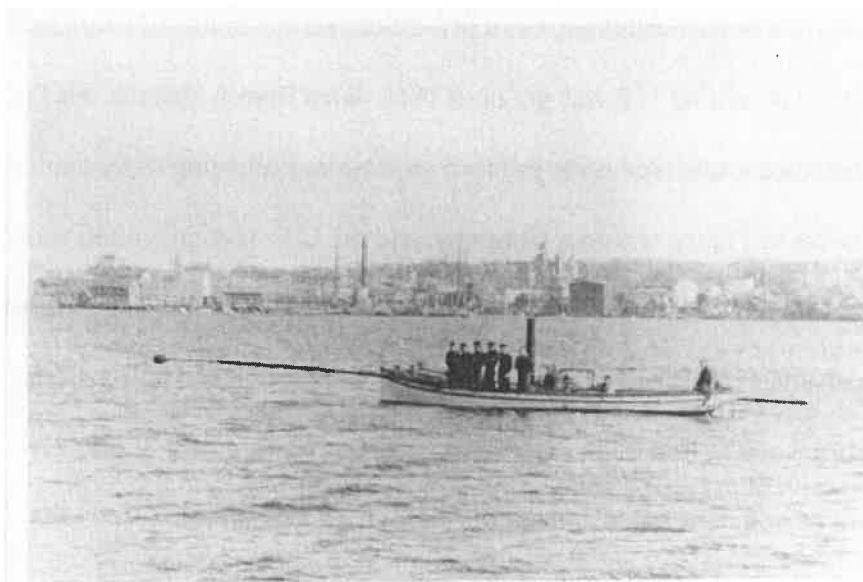


Figure 2. Spar Torpedo Rigged Out, circa 1865.¹⁶

With the advent of novel naval weapon systems and growing interest in naval capabilities due to the Civil War, Congress re-established the Bureau of Ordnance (BuOrd) in 1862 to replace the Bureau of Ordnance and Hydrography created two decades earlier. With its hydrographic functions transferred to the Bureau of Navigation, BuOrd assumed responsibility for advancing, procuring, storing, and deploying all naval weapons. After the war, the bureau continued to exist and helped drive plans to explore advanced torpedo technology further. With

¹⁵ "H.L. Hunley." Encyclopedia Britannica (03 December 2018), <https://www.britannica.com/topic/H-L-Hunley>.

¹⁶ Fig. 2, Anonymous, *Spar Torpedo Rigged Out*, BW Photograph, circa 1865, (Naval History and Heritage Command, NH 82827, Courtesy of Naval Underwater Systems Center, Newport, Rhode Island), <https://www.history.navy.mil/content/history/nhnc/our-collections/photography/numerical-list-of-images/nhnc-series/nh-series/NH-82000/NH-82827.html>.

developed. BuOrd dropped both the Harvey and Spar torpedoes from the U.S. inventory in the 1880s following the invention of the automobile torpedo.²² Rear Admiral Alfred Thayer Mahan viewed these devices as offensive-defensive measures utilized only for harbor defense, with significant drawbacks due to their reliance on night attacks at close range to the target.²³ While spar and towed torpedoes added additional tactical options, the concepts did not eliminate ship-to-ship engagements and were primarily intended for use against stationary and anchored targets until they were removed from the fleet.

In 1866, Robert Whitehead released the first iteration of his eponymous torpedo, invented from a design first conceived by Giovanni Luppis of the Austro-Hungarian Navy. A three-cylinder, compressed-air engine propelled the Whitehead torpedo and did not have horizontal control in the first iterations of the concept. In addition to horizontal control drawbacks, the first version of the Whitehead was plagued with depth control issues that were not resolved until 1870 with the introduction of a balance chamber. This pendulum-and-hydrostatic control system monitored resistance and adjusted to external water pressure.²⁴ These earliest automobile torpedoes had a speed of 18 knots and a range of 830 yards, a significant improvement over previous torpedo designs. The invention of the first self-propelled automobile torpedo marked a critical turning point in torpedo development; shifting the weapon from a defensive sea denial tool to an offensive weapon that could travel undetected underwater from a distance to strike its target.²⁵

²² Gleaves, *Torpedoes, U.S. Naval War College Lecture*, 3.

²³ John Hattendorf, *Mahan on Naval Strategy* (Annapolis, MD: Naval Institute Press, 2015), 126.

²⁴ Newpower, *Iron Men and Tine Fish: The Race to Build a Better Torpedo During World War II*, 13.

²⁵ Newpower, *Iron Men and Tine Fish: The Race to Build a Better Torpedo During World War II*, 12.

Meanwhile, in 1869 the U.S. declined an offer to purchase the design and the right to manufacture the Whitehead. Several years later, a former employee of the Whitehead Company offered to sell complete working drawings to BuOrd, but again this offer was refused as the U.S. was busy pursuing domestic solutions. Instead, the U.S. worked to produce a superior domestic automobile torpedo. In 1871, Lieutenant Commander J.A. Howell invented a two-cylinder reciprocating engine, fly-wheel propelled torpedo. The design required an air flask to hold air pressure in the hull of the device, which proved difficult for the U.S. to manufacture consistently.²⁸ With the fly-wheel design, the Howell torpedo had both vertical and horizontal control, but difficulties with leaking air flasks caused inconsistent vertical control. Although invented in 1871, the Howell was not patented and contracted for production by the U.S. Navy until 1884.²⁹ It was not until May 1891 that the Navy Department officially adopted the Whitehead torpedo when it formally entered into a contract with the E. W. Bliss Company to manufacture the Whitehead design.

The Howell torpedo was a viable competitor to the Whitehead, and both designs were pursued by BuOrd under a risk-reduction strategy.³⁰ By pursuing two solutions, the BuOrd was not relying on the success of one design, instead reducing risk by pursuing both. When the Obry Company invented gyroscopic steering gear in 1896, solving the horizontal control issues of the Whitehead, BuOrd decided to remove the Howell from its portfolio.³¹ The stumbling block of the Howell was its lack of directive force vertically. Had this problem been as successfully worked

²⁸ Newpower, *Iron Men and Tine Fish: The Race to Build a Better Torpedo During World War II*, 13.

²⁹ Stephen Stein, *From Torpedoes to Aviation: Washington Irving Chambers and Technological Innovation in the New Navy, 1876-1913* (Tuscaloosa: The University of Alabama Press, 2007), 122.

³⁰ Katherine Epstein, *Torpedo: Inventing the Military-Industrial Complex in the United States and Great Britain* (Cambridge, Massachusetts: Harvard University Press, 2014), 38.

³¹ Stein, *From Torpedoes to Aviation: Washington Irving Chambers and Technological Innovation in the New Navy, 1876-1913*, 123.

torpedoes, but the U.S. Navy fared no better, scoring no confirmed hits with torpedoes in the Spanish-American War.³⁴ Due to the Navy's underwhelming performance in the conflict, Secretary of the Navy John D. Long established the General Board in March 1900. The board was the Navy's first centralized planning institution that sought to unite the bureaus to form rational, coherent naval policy.³⁵ BuOrd, the primary decision point for advancing torpedo concepts up until this point, now had to seek approval and planning consensus from the General Board. In the early 1900s, BuOrd's requests to the General Board were often overshadowed by the fierce debate surrounding shipbuilding and battleship development.³⁶ Even though the goal of creating the General Board was to streamline naval technology development, BuOrd received fluctuating support for torpedo initiatives until the Russo-Japanese War.³⁷

In the Russo-Japanese War, both sides used Whitehead torpedoes extensively and proved their value as a weapon of offense beyond all questions of controversy. While the torpedo had not yet attained the notoriety of the gun, its striking effect, shot for shot, was significant. Similar to gunnery at the time, the weaknesses in precision and accuracy were overcome by launching higher quantities of shots, understanding only a few will hit the target. In the night attack on Port Arthur on February 8, 1904, a Japanese flotilla of twelve destroyers entered the Russian anchorage and, at a range of 200 yards, torpedoed two battleships and one protected cruiser. The night was calm and dark, and the conditions were ideal for torpedo work. Incredibly, of the twenty-four torpedoes fired, only three hit their targets, but all three torpedoes caused significant

³⁴ Gleaves, *Torpedoes, U.S. Naval War College Lecture*, 12.

³⁵ Stein, *From Torpedoes to Aviation: Washington Irving Chambers and Technological Innovation in the New Navy, 1876-1913*, 139. See also John T. Kuehn, *America's First General Staff: A Short History of the Rise and Fall of the U.S. Navy's General Board, 1900-1950* (Annapolis, MD: Naval Institute Press, 2017).

³⁶ Kenneth Hagan and Michael T. McMaster, *In Peace and War: Interpretations of American Naval History, 30th Anniversary Edition* (Westport, CT: Praeger Security International, 2008), 136.

³⁷ Craig Symonds, *Historical Atlas of the U.S. Navy* (Annapolis, MD: The Naval Institute, 2001), 121-123.

before the Bliss-Leavitt Mark VII utilized wet guncotton. Trinitrotoluene (TNT) was adopted for use in the warhead in the Bliss-Leavitt Mark VII and future iterations. Table A1 in Appendix A summarizes the torpedo types the U.S. Navy fielded in the years leading up to and through World War I.

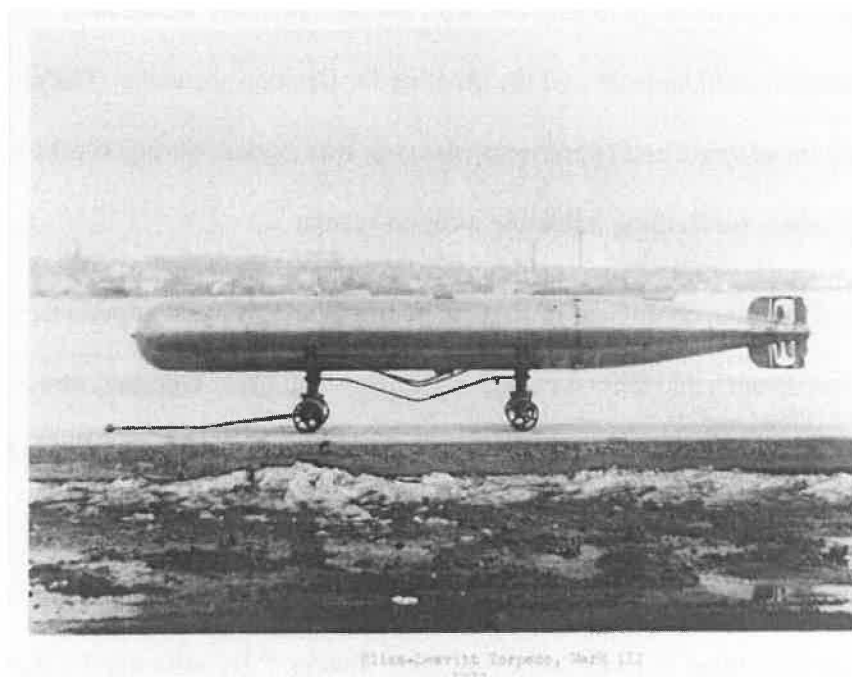


Figure 5. Bliss-Leavitt Torpedo MK 3, 1911.⁴¹

In World War I, torpedoes displayed both direct and indirect effects in battle. Indirectly, the threat of the torpedo had a significant impact on psychology, impacting decision-makers at the strategic level. For instance, the British decided to set up a distant blockade of the North Sea due to the threat of mines and torpedoes along the German coast.⁴² The British, the dominant sea power during the war, were threatened by Germany's novel advances in naval weaponry.

⁴¹ Fig. 5, Anonymous, *Bliss-Leavitt Torpedo Mark 3, 1911*, BW Photograph, 1911, (Naval History and Heritage Command, NH 82836, Copied from an original negative held by Naval Underwater Systems Center, Newport, Rhode Island), <https://www.history.navy.mil/content/history/nhnc/our-collections/photography/numerical-list-of-images/nhnc-series/nh-series/NH-82000/NH-82836.html>.

⁴² Nicholas Lambert, *Sir John Fisher's Naval Revolution* (Columbia, SC: University of South Carolina Press, 2002), 122.

submarine warfare in 1915, a U-boat torpedoed the British-owned steamship *Lusitania*, killing 1,195 people, including 128 Americans.⁴⁴ Due to the employment of U-boats and torpedoes, the U.S. joined the war on the Allies' side.

When the U.S. entered the war, the Navy deployed the Bliss-Leavitt Mark VII torpedo, which had a range of 4,000 yards at 32 knots. Opposite to Germany's success, of the eleven torpedoes fired by the U.S., zero hit their target.⁴⁵ Unfortunately, the complete failure of Bliss-Leavitt Mark VII torpedoes in the war is often overlooked. The image of thousands of American troops coming home after victory over the Central Powers overshadowed the ineffectiveness of the U.S. torpedo. Additionally, the scale of the land war drew attention away from the naval portion of the war, especially after the neutralization of Germany's U-Boats. By the time the U.S. entered the war, torpedo concepts were ready for demonstration on the battlefield after years of development, prototyping, and fleet testing. Although a rudimentary framework for developing and testing design iterations had been broadly established, testing from the component level to a fully integrated torpedo was inconsistent. While Captain William S. Sims of the Atlantic Fleet's Torpedo Flotilla had realized the importance of fleet testing and the development of tactics and doctrine, his influence had not yet ensured the successful use of torpedoes in World War I, though it did pave the way for success in the future.⁴⁶ Fleet testing and the development of tactics and doctrine are important but useless if the technology does not perform consistently.

⁴⁴ Annette McDermott, "How the Sinking of *Lusitania* Changed World War I," HISTORY Channel, 17 April 2018, <https://www.history.com/news/how-the-sinking-of-lusitania-changed-wwi>.

⁴⁵ Frank Blazich, *Newport's 90-Pound Rube Goldberg Device: Reexamining the Mark 6 Mod 1 Exploder* (National Museum of American History, September 2022), 7.

⁴⁶ Trent Hone, *Learning War: The Evolution of Fighting Doctrine in the U.S. Navy, 1898-1945* (Annapolis, MD: Naval Institute Press, 2018), 120.

While the creation of the NTS was a significant event in the torpedo's developmental timeline, it also marked the beginning of the U.S. establishing specialized technical activities to advance specific technology areas, the impact of which can be seen across the nation in national laboratories and research centers today. Upon its inception, the station served as the Navy's research and experimental center for developing torpedoes, explosives, and electrical equipment.⁴⁹

In addition to being a research center, the NTS also functioned as a school for training sailors on torpedoes. In the early years of schooling, courses were developed to teach students about the design, development, and fleet use of stationary (moored) mines, spar, towed, and automobile torpedoes. Additionally, courses included instruction on explosives in the warheads and the corresponding manufacturing process and electrical devices in torpedoes, including fuses, batteries, lighting systems, generators, and wire-guided systems. Initially, all students at the NTS were in the military and, in addition to coursework, participated in the research and development of various underwater weapons. The station continuously refined and focused its instruction as novel concepts were introduced, developed, and tested. Over the years, as the station grew, its workforce became a mixture of military professionals and civilians. Civilians provided support primarily in conducting research and filling roles in production facilities on the island.

During torpedo development, having a facility explicitly dedicated to R&D, training, and experimentation was vital to enhancing the integration and deployment of the weapon. From its inception, the NTS at Goat Island conducted a wide variety of experimental tests on numerous

⁴⁹ Simpson, *Goat Island and the U.S. Naval Torpedo Station: Guncotton, Smokeless Powder and Torpedoes*, 26.

site storage until 2018, when the NHC made the records available to researchers. Still, since the records had not been fully processed and arranged chronologically, researchers were causing damage to the documents by sifting through multiple boxes while searching for specific information. In 2021, the NHC closed the collection and began a large-scale processing project to perform conservation, stabilize the materials and arrange them chronologically to facilitate research. When the first review of the collection occurred in 1977, there were 518 boxes of documents. In 2018, the NHC noted 23 boxes unaccounted for during inventory. Thirteen of these boxes were determined to be missing before the collection's return. The remaining ten boxes may not have been checked off during inventory due to human error.⁵² The contents of the missing boxes were not tracked, and there is no way of knowing what is missing until the entire collection has been inventoried and organized. The NHC plans to have its in-depth processing complete by 2024.

Understanding the history of the records is essential when analyzing test data gathered from the collection. As of March 2023, records from 1883 through the 1920s had been processed and organized chronologically. The records analyzed in this research are specifically from the collection between 1896 to 1917. Although the collection has not been fully processed, analyzing the data from the years leading up to the U.S. joining World War I is vital to understanding the early history of torpedoes' development, testing, and evolution. While over time, some reports and documents have been lost in custody due to changes and movement of the collection, the quantitative magnitude of tests, methods, specifications, and requirements of torpedo test reports

⁵² Stacie Parillo, "NTSR Survey" Naval Historical Collection, August 2018.

attention to the necessity to understand the correlation between testing and successful integration and use by the fleet. The Navy needed to establish a strategy for technological innovation.

Without an established method or guidelines for developing, integrating, and fielding a complex weapon system, the Navy utilized a number of tests to mature torpedo technology. Notable methods included range, depth, speed, explosive and operational testing. Range testing was conducted by launching a torpedo from a testing site and measuring the distance it traveled before running out of fuel and sinking or surfacing. Range testing was generally conducted in a bay under somewhat controlled environments but also occurred in open water at sea. Variables such as water current and pressure, as well as varying torpedo speed throughout runs, make it difficult to track and measure the distance traveled.⁵⁵ As the achievable range increased, field testing in the open sea and bays became more difficult because of the difficulty in keeping the factors in the equation constant when comparing various aspects of torpedo performance. Range testing was significant in understanding torpedoes' distance limitations, which helped develop tactics and target sets.

Depth testing was conducted to ensure the torpedo could maintain a constant depth throughout the entirety of its operation. One method of depth testing included wire-guided torpedoes in which a wire was used to guide the torpedo during its run and monitor its depth.⁵⁶ Another method for monitoring depth was to mount a hydrostatic depth-measuring device to a torpedo during its run that measured water pressure as the torpedo traveled.⁵⁷ A third and low-fidelity method was visually monitoring the torpedo with a periscope throughout its run.

⁵⁵ Naval Torpedo Station Records, MSC-031, Boxes 1896 Jan – 1917 Dec. Naval War College Archives, U.S. Naval War College, Newport, RI.

⁵⁶ Polmar, *The American Submarine*, 14.

⁵⁷ Polmar, *The American Submarine*, 14.

modifications of the same variant. Given this relationship, correlating torpedo variants to target sets based on the results of speed testing was vital for successfully fielding and utilizing the weapon in battle.

Explosive testing was also conducted to understand a torpedo's explosive power and ability to damage a target. The testing occurred by detonating the torpedo against a target and quantifying the extent of the damage. Explosive testing was conducted in a laboratory as well as in the field. The detonator mechanism and timing were tested in the laboratory while war shots were fired at targets in the field. Field tests with war shots were conducted with the all-up weapon system and were not conducted often due to budgetary constraints. In the field, devices measuring the shockwave after detonation, as well as damage to the target, were methods of collecting data.⁶¹ Targets were generally retired and unusable ships. Additionally, aging tests on explosive materials were also conducted to develop an understanding of the lifespan of the materials. As the characterization of explosives increased, explosive charges were enhanced, and the capable battle damage increased. The Navy collected monthly guncotton testing data and reports outlining results and progress in the years leading up to World War I. Explosive testing enabled warhead enhancement and increased battle damage capabilities as torpedo variants progressed.

Operational testing combined all of the above methods to evaluate the overall performance and effectiveness of torpedoes in combat situations. Both NTS and the fleet conducted operational testing. Operational tests included exercise runs and war shots. Exercise runs utilized inert warheads, or exercise heads, while war shots were live fires with explosive

⁶¹ Epstein, *Torpedo: Inventing the Military-Industrial Complex in the United States and Great Britain*, 42.

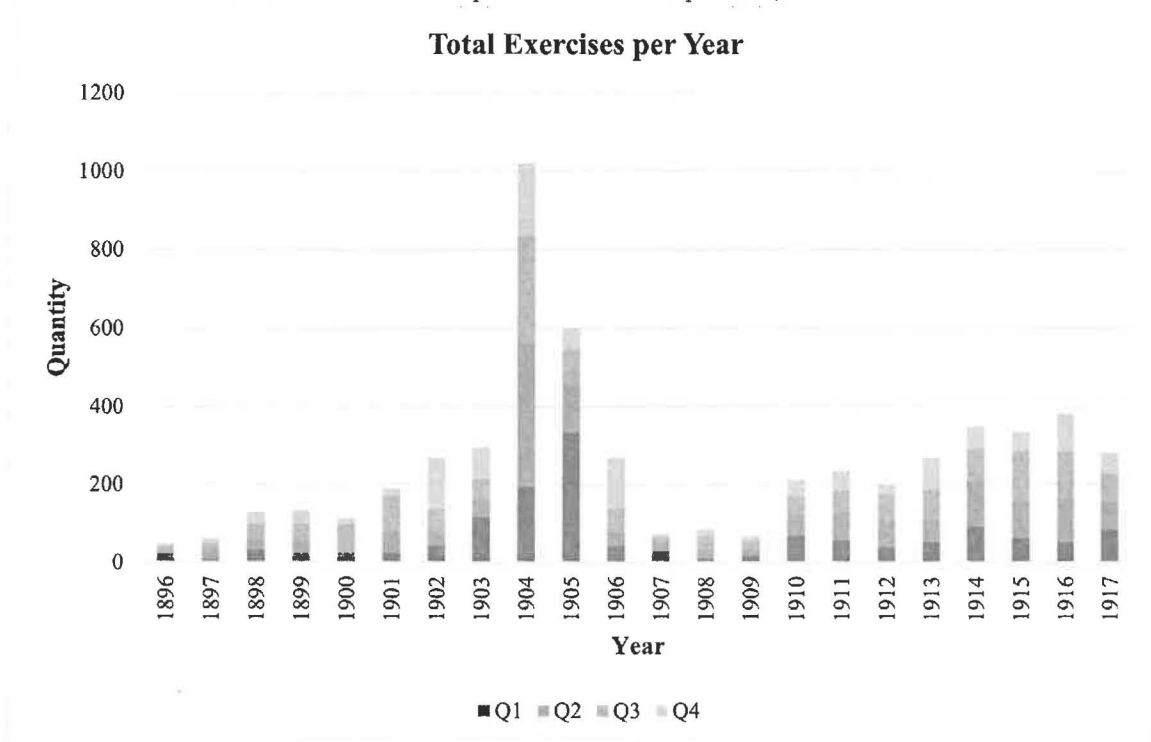
use in battle. Generally, when a weapon does not work properly in the field, the failure is tied to a specific component failure or operator error. While these reasons may be adequate, digging deeper, both can be attributed to testing or the lack thereof. For this research, the analysis will be focused on operational testing. Operational testing was selected as the focus to identify correlations between all-up weapon system exercises and effectiveness in battle. Operational testing is the final step before fielding and integration. The results of analyzing the NTS's operational data from 1896 to 1917 illustrate that there were issues in torpedo development well before World War II, which is when historians typically focus their attention on U.S. Navy torpedo failures.

With the data presented in the following sections, keep in mind the following assumptions and constraints: analysis is based on the reports in the collection, meaning some could be missing; testing reports and the format of data collection varied over the years; and variables chosen for analysis were selected based on uniform appearances in reports across the selected years. Furthermore, from 1896 to 1907, the recorded operational exercises were completed entirely by the fleet, not the NTS, whereas in 1907, there was a shift to both the fleet and NTS conducting operational testing. The shift from fleet only to the fleet and NTS will be discussed further in the following section; the charts, however, include both the fleet and NTS operational tests and do not delineate the two. Additionally, the operational tests in this analysis are for exercise runs only and not war shots. The conclusions drawn from this data do not relate to the warhead's effectiveness during this era.

Table I and II on the following page illustrates the total number of operational exercises completed yearly from 1896 to 1917. Notable spikes can easily be correlated to significant historical events. In 1898, torpedo exercises nearly doubled from the previous year due to the

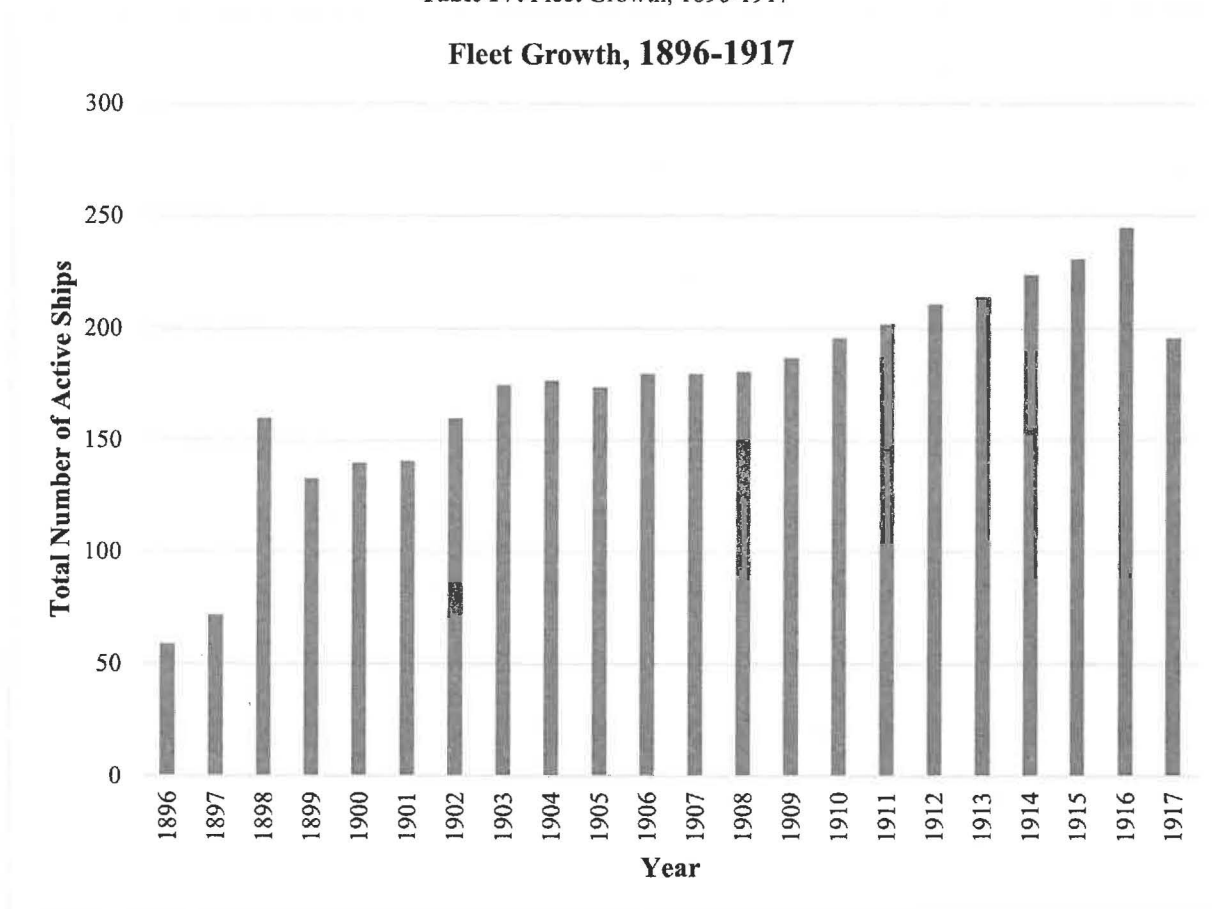
tests. Since most of the fleet was occupied with the voyage, the priority to test torpedoes decreased. As mentioned above, from 1896 to 1907, the recorded operational exercises were completed entirely by the fleet, not the NTS, whereas after 1907, there was a shift to the fleet and NTS operational testing. The shift resulted from BuOrd realizing the need to continue operational tests even when the fleet was engaged in higher-priority operations. After the return of the Great White Fleet, the number of exercises again fluctuated until the start of World War I in 1914. From 1914 until the U.S. joined the war in 1917, torpedo exercises and tests remained consistent. When the U.S. joined the war, operational tests were completed almost entirely by the NTS, which accounts for a drop in the number from the previous year.

Table I. Total Operational Exercises per Year, 1896-1917⁶⁴



⁶⁴ Naval Torpedo Station Records, MSC-031, Boxes 1896 Jan – 1917 Dec. Naval War College Archives, U.S. Naval War College, Newport.

In Tables III and IV below, the number and type of torpedoes in the fleet, as well as the growth of the fleet each year, is illustrated. As shown, the frequency of tests does not clearly correlate to the growth of the fleet and the number of torpedoes procured. In 1904 and 1905, following the Russo-Japanese War, an increase in the procurement of torpedoes occurred along with the increase in tests. As torpedoes were procured in 1904, 1910, and 1911, the number of exercises in that year also increased. On the contrary, the same trend was not displayed in 1905 or 1912 as additional torpedoes were added to the fleet. Additionally, from 1901 on, the fleet continued to grow as the nation realized the importance of maintaining a powerful navy with the influence of President Theodore Roosevelt. A drop in fleet size and the number of torpedo exercises is notable in 1917, correlating with the U.S. entering World War I, decommissioning ships, and shifting focus away from torpedo testing. Overall, torpedo procurement correlates directly to fleet growth, although trends between the two concerning the number of exercises are not consistent.

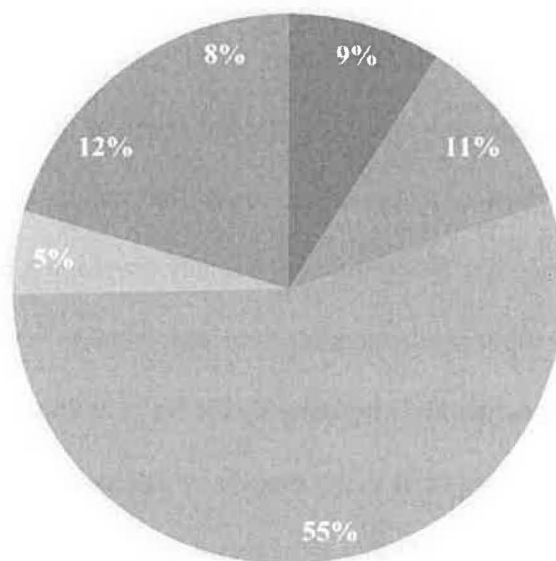
Table IV. Fleet Growth, 1896-1917⁶⁷

Results were compiled after collecting the total number of tests conducted per year. Table V illustrates the overall results from comments noted in reports and the documented error in target accuracy. Results were documented as one of the following: good run, curved left, curved right, sank/lost, surfaced early, or no comment. The good runs hit the target and operated as expected. The runs that curved left or right missed the target but did not surface or exhibit depth issues during the exercise. The tests noted as sinking or lost did not hit the target and either ran into the ground and were retrieved or lost without recovery. Tests that were completed in bays

⁶⁷ Naval Torpedo Station Records, MSC-031, Boxes 1896 Jan – 1917 Dec. Naval War College Archives, U.S. Naval War College, Newport.

Table V. Operational Test Results⁶⁸

Operational Test Results



■ Curved Right ■ Curved Left ■ Good Run
 ■ Sank / Lost ■ Surfaced Early ■ No Comment

THE EVOLUTION OF TESTING

"A good Navy is not a provocation to war. It is the surest guarantee of peace." – President Theodore Roosevelt, 1902⁶⁹

From 1896 to 1917, the U.S. struggled to conduct operational tests and exercises consistently. Although the Navy made significant progress in conducting testing, the organization as a whole did not grasp the value of the following areas: proactive and consistent guidance for required capabilities, repetitive testing and qualification of individual components, and fleet training to build operational experience with the all-up-weapon system. An all-up

⁶⁸ Naval Torpedo Station Records, MSC-031, Boxes 1896 Jan – 1917 Dec. Naval War College Archives, U.S. Naval War College, Newport.

⁶⁹ Theodore Roosevelt, "Message of the President of the United States Communicated to the Two Houses of Congress at the Beginning of the First Session of the Fifty-Seventh Congress," (Washington, DC: Government Printing Office, 1901): 29.

forces and capabilities.⁷¹ During torpedo development, BuOrd represented the closest agency to the DoD. Additionally, DoD guidance for developing weapon systems and other equipment for the military had not been created. The NTS and BuOrd, in their testing continuum described previously, paved the way for the DoD and TRL guidelines and enhanced understanding of testing requirements when developing new technology. As reflected by the various types of tests mentioned above, torpedo development was stepping through similar milestones per current DoD TRL guidelines. However, the process of repetitively testing individual components in the same controlled environment to enhance reliability before all-up system integration was not robust during torpedo development. While repetitive testing utilizing exercise heads was conducted, destructive testing was neglected. Destructive testing was more expensive to complete due to the tests expending energetics. Budgetary constraints on torpedo development led to the neglect of the firing mechanism. Since no defined and uniform process with milestones existed, torpedo developers struggled to develop a high-fidelity testing matrix for the system and all of its components, including the firing mechanism and warhead.

The following is a brief summary of each TRL and its associated milestones according to current DoD guidance: TRL 1: Basic principles observed and reported: This is the earliest stage of technology development. TRL 2: Technology concept and application formulated. TRL 3: Analytical and experimental critical function and characteristic proof of concept. The technology has been tested in a laboratory environment to prove its critical functions and characteristics. TRL 4: Component validation in a laboratory environment. TRL 5: Component validation in the relevant environment. TRL 6: System/subsystem model or prototype demonstration in a relevant

⁷¹ Roger Trask and Alfred Goldberg, "The Department of Defense 1947 – 1997," (Washington DC: Office of the SECDEF, Historical Office: 1997): 2.

that has been developed today. To adequately set the fleet up for success, testing and building reliability in the system is a necessity.

From the invention of the naval mine to numerous automobile torpedo concepts, the U.S. struggled to be proactive in fielding the complex weapon system ahead of adversaries. In the midst of an era surrounding technological advancement, the U.S. began to develop the R&D cycle, enhance domestic industry and increase experimentation and testing of novel concepts at the NTS. Balancing strategy, training, and manufacturing of a novel weapon system that was consistently advancing in capability and introducing novel modes of warfare proved challenging for the U.S. Throughout the 19th and 20th centuries, the weapon system altered naval history, impacting countless battles and influencing strategy, psychology, and decisions. Since its invention, the concept of the torpedo shifted from a stationary area-denial tool to a propelled offensive weapon capable of traveling quickly, at range to strike a moving target. Although the performance of the torpedo is often correlated to its failures early in World War II, the problems were noted decades earlier and reflected the U.S. struggle to define an optimal R&D infrastructure. Furthermore, wartime experience in World War I exposed numerous limitations of the current torpedo technology and triggered the requirement for more sophisticated doctrine in technology and strategy development.⁷⁵

Analyzing torpedo development leading to World War I adds an essential piece to the narrative and emphasizes the need for a defined innovation and fielding process with complex weapon systems. The R&D community, along with the DoD, must deliberately and consistently conduct testing of complex technologies and their components. While the U.S. Navy conducted

⁷⁵ Hone, *Learning War: The Evolution of Fighting Doctrine in the U.S. Navy, 1898-1945*, 120.

Appendix A

Table A1. U.S. Fleet Torpedo Types & Characteristics through WWI⁷⁶

Kind	Mark	Range [yds]	Speed [knots]	Explosive Charge [lbs.]	Procurements [qty]
Schwartzkopff - 3.55m	I	800	28	119	12
Howell - 3.35m	I	400	25	96	50
Whitehead - 3.55m	I	800	26	119	100
Whitehead - 3.55m	II	800	28	119	50
Whitehead - 3.55m	III	800	28	119	109
Whitehead - 5m	I	1,000	28	220	125
Whitehead - 5m	II	1,500	29	132	30
Whitehead - 5m	V	Mod 1: 4,000 Mod 2: 2,000 Mod 3: 1,000	Mod 1: 27 Mod 2: 36 Mod 3: 40	200	500
Bliss-Leavitt - 5m	I	Mod 1: 4,000 Mod 2: 4,000	Mod 1: 27 Mod 2: 26.5	200	250
Bliss-Leavitt - 5m	II	3,500	26	207	230
Bliss-Leavitt - 5m	III	4,000	26	218	210
Bliss-Leavitt - 5m	IV	Mod 1: 2,000 Mod 2: 3,000	Mod 1: 30 Mod 2: 29	200	100
Bliss-Leavitt - 5m	VI	2,000	35	200	100
Bliss-Leavitt - 5m	VII*	4,000	32	205**	240
Bliss-Leavitt - 5m	VIII	Mod 1: 10,000 Mod 2: 12,500 Mod 3: 13,500	27	320	***

*After World War I, all iterations before the Bliss-Leavitt Mark VII were discontinued from fleet use.

**TNT replaces guncotton in the warhead.

***Torpedoes of this kind were not produced until after WWI.

⁷⁶ Naval Torpedo Station Records, MSC-031, Boxes 1896 Jan – 1917 Dec. Naval War College Archives, U.S. Naval War College, Newport.

Fig. 3, Anonymous, *Whitehead Torpedo, MK 1*, BW Photograph, October 1892, (Naval History and Heritage Command, NH 84482, Newport, Rhode Island), <https://www.history.navy.mil/content/history/nhhc/our-collections/photography/numerical-list-of-images/nhhc-series/nh-series/NH-84000/NH-84482.html>.

Fig. 4, Anonymous, *Howell Automobile Torpedo*, BW Photograph, October 1898, (Naval History and Heritage Command, NH 73953, Copied from the Journal of Scientific American Coast Defense Supplement), <https://www.history.navy.mil/content/history/nhhc/our-collections/photography/numerical-list-of-images/nhhc-series/nh-series/NH-73000/NH-73953.html>.

Fig. 5, Anonymous, *Bliss-Leavitt Torpedo Mark 3, 1911*, BW Photograph, 1911, (Naval History and Heritage Command, NH 82836, Copied from an original negative held by Naval Underwater Systems Center, Newport, Rhode Island), <https://www.history.navy.mil/content/history/nhhc/our-collections/photography/numerical-list-of-images/nhhc-series/nh-series/NH-82000/NH-82836.html>.

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