Fire One, Fire Ten…: The challenge of correcting design flaws in U.S. Navy torpedoes during World War II

(*A cautionary tale of organizational structure and decentralized leadership*)

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(Originally appeared on "Strategy Bridge" Feb 2018)

Introduction: On 23 July 1943, the *USS Tinosa*, an American submarine on war patrol in the Pacific, spent the entire day firing off virtually its entire complement of torpedoes in a futile effort to sink a large, stationary, unprotected Japanese oil tanker. The *Tinosa* fired fifteen torpedoes and the final result was that twelve torpedoes hit the target *but only one of them exploded upon impact*. This was the most dramatic example of a strategic problem that plagued the U.S. Navy during the first half of World War II in the Pacific. The Pacific War was, to a great extent, a naval war and American submarines were called upon to play a strategic role in this conflict. Unfortunately for U.S. naval strategy, the majority of American torpedoes at the beginning of the war were defective and it took the first half of the war to identify and correct these torpedo design flaws. This situation had strategic consequences because it imposed costly delays on the United States as it sought to exploit Japanese strategic vulnerabilities and frustrate Japanese strategic plans.

This is an account of the torpedo crisis and it is designed to illustrate several important management issues that are embedded in this crisis. The first issue of interest relates to the question of how an advanced-technology weapons system could be deployed when it suffered from a variety of crippling design flaws that significantly affected its operational performance. The second issue of interest relates to the question of why it took the first twenty-one months of the war to identify and correct these defects. World War II was the greatest military conflict in U.S. history and the American military establishment radically and rapidly transformed itself to meet this global military challenge. The torpedo crisis was eventually resolved but the resolution took far longer and came at a much higher price than it should have. This case provides a discussion of the ways in which aspects of organizational strategy, structure, culture and leadership decisively shaped decisions and outcomes that occurred during this crisis.

Uncovering the problem: In the summer of 1943, the *USS Tinosa*, a submarine under the command of Lieutenant Commander Dan Daspit, was on patrol west of the island of Truk in the Central Pacific. On the morning of 24 July 1943, Daspit raised his periscope and stared in amazement as the 19,000 ton *Tonan Maru III* came directly into his crosshairs. A primary strategic mission for American submarines was the destruction of the Japanese merchant fleet-

and here was the largest oil tanker in the Japanese merchant fleet steaming at 13 knots without any protection in sight. It was a perfect opportunity for the submarine crew. They had been on patrol for the last few weeks but they still had sixteen torpedoes left. The American sailors immediately computed firing data and fired several torpedoes. The results were disappointing. The Japanese ship sustained some damage and came to a complete stop but it did not sink. What happened over the next few hours took the American crew from disappointment to disbelief. Able to take his time due to the immobility of his target and the lack of Japanese escort ships, Daspit deliberately fired all but one of his torpedoes in an unsuccessful attempt to sink the *Tonan Maru*. By the end of the day, he had fired fifteen torpedoes and registered twelve hits on his target. Of the twelve torpedoes that hit the *Tonan Maru*, only one actually exploded.[1]

> The sub captain saved his remaining torpedo for examination and sailed back to Pearl Harbor. The Japanese ship was eventually towed to safety. When Daspit reported to Fleet headquarters at Pearl Harbor, his commander remembers that the young sub officer was "*so furious as to be practically speechless*."[2] Even though the Pacific War was almost half over, the U.S. Navy was still struggling with the fact that the Mark 14 torpedo, the primary weapon of the U.S. submarine fleet, was defective.
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> Although American torpedoes were examples of advanced technology, it gradually became apparent that the majority (perhaps seventy-five per cent) of all American torpedoes were defective. Identifying and fixing the problem of torpedo design flaws took almost two years, in part, because of a vicious bureaucratic war that existed between submarine commanders in the Pacific and the Bureau of Ordnance back in the United States. The Bureau insisted that the unsatisfactory performance of the Mark 14 torpedo derived, not from design flaws, but from the incompetence and inexperience of submarine commanders and crews. The elimination of torpedo design flaws in late 1943 was eventually achieved by junior officers conducting makeshift tests on Pacific islands during combat operations. The fact that the problem was not solved by personnel in the research laboratories of the Bureau of Ordnance led one historian to conclude that "*The torpedo scandal of the U.S. submarine force in World War II was one of the worst in the history of... warfare*."[3]
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> **Background:** By 1941, the U.S. Navy had been anticipating war with Japan for several decades. According to American naval strategy, submarines were designed to play a key role in naval conflict in the Pacific. Although much of the American military establishment suffered from underfunding and budget shortfalls during the Depression,

the U.S. Navy entered the war with the "*finest submarines in the world.*"[4] American fleet submarines were equipped with high technology Mark 14 torpedoes that featured top-secret magnetic exploders designed to explode beneath the keel of enemy battleships. This level of submarine technology would eventually turn out to be of strategic importance in the Pacific War. Japan was an island nation that needed a large navy to project combat power and a large merchant fleet to import raw materials. Both of these factors were potential vulnerabilities and the American submarine fleet eventually turned out to be astonishingly successful at exploiting those vulnerabilities.

The Pacific War was, in large part, a war of attrition and American submarines came to be described as "*one of the most devastating weapons in the Pacific.*"[5] Before the war ended, American submarines were able to completely isolate Japan from imported food and raw materials and this was a task that German U-boats failed to accomplish against England in both World Wars. After the war, it was determined that submariners (who comprised two per cent of the U.S. Navy) were responsible for sinking more than half of all of the Japanese ships (civilian and military) that were destroyed in the Pacific War.[6]

Unfortunately for its naval strategy, America spent the first half of the Pacific War with unreliably armed submarines. The cost of this lost opportunity may be estimated by comparing submarine achievements in the first and second half of the war. By the end of 1942, after one full year of unrestricted submarine warfare, Japanese shipyards were still building ships as fast as U.S. submarines could sink them. In contrast, American submarines sank more Japanese ships in 1944 (after resolving their torpedo problems) than they did in 1942 and 1943 combined.[7]

Another strategic consequence of defective American torpedoes was the inability of the U.S. Navy to significantly impede Japanese military operations in the early months of the war. In the immediate aftermath of the Pearl Harbor attack, submarines represented a significant portion of the U.S. Navy's offensive capability in the Pacific but the torpedo problem greatly reduced their combat effectiveness. Several days after bombing Pearl Harbor, the Japanese carried out a full-scale invasion of the Philippines that led to the surrender of all U.S. forces in the Philippines five months later. A noted naval historian states that "*Intelligently employed, with a workable torpedo, submarines might have entirely prevented the Japanese invasion of the Philippines…The war in the Pacific might have been shortened by many, many months*."[8]

Background

Primitive submersibles had been featured in wars dating back to the American Revolution but it was not until the twentieth century that submarines became capable of playing a strategic role in warfare. In World War I, Germany built 390 submarines that sank millions of tons of Allied shipping in a failed attempt to blockade England. The use of German submarines against merchant shipping was a major factor in the American decision to enter World War I and the achievements of German submarines opened eyes around the world to the potential of submarine warfare.

By 1941, submarines had improved substantially in the twenty-three years since the end of World War I. One of the most advanced components on a submarine was the torpedo. By the beginning of World War II, the quarter-ton of TNT in the torpedo warhead could be detonated using one of two completely different methods. Traditionally, a torpedo was fired directly at an enemy ship and, once it hit its target, a contact exploder caused the warhead to explode. This method worked well against merchant shipping or lightly armored warships. During the inter-war period, in reaction to the unforeseen success of German U-boats, battleship design evolved to make more extensive use of compartmentalization and armor-plating. As part of the never-ending escalation of weapons design, U.S. torpedoes then evolved by making use of some of the most advanced technology of the time. Instead of firing a torpedo directly at the side of a battleship and attempting to punch through its armor plating, it was considered much more effective to have a torpedo explode as it traveled beneath the keel of its intended target.

This tactical shift required a torpedo to have three different control mechanisms. A torpedo needed to have a traditional contact exploder that enabled it to explode when it physically collided with the hull of a ship. In addition, a modern torpedo needed a magnetic exploder and a depth control mechanism that allowed a torpedo to run at a specific depth beneath an enemy ship and explode when it sensed the magnetic field of a steel hull. This allowed the torpedo to explode without ever making direct contact with its target. In the United States, the highly classified result of this research and development became known as the Mark 14 torpedo. No one realized that this new torpedo suffered from crippling design flaws that affected all three control mechanisms- the depth control mechanism, the magnetic exploder and the contact exploder.

Why weren't these problems identified before sending the torpedo to the fleet?
One of the reasons why the United States began the war with a seriously flawed torpedo can be found by examining the prewar organizational structure of the U.S. Navy. The

Navy was divided into two major, semi-autonomous components- the fleet and the shore establishment. The fleet component consisted of the three regional fleets- the Atlantic Fleet, the Pacific Fleet, and the Asiatic Fleet. (Note: in the first half of the twentieth century, there were two different U.S. Navy fleets in the Pacific Ocean. The Pacific Fleet was stationed in Hawaii. The Asiatic Fleet was stationed in the Philippines. By 1942, the Asiatic Fleet was renamed the Southwest Pacific Fleet and had been driven by the Japanese from Manila to Australia). These fleets operated under the authority of the Chief of Naval Operations (CNO). The shore establishment of the U.S. Navy primarily consisted of the technical Bureaus, many of which had existed for more than one hundred years. These bureaus (such as the Bureau of Ships and Bureau of Ordnance) were responsible for the development, design and funding of Navy ships and equipment. These bureaus were not under the authority of the CNO. They reported directly to the Secretary of the Navy and to Congress.

Slowly but noticeably in the history of the U.S. Navy, an antagonistic relationship developed between the fleet and the Bureaus. In the words of one admiral, "*it cannot be said that the Bureaus have ever been popular with the operating forces of the Navy*."[9] This antagonism made it difficult for managers at sea and on shore to effectively communicate with each other. Fleet officers resented the degree of control exercised by the Bureaus over naval funding and innovation. A biography of Admiral Ernest King (the CNO during World War II) is filled with examples of his contentious relationship with civilians in the Department of the Navy (up to and including Secretary of the Navy Knox). King's biographer notes "*King's ire frequently centered on the Bureaus of Ships, Aeronautics and Ordnance- traditionally autonomous, independent of the CNO and responsible solely to Congress and the Secretary of the Navy. Reflecting the antipathy of most seagoing officers, King regarded the bureaus as inefficient and unresponsive to the needs of the fleet*."[10]

The Bureau of Ordnance (BuOrd) was one of the most powerful of the Navy Bureaus. It was responsible for all Navy weapons and explosives and it consisted of five different divisions made up of twenty fairly independent sections. The heart of BuOrd was the Technical Division, which consisted of twelve of these independent sections. So, for example, in the Technical Division, one section was responsible for all aspects of naval guns, another for gun turrets and another for mines and depth charges. By tradition, all of these section chiefs reported, not to their division head, but directly to the BuOrd Chief. This reporting and communication structure worked well in the slow pace of peacetime activity and ensured that the Bureau chief was constantly aware of all BuOrd activity.

With the coming of World War II and the rapid expansion of the Navy, this peacetime structure caused information and action bottlenecks.[11]

The section of BuOrd that is relevant to this case is the Torpedo Section that controlled the Naval Torpedo Station at Newport, Rhode Island (NTS- Newport). The Naval Torpedo Station was responsible for developing, manufacturing and testing all torpedoes in the U.S. Navy. NTS- Newport began manufacturing torpedoes in 1907 and it quickly became a mainstay of the Rhode Island economy. As a result, the station and its civilian workforce quickly became a priority of the Rhode Island congressional delegation. These members of Congress protected the autonomy of the civilian workforce and worked hard to ensure that NTS-Newport was the sole source of torpedoes for the Navy. This is understandable given the importance of this activity to the Rhode Island economy but the result of this insulation and protection from competition was "*monumental inertia, a thin trickle of finely machined steam torpedoes (and) resistance to change*…"[12]

In addition to structural issues and organizational inertia, another significant aspect of the prewar problem was that testing of torpedoes was a very expensive process and the Navy budget was thinly stretched during the Depression. First of all, torpedoes themselves were expensive. The Mark 14 torpedo cost about $12,000 in an era when a new car cost $700. Three torpedoes cost as much as an Army tank and a thorough testing process required the destruction of many torpedoes. Secondly, ideal testing conditions would require that torpedoes be fired at targets that closely approximated their intended wartime targets and the U.S. Navy did not have many spare warships to expend on torpedo target practice. Finally, testing new advances in torpedo technology presented a never-ending challenge because torpedoes were a miniature collection of interlocking and interdependent systems- firing systems, propulsion systems, guidance systems and stabilizing systems. An improvement to one of these component systems could have unforeseen consequences on the performance of the other systems. In an ideal world, improvements in one system would trigger an entire new set of tests but, in reality, this did not occur.

The high cost of torpedoes had an additional ripple effect out in the submarine fleet. In the prewar years, submarine officers could spend their entire career without firing an actual torpedo at a realistic target. As one historian noted, "*a generation of submariners grew up without ever having seen or heard a torpedo explode*." [13] As a result, the torpedo design flaws were not discovered during testing nor were they noticed by their end-users because submariners were never allowed to train with actual, functioning torpedoes. The bottom line was that, in an era marked by severely constrained resources, the Navy had

adopted a weapons system whose cost prevented both proper testing and realistic training.

Why did it take so long to correct the problem once the war started?

During the first months of the Pacific War, the submarine fleet experienced a great deal of turmoil that obscured the problem with defective torpedoes. With the outbreak of war, one of the most disorienting aspects for submarine commanders was that submarines were suddenly and unexpectedly given a fundamentally different mission than the one for which they had trained since World War I. In the 1940s, submarines were still a relatively new addition to the U.S. Navy. There had only been a few submarines in the U.S. Navy during World War I and they had played a very limited role. In fact, the first time in the twentieth century that an American submarine sank an enemy ship with a torpedo was in December 1941 when the *USS Swordfish* on its first wartime patrol sank a Japanese ship. American submarines had spent the inter-war years practicing coastal defense missions and stealth missions against enemy capital ships. Within 24 hours of the attack on Pearl Harbor, the U.S. government unexpectedly issued an order that called for unrestricted warfare on all Japanese shipping- merchant ships as well as naval ships. This was a completely new mission for submarines. Instead of cautiously operating on the fringes of fleet actions, they were immediately ordered to boldly roam the Pacific and sink any ship with a Japanese flag. This required the submarine fleet to completely transform its strategy, culture, doctrine and tactics. As a consequence, American submarines were carrying out attacks in combat that were very different than those they had practiced in peacetime. It gradually became clear that submarine commanders who had performed well in peacetime were not necessarily the most successful wartime commanders. During the first year of combat operations, it is estimated that thirty per cent of submarine commanders were relieved of duty.[14]

A second reason for the delay in correcting the torpedo problem was that submarine warfare in World War II was, by its very nature, a highly complex operation. Submarine crews exhibited a wide variety of operational characteristics (some crews were well trained, some weren't; some skippers were very aggressive, some weren't). They were also facing enemy ships with a wide variety of operational characteristics (some were fast, some were slow, some were heavily armored, some weren't) and the subs were attacking these ships under a wide range of combat conditions- day attacks, night attacks, submerged attacks or surface attacks. As a result, U.S. submarine operations in the first year of the war displayed an unpredictable range of success and failure. In the first full year of the war (1942), U.S. submarines sank 134 Japanese merchant ships[15] but

submarine commanders became convinced that defective torpedoes had deprived them of many other opportunities. The number of variables that were present in combat operations made it difficult to arrive at indisputable conclusions about torpedo performance. It became clear that a war patrol was not an ideal laboratory for conducting valid and reliable scientific tests.

It took months of combat operations for submarine commanders and their superiors to come to the conclusion that the poor performance of the submarine fleet was primarily due to faulty torpedoes. The delay in understanding the nature of the problem was compounded by decisions that the Navy had made about its organizational structure. As the submarine arm became more prominent in the inter-war era, the Navy had to make strategic decisions about the command structure of the submarine fleet. The Navy chose a decentralized command structure for U.S. submarines and this meant that there was no over-all commander for all U.S. submarines. During the war, each of the three Navy fleets (Atlantic, Pacific and Southwest Pacific Fleets) had their own headquarters and the highest ranking submarine commanders in the U.S. Navy were stationed at each of these regional fleet headquarters.

This decentralized command structure had serious consequences for the resolution of the torpedo crisis. First of all, there was no one in Washington in a position of authority who could present the perspective of the field commanders or speak for the entire submarine community. [16] Additionally, there was no one who could ensure that all three submarine fleets shared information and coordinated their actions. As a result of this decentralization, the Bureau of Ordnance did not initiate new torpedo tests until the Chief of Naval Operations himself became involved in the issue. Regrettably, it took a long time for the torpedo problem to get to the CNO's desk because of the demands on his time during the first year of the war. Beginning in December 1941, the Navy began on a trajectory that would see it grow 850 percent (from 337,000 sailors to 3.2 million sailors) within 3 years. In 1942 alone, Admiral King had to attend several allied conferences with President Roosevelt, develop a global strategy for winning a world war, supervise the Battle of the Atlantic against German U-Boats and oversee the Battles of the Coral Sea, Midway and the Guadalcanal campaign. The press of events at the beginning of a global war left him with very little time to focus on the problems of one weapons system in the submarine fleet.

Resolution of the torpedo crisis

There were several significant events that ultimately resolved the torpedo crisis and the first of these occurred in the summer of 1942 when Rear Admiral Charles Lockwood was commander of the submarines in the Southwest Pacific Fleet. Lockwood paid particular attention to the highly critical comments written about the unsatisfactory performance of torpedoes by submarine commanders in their war patrol reports. Due to the unresponsiveness of BuOrd, he decided to carry out local tests to identify the problem. In June 1942, he had fishing nets stretched across part of Frenchman's Bay in Australia and then had the *USS Skipjack* fire inert torpedoes at the nets. Upon examination, it was found that the torpedoes made holes in the fishing nets at least 10-15 feet lower than they were programmed to do. This was the first solid evidence of the faulty depth control mechanism of the Mark 14 torpedo. When the Bureau of Ordnance was informed of the test results, their reaction reinforced the negative image held of them by many submarine commanders. "*BuOrd and NTS- Newport criticized the methodology and were reluctant to accept the results of the Frenchman's Bay firings and it was not until August of 1942, after intervention by the CNO, Admiral Ernest J. King that they re-investigated and agreed that there was a ten foot depth error in the Mark 14 system*."[17] Over the next few months, instructions and kits designed to correct the depth control problem were issued to the submarine fleet. The first torpedo defect was resolved.

The second concluding event occurred in June of 1943 when RADM Lockwood (who had now become commander of the submarines in the Pacific fleet) ordered all Pacific Fleet submarines to deactivate their magnetic exploders. This directive was caused by multiple war patrol reports that detailed the unreliable performance of these exploders. Interestingly, both the British and German submarine fleets had deactivated their magnetic exploders almost two years earlier in the Battle of the Atlantic of 1941. What the Bureau of Ordnance had not taken into account during the research and development phase was that there is a significant variance in the Earth's magnetic field depending on the location of a submarine. A magnetic exploder that was developed in New England and tested in the North Atlantic will exhibit very different performance characteristics when it is used in different latitudes on the other side of the world.[18] The Southwest Pacific fleet followed the example of the Pacific Fleet and ordered the deactivation of all magnetic exploders a few months later. These exploders were not used for the rest of the war. The second defect of American torpedoes was resolved.

The third and final event occurred in the wake of USS *Tinosa's* disastrous attack on the *Tonan Maru* in July of 1943. The *Tinosa's* commander had saved his one remaining torpedo so that it could be examined back at Pearl Harbor. The Navy had the clearest

possible evidence, almost two years into the Pacific War, that the contact exploders of the Mark 14 torpedo were defective. This problem had been overlooked earlier because it had been assumed that previous erratic torpedo performance was the fault of unreliable magnetic exploders. It became clear to Pacific Fleet submariners that their torpedoes suffered from contact exploder problems because, at the time of the *Tonan Maru* attack, all magnetic exploders had been deactivated earlier that year.

Submarine officers at Pearl Harbor conducted two different tests on the suspect contact exploders. They fired inert torpedoes at underwater cliffs near Kahoolawe and, in a second test, they lifted inert torpedoes 90 feet in the air and dropped them onto steel plates (interestingly- these tests were portrayed in a 1951 John Wayne submarine movie entitled *Operation Pacific*). The results of these tests showed that 70% of contact exploders were defective. The reason was relatively simple. In earlier torpedo models, the contact exploder had been tested and the results showed that it operated in a reliable manner. One of the improvements of the Mark 14, however, was that it ran at higher speeds that earlier torpedo models. "*What was overlooked was that in going from 33.5 knots to 46.3 knots the inertial forces involved in striking the target… were almost doubled.*"[19] Increasing the speed of a torpedo meant that the firing pin of the contact exploder would frequently warp when it hit an enemy ship and this would cause the torpedo to misfire. Once the problem was identified, new firing pins were designed and manufactured in the machine shops of the Pearl Harbor Submarine Base. The third and final defect of American torpedoes was resolved. On 30 September 1943, *USS Barb* left on war patrol with newly manufactured contact exploders. It was the first American submarine to go on patrol with a full load of reliable torpedoes- and the Pacific War was already half over.

Conclusion

In the history of warfare, change is inevitable and sometimes decisions that are made in a highly dynamic and complex world can have unforeseen and disastrous consequences. In the twentieth century, submarines became valuable strategic weapons but leaders in the United States did not fully realize the strategic importance of submarine warfare. This misunderstanding was evident in the development of the submarine command structure of the U.S. Navy. Although the submarine was capable of playing a strategic role in American warfare, there was no submariner in the U.S. Navy command structure with overall responsibility for all submarines. This was a decision of organizational structure and one of the consequences was that there was no one with operational responsibility for submarines who had the authority to focus strategic attention on submarine problems.

This was a fundamental mismatch between the operational capability of submarines and the operational structure of the U.S. Navy, similar to the idea of trying to fit a very large bullet into a very small gun. Because the U.S. Navy was not structured with a submarine officer at strategic levels in its chain of command, the torpedo problem languished for years as the subject of bureaucratic in-fighting and organizational inertia.

Ask any football coach to list their most common frustrations and at the top of the list is the fact that plays that work smoothly during practice turn out to be completely ineffective on game day. One of the most obvious reasons why the world of practice and simulations can be completely different than the real world is that strategy is an activity conducted in an environment where forces act and react in unpredictable ways. The competition can be unpredictable; customers can be unpredictable; major stakeholders can be unpredictable and all of this unpredictability can have serious and unforeseen consequences for strategy.

Two of the pivotal events in our case were examples of unpredictability. First of all, the United States was caught completely off guard by the timing and nature of the Japanese attack on Pearl Harbor and secondly, American reaction to this attack was completely unforeseen. For more than a year, the United States had watched with seeming equanimity as Nazi Germany threatened U.S. interests and attacked U.S. Navy ships in the Atlantic. The attack on Pearl Harbor, in contrast, created a violent American backlash and one aspect of this backlash utterly transformed the strategic mission of the U.S. submarine fleet. American submariners had spent the inter-war years training and preparing for a wartime mission of sneaking and peeking on the fringes of fleet action. That mission placed a premium on submarine commanders who were stealthy and cautious. As the Pacific War crashed into being, American policy makers made the snap decision to have its submarine fleet attack anything afloat with a Japanese flag. This new mission placed a premium on submarine commanders who were bold and aggressive. Submarine strategy, culture, doctrine and operations had been utterly and unexpectedly transformed by this decision and decades of personnel selection and operational training went out the window.

The torpedo crisis in the U.S. Navy was a result of the organizational conflict that developed between the fleet and the Navy bureaus, the consequences of the command structure of the U.S. Navy and the inevitable fog of war that always occurs in a dynamic and complex combat environment. This crisis was marked by antagonism, misunderstanding and a lack of trust. All of these elements conspired together to prolong

the torpedo crisis. This example has profound implications for the strategic leaders of today's world. Twenty-first century organizations are nothing more than collections of specialized and semi-autonomous units and their ability to coordinate activities and work together is central to effective operations. Strategic leaders have to be expert at bridging organizational boundaries because those who are expert at this task will usually have competitive advantage over those who are not expert at this task.

[1] Theodore Roscoe, 1949. *United States Submarine Operations in World War II*. Annapolis, MD: United States Naval Institute.

[2] Charles A. Lockwood, 1951. *Sink 'Em All: Submarine Warfare in the Pacific*. New York: E.P. Dutton & Co. p. 112.

[3] Clay Blair, 1975. *Silent Victory: The U.S. Submarine War Against Japan*. Philadelphia and New York: J.B. Lippincott Company. p. 879.

[4] Ronald H. Spector, 1985. *Eagle Against the Sun: The American War with Japan*. New York: Vintage Books. p. 451.

[5] Samuel Eliot Morison, 1963. *The Two-Ocean War: A Short History of the United States Navy in the Second World War*. Boston: Little, Brown and Company. p. 493.

[6] Roscoe, p. 493.

[7] Ibid., p.523

[8] Blair, p. 20.

[9] Julius A. Furer, 1959. *Administration of the Navy Department in World War II*. Washington, D.C.: U.S. Government Printing Office. p. 206.

[10] Thomas B. Buell, 1980. *Master of Sea Power: A Biography of Fleet Admiral Ernest J. King*. Boston: Little, Brown and Company. p. 235.

[11] Furer, p. 316.

[12] Blair, p. 31

[13] Wilfred J. Holmes, 1966. *Undersea Victory: The Influence of Submarine Operations on the War in the Pacific.* Garden City, NY: Doubleday & Company. p. 43.

[14] Blair, p. 361. Also see Montgomery C. Meigs, 1990. *Slide Rules and Submarines: American Scientists and Subsurface Warfare in World War II*. Fort McNair, Washington, D.C.: National Defense University Press. p. 162.

[15] Roscoe, p. 523.

[16] Holmes, p. 45.

[17] Frederick J. Milford, 1996. U.S. Navy Torpedoes. *The Submarine Review*, October, 1996. pp. 3-4.

[18] Blair, pp. 61-62.

[19] Milford, p. 8.