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Mark XIV Torpedo Case Study

26 February 2011

by

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Graduate School of Business & Public Policy
Naval Postgraduate School

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Abstract

The U.S, Navy submarine force entered World War II with a defective primary weapon system, the Mark XIV Torpedo. It was developed in the mid 1920's, but never adequately developmentally or operationally tested prior to entering full rate production. After the inception of hostilities, submarine commanders reported multiple problems with malfunctioning torpedoes. This case study presents the Mark XIV's developmental history, initial combat performance, and the 21 month effort to find and remedy the three root causes that were significantly degrading the torpedo's combat effectiveness. The study subsequently analyses the derived lessons learned in requirements development, developmental testing, and operational testing.

Keywords:

Torpedo, submarine, testing, requirements

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An Ordnance Corps logistician for the first two decades of his career, he served successively in the office of the Deputy Chief of Staff for Logistics, HQ, Department of the Army; Chief of the Logistics Division, Multiple Launch Rocket System Project Management Office; Commander of the U.S. Army logistics and materiel acquisition organization assisting in the modernization of the Royal Saudi Land Forces; and finally, as Project Manager, Army Tactical Missile System from 1990-1994. During the latter assignment, he was selected to receive the Secretary of the Army's 1991 Project Manager of the Year Award. In June 2003, December 2004, September 2007, and again in June 2009, he was selected to receive the Meyer Award for Teaching Excellence in Systems Engineering. He has served for the past sixteen years as a Senior Lecturer at the Naval Postgraduate School, teaching Project Management, Acquisition Logistics, and Defense Systems Acquisition.

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Table of Contents

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Introduction

The Mark XIV torpedo started development in 1922, but the Navy Bureau of Ordnance (Bu Ord) did not get it fully operationally effective and suitable until the late summer of 1943, despite U.S. Navy submarines having taken it to war on December 7, 1941. It is one of the saddest tales in all of Defense Acquisition and is the motivation for assembling this case study.

I put together a Mark XIV torpedo case study in 1996 as a class presentation and have since supplemented that with a History Channel documentary that came out in 2001. The subject of this case study is the Navy's primary submarine-launched torpedo at the inception of WWII—the Mark XIV. In this case study, I discover lessons learned in requirements determination, particularly the danger of not reacting when the requirement changes, and also in developmental and operational testing. The biggest lesson, as I will demonstrate in this case study, is the risk taken when adequate developmental and operational testing are not performed. Another lesson learned is what happens when complaints from the field (or, in this case, from the fleet) are received that something is wrong with their equipment and those complaints are not taken seriously. Developmental activities that try to blame operator incompetence or laziness for poor hardware performance without conducting a thorough investigation of operator concerns put American warfighters' lives at risk.

In the case of the performance problems experienced by the Mark XIV torpedo, there were three separate root causes that I will discuss as the case study unfolds. I look at the Mark XIV torpedo from its gestation in 1922 until the last of the three root causes was discovered and "fixed" in the late summer of 1943. Obviously, with Pearl Harbor occurring in December 1941, it is clear that it took an inordinately long time (21 months) to finally fix the Mark XIV torpedo so that it was a combat-effective warshot torpedo with a high probability of destroying the Japanese merchant ships against which it was primarily targeted. The trouble-shooting challenge was exacerbated because the three root causes masked each other.

The Germans fought with torpedo-firing submarines in a very successful (at least initially) Battle of the Atlantic in WWI that almost severed the sea lines of communication (SLOC) to Great Britain. They were poised to severely interrupt the war effort by constraining food, ammunition, and war supplies en route to Great Britain because they sank so many Allied merchant ships prior to the implementation of the convoy system. The U-boat successes in WWI validated the potential effectiveness of the torpedo-firing submarine as both a tactical and a strategic weapon for future wars.

In WWI, the torpedo-firing submarine was a strategic weapon in the sense that the Germans were trying to blockade England and the Allies. It was projected to become a tactical weapon in WWII because the U.S. Navy's plan was that the next generation of U.S. submarines that were being developed during the 1920s (which became known as the "fleet boat") would operate with the U.S. battleship fleets.

In the 1920s, the U.S. battle fleet consisted of battleships that had maximum speeds of in the range of 18–22 knots. The fleet boat submarine that was designed in the 1920s was developed against a requirement to achieve a surface speed of at least 21 knots so that it could keep up with the battle fleet. It was envisioned that this fleet boat would be an auxiliary in battleship-to-battleship surface warfare and that U.S. submarines would be coordinated to go out and attempt to sink and damage the enemy's battleships. Therefore, with that concept as the initial requirement, torpedo efficacy against capital ships was to be the key to success. However, it turned out that the U.S. Navy undersea warfare community, for a number of different reasons, was not up to the task. The biggest impediment was the insular nature of the Bu Ord's torpedo program that was located on Goat Island at the Naval Torpedo Station, Newport, RI. The Navy did not generally realize that its torpedo designs were somewhat archaic compared to those of the Europeans, and more particularly to those of the Japanese (Blair, 1975, p. 881).

The Imperial Japanese Navy torpedoes devastated the U.S. surface fleet in the initial battles off of Salvo Island in August 1942, right after the U.S. Marine Corps' amphibious invasion of Guadalcanal. The U.S. lost so many ships that the Sailors came to call the area "Iron Bottom Sound." The vulnerability thus created led to the remainder of the fleet abruptly leaving Guadalcanal after only three days of partially unloading the logistics support for the 1st Marine Division. The Japanese Navy's night-fighting acumen and superior surface-launched torpedoes (known as the "Long Lance") had destroyed much of the U.S. naval combat force, particularly its cruisers, in the preceding two nights of combat. Japanese surface-launched torpedoes were 24 inches in diameter. U.S. and Japanese submarine-launched torpedoes were both 21 inches in diameter. The latter had 50% heavier warheads and higher energy fuel than did the Mark XIV. Therefore, Japanese torpedoes were faster and considerably more destructive than the U.S. torpedoes. The Japanese Navy's successes basically left the supply fleet "denuded" of capital ships to defend themselves, and Vice Admiral Gromley felt that he had to withdraw, leaving MG Vandergrift and the 1st Marine Division with very little artillery and ammunition because these things were not yet unloaded and leaving them short on most other supplies and equipment.

In fact, the Seabees built Henderson Field airfield primarily with captured Japanese equipment that they had been using to build their yet-to-be operational airfield when the U.S. landed. To a significant extent, the Marines had to live off captured rations and other supplies.

The MARK XIV was part of a family of three related U.S. torpedoes. The U.S. had the surface-launched Mark XV torpedo that was carried by destroyers and by cruisers that were equipped with torpedo tubes. The U.S. also had the air-launched Mark XIII torpedo as well as the submarine-launched Mark XIV torpedo.

The Bu Ord in the interwar U.S. Navy was known informally as "the Gun Club." The Bu Ord no longer exists because the Naval Sea Systems Command (NAVSEA) has usurped its functions along with the functions of many other ship-related organizations, such as the Bureau of Engineering (Bu Eng), the Bureau of Construction and Repair (Bu C & R), etc. At both the time between the world wars as well as during WWII, the Bu Ord was probably the most powerful bureau in the Navy bureaucracy regarding ships, explosives, and weapons. They were known as the Gun Club because their focus between the wars (actually even before WWI) had been on Dreadnaughts, which had evolved into battleships and were mounted with the largest possible guns. During WWI, very few battleships had guns any larger than 14 inches. The standard in WWII was 16 inches. The Japanese had two illegal (that is, illegal under the Washington Naval Treaty of 1922) "super battleships" with guns slightly larger than 18 inches. The basic interwar idea of naval warfare was that your battleships had to sink the enemy's battleships; effective guns and gunnery acumen, of course, were absolutely essential for that. The Bu Ord—although responsible for torpedoes, mines, and explosives, as well as for guns and projectiles—was primarily known as the Gun Club.

In addition, the Bu Ord had become an elitist organization that received primarily the very highest ranked Naval Academy graduates to perform their shore tours there. After their initial sea tour, many of them were sent to graduate school. In the case of the Newport Torpedo Station, they were sent to the Massachusetts Institute of Technology (MIT), which featured a torpedo curriculum and torpedo labs that worked with the Navy at Goat Island. One of the officers sent to that course was a submarine-qualified lieutenant named Ralph W. Christy who, when he finished his master's degree, was assigned to Goat Island. He was placed in charge of what today would be called a "black project" to develop a magnetic influence exploder for the U.S. submarine-launched torpedo, the Mark XIV.

The first question that arises is why did the U.S. need a high-technology magnetic influence exploder instead of just a conventional contact exploder that would initiate the warhead when a torpedo impacted the hull of a targeted ship? Torpedoes had been around for a long time; it was a primitive "torpedo" carried by Huntley, a Confederate States of America submarine, that tried to sink a Union warship in Charleston Harbor, SC, during the Civil War. The torpedo was temporarily attached to the submarine and then to an enemy warship. The Huntley ended up sinking herself after attaching its warhead to a Union man-of-war. Torpedoes had been slowly developed worldwide in the late 19th century, and by the advent of WWI, the Germans and the British had pretty effective torpedoes.

Torpedoes were viewed by battleships as a threat, particularly those with torpedo boats (patrol torpedo boats or PT boats) and particularly because torpedo-armed destroyers and cruisers were abundant in the world's navies. Therefore, battleships were being designed with what are called "torpedo blisters." This meant that outside of their armor belts, they had a second unarmored hull that was usually filled with drinking water and, once they had converted from coal, with fuel oil; it was designed to be a "sacrifice structure." If a torpedo with a contact exploder were to hit it, it would blow a hole in this outer hull that would leak out drinking water, oil, or whatever was stored in there, but it would protect the main hull of the battleship from being impacted by the torpedo. The enemy would have to make a pretty lucky shot to put a second torpedo through the hole made by the first one and reach the primary hull; most battleships were built on this premise. WWI battleships were very wide, and part of that width was the torpedo blisters. A potential way around the torpedo blisters is to have a torpedo that explodes beneath the targeted ship. Figures 2–10 show pictures from the operational test of an Australian Mark 48 advanced capability (ADCAP) Torpedo (built under license from the U.S.).

When an explosion takes place in water, particularly at depth, the water has a tamping effect in all directions except straight up because that is the path of least resistance. When the torpedo warhead detonates, it is almost as if there is a lens that focuses the force of the torpedo's explosion straight up. If a torpedo were to explode under the keel of a ship and all the force were focused upward, it would probably would break the keel, or at least do great damage. The explosion might not break the keel of a large battleship with the first torpedo, but it would break the keel of a smaller ship, and it certainly would create very significant damage inside the battleship in the areas where the torpedo exploded.

This idea of developing a magnetic influence exploder was based on attempts by the Germans in WWI to make a magnetic influence–triggered sea mine. This emerging technology was very appealing in terms of the torpedo's efficacy, or "combat effectiveness" in today's lexicon, against an enemy battleship. The idea was that the magnetic field inherent in the battleship would be sensed by the torpedo and used to detonate it at the proper time. There were a lot of fallacies with that concept, which I will discuss later.

Figure 1 below provides the background of a test that demonstrates the destructive force of a torpedo detonating directly under the keel of a warship. Figures 2–10 are a series of photographs of a 1999 Royal Australian Navy operational test of an Australia-manufactured version of a U.S. Navy–designed Mark 48 torpedo that dramatically demonstrate the destructive power of a warhead detonated directly under the keel of a target ship.

THE AUSOME POWER OF THE SUBMARINE LAUNCHED MARK-48 TORPEDO

On Monday June 14, 1999 the Australian Collins class submarine, HMAS *Farncomb*, fired a Mark-48 war-shot torpedo at the 28 year old former Destroyer Escort *TORRENS*.

The firing was part of the *Collins* class trials requirements and was designed to validate the submarine's combat system. The submerged *Farncomb* fired the Mark-48 torpedo at the stationary hulk of the 2700-ton Destroyer Escort from over the horizon. The plume of water and fragments shot some 150 meters skyward as the blast of the torpedo cut the ship in two. The stern section sank rapidly after the torpedo hit, the bow section remained afloat but sank sometime later.

The torpedo warhead contains explosive power equivalent to approximately 1200 pounds of TNT. This explosive power is maximized when the warhead detonates below the keel of the target ship, as opposed to striking it directly. When the detonation occurs below the keel, the resulting pressure wave of the explosion "lifts" the ship and can break its keel in the process. As the ship "settles" it is then seemingly hit by a second detonation as the explosion itself rips through the area of the blast. This combined effect often breaks smaller targets in half and can severely disable larger vessels.

The Mark-48 torpedo used in this test is a variation of the MK-48 ADCAP (Advanced Capability) torpedo developed for the United States Navy.

Photos and Mk-48 Torpedo information provided by Maritime Headquarters and DSTO Australia. Photos by PO Scott Connolly and AB Stuart Farrow.

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Figure 1. Test Background
(Navy Undersea Warfare Center, 1999)

Figure 2 is a picture of the obsolete full-sized Australian destroyer that served as the test target. Everything useful was removed from the destroyer—all turrets, depth charges, secondary armament, etc. The configuration is visible in subsequent photos. Figure 2 shows the target ship sitting dead in the water waiting to be engaged.

Figure 2. Destroyer Prior to Detonation
(Navy Undersea Warfare Center, 1999)

Figure 3 is a photograph of the moment the torpedo was detonated. The photograph shows that smoke has been blown out of the stack because of the power of the explosion, and it shows that water is starting to erupt on either side of the ship. In Figure 3, the ship already appears to have had its keel broken because the bow and the stern are lower than the center of the ship.

Figure 3. Initial Reaction
(Navy Undersea Warfare Center, 1999)

Figure 4 is a photograph of a few seconds, maybe even milliseconds, later. The explosion has propagated even further, and the power of the torpedo warhead's explosive is visible as it goes straight up through the bowels of the ship along the center line—and it only gets worse.

Figure 4. Further Damage
(Navy Undersea Warfare Center, 1999)

Figure 5 clearly shows that the back of the destroyer has been broken. The extensive level of damage that is taking place is obvious.

Figure 5. The Keel Has Broken
(Navy Undersea Warfare Center, 1999)

Figure 6 shows that the level of damage is now catastrophic.

Figure 6. Bow and Stern Sections Separate
(Navy Undersea Warfare Center, 1999)

As the smoke clears in the photograph in Figure 7, it is clear that the destroyer has broken into two halves and that the stern section is about to sink.

Figure 7. The Stern Begins to Sink
(Navy Undersea Warfare Center, 1999)

Figure 8 shows that the observation made in Figure 7 is accurate: the stern section is headed to “Davey Jones’ Locker.” The photograph in Figure 8 is a close-up of the destroyer as it slips beneath the waves.

Figure 8. The Stern Slips Under the Waves
(Navy Undersea Warfare Center, 1999)

Figure 9 is a close-up photograph of the residual debris field.

Figure 9. The Stern Disappears
(Navy Undersea Warfare Center, 1999)

Figure 10 is a photograph of the bow section of the ship. As the photograph shows, it is not economically repairable. The damage is so bad that by the time the Australian Navy would have tried to salvage what is left there in order to rebuild a new ship around it, it would have been better to have started from scratch. Plus, ship designs evolve, and if this were an older ship, it would probably be better from a cost-effectiveness standpoint to acquire a "latest and greatest" warship of a similar class to replace this one. In this test, the bow section actually sank a few hours after the photograph in Figure 10 was taken.

Figure 10. The Residual Bow Section
(Navy Undersea Warfare Center, 1999)

Coming back to the Mark XIV's developmental history, there were significant technical challenges facing the Mark VI magnetic exploder. First, there was the signature of the target ship's magnetic fields. A "secret" test that was done at the equator in the very early 1930s that attempted to characterize the magnetic field of (in this case) the heavy cruiser Indianapolis. Ironically, this cruiser was the same Indianapolis that took the “Fat Man” Plutonium bomb to Tinian Island in July 1945 and, after departing the island, was somehow lost track of by the Navy and sunk by a Japanese submarine. The crew spent about four days in shark-infested waters before the Navy realized that the Indianapolis was missing. A search was mounted, the cruiser’s sinking site found, and the remaining survivors finally rescued.

Second, although they did conduct this one magnetic field test, Bu Ord did not readily realize that in divergent parts of the world, the magnetic fields have different characteristics and that it is very hard to capture those—this was particularly true with the immature technologies of the time.. At that point in time, the magnetic influence exploder was impractical, but Newport did not realize it; Lieutenant Christy pushed it through in ignorance. Due to a shortage of funding, Bu Ord did only limited, but very inadequate, developmental testing. Based on only two live fire shots (one of which failed), they declared the Mark XIV torpedo developmental program (complete with the Mark VI magnetic exploder) a success and began producing the torpedo in quantity.

The Mark XIV was constrained to a warhead 21 inches in diameter (the same diameter as the torpedo) because all the torpedo launching tubes that the U.S. had in its Navy at that time were 21 inches. With that large of an infrastructure investment in launchers, the Navy had no choice but to have the same size torpedo that the launcher was built for.

Therefore, Bu Ord had to make some trades in the requirements between speed, range, and warhead size in order to optimally engage moving targets. The faster a target is moving, the harder it is to hit. The Mark XIV torpedo ended up having two speeds: one a slower 31.5-knot speed that permitted long-range engagements of up to 9,000 yards, and the other a higher 46-knot speed for shorter ranges of up to 4,500 yards in order to yield better accuracy (Blair, 1975, p. 61). If the speed of the target over a long range with a slow torpedo were miss-estimated, the chances of achieving a hit would be poor.

There was also an issue on the propulsion for the torpedo. The U.S. ended up using a steam torpedo where a chemical reaction was supposed to be used in order to create steam to drive turbines that, in turn, drove the propellers. The result was a torpedo with a sizeable wake of gas bubbles that told anyone being fired upon that coming right at them was a torpedo. In many cases, sighting the wake would give the target time to maneuver and avoid the torpedo entirely. The physical size of the Mark XIV was limited by the existing U.S. Navy torpedo-launching infrastructure, and so in order to carry enough fuel to attain the required range, the warhead's lethal mechanism was restricted to only about 500 pounds of TNT (initially). This relatively lightweight warhead was another reason why the magnetic influence exploder was adopted; it optimized what explosive weight could be carried by theoretically detonating more destructively directly under the keel of the enemy target.

The Japanese, on the other hand, used a fuel of liquid hydrogen peroxide that yielded much more energy and gave their torpedoes considerably more range than those of the U.S. or, in the trade-off, much more speed. Because of their more energetic fuel, the Japanese could trade-off fuel capacity to increase the size (and, therefore, lethality) of their warheads to about 750 pounds.

There were also issues with depth control. Depth control on the Mark XIV was very complicated because of the complex hydrodynamic control subsystem that Bu Ord had developed without adequate testing. Due to very limited testing, the Navy did not know that it had a depth control problem with the Mark XIV until operational skippers started reporting their suspicions at the onset of WWII.

There were also logistics and maintenance issues. Eli Whitney and his concept of interchangeable parts did not apply to torpedoes. Critics alleged that the torpedoes were over-engineered and handmade by skilled machinists. The parts, in many cases, were custom-matched and, therefore, not readily interchangeable between different torpedoes. The parts were similar, but each torpedo was carefully machined to very tight tolerances. This process resulted in the lack of a universal set of interchangeable parts, which added markedly to the logistics burden placed upon Sailors. In addition, functions such as the depth control, which was very sensitive, required frequent adjustments and a lot of skill to maintain properly.

In order to help clarify why critics accused Goat Island of “splendid isolation” (Bridges & Weiss, 2000), let me also provide a little political history. During WWI, the Navy activated a second torpedo factory in Old Town Alexandria, VA, which today is a boutique and art gallery. At the end of WWI, congressional delegations from the New England states of Massachusetts, Connecticut, and Rhode Island—worried about jobs and influence—persuaded Congress and the DoN to close the Alexandria torpedo station in order to have only one torpedo station, which was to be at Newport on Goat Island.

Everything was consolidated at Goat Island by about 1919. Now, add a black project, add an island well out in Newport harbor with severe security restrictions on who could even land on it, and add inadequate developmental and test funding and it creates a prescription for potential developmental disaster.

During WWII, the Navy reopened the Alexandria torpedo factory and also built an additional one on the West Coast at Keyport, WA, which is right next to Bangor on the Olympic Peninsula, where the ballistic missile submarine base is today. Keyport it is one of two bases that hosts the Navy Undersea Warfare Center.

Because of the torpedo shortage that arose in light of the 1938 Munich Agreement between the British, French, and Hitler, and because of the likelihood of a WWII, the U.S. Navy suddenly realized that it had to rapidly expand production of the Mark XIV. These expensive, difficult-to-machine torpedoes had been produced by Newport at a very low rate because of cost and production constraints, and the Navy now forecasted a severe shortage if the U.S. were to have to go to war.

Therefore, at the outbreak of World War II, submarine captains were told to exclusively use the magnetic exploder to economize upon torpedoes so that a submarine could expend just one torpedo per target and stretch the existing stockpile as far as possible.

The direction to exclusively use the magnetic exploder made the Navy dependent in combat upon an inadequately tested and, as it turned out, unreliable magnetic exploder. Submarine attacks also suffered from premature detonations. There were several reasons for that. First, the torpedo did not "arm" until it was a safe distance from the submarine in case it did explode accidentally. Second, skippers' ignorance of the differential worldwide magnetic fields meant that in some areas of the world when the magnetic exploder armed, it immediately went off because it sensed the magnetic field signal for which it was programmed. However, this signal was not coming from an enemy ship; instead, it was coming from the earth.

A third major deficiency appeared when submarine captains, seeing torpedoes run under a target without detonating, started setting them to run shallower because they wanted to rely on the contact exploder. However, they found that even when set shallow, the torpedoes did not explode and appeared to run under their targets. After receiving many complaints, Bu Ord sent a team of experts to Pearl Harbor in late January 1942 to inspect the torpedoes and submarines. The team talked to the crews and skippers and concluded that poor torpedo performance was an operator maintenance and training problem and was aggravated by unaggressive skippers. They asserted that the problem was not the torpedoes, and they did not do any further empirical testing on the Mark XIV torpedo at that time.

A report about this visit that was made by a senior COMSUBPAC staff officer at the time of the visit read as follows:

> The Bureau of Ordnance flew a [team headed by] torpedo expert, Lieutenant Commander Walker, all the way out from Washington to investigate torpedo problems. He put us through rigorous drills preparing torpedoes for firing and in routine maintenance procedures. Near the end of our checklist in getting one of the torpedoes ready, Walker interrupted the proceedings, made a couple of checks, then directed me to lock the gyros in place. I looked … and noted that he had turned the gyro backwards [a Mark XIV 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 the enemy ships instead of our own. His face fell half a foot. … Walker did not point out a single fault in our preparations and maintenance procedures; nevertheless, [his] report, in summary, placed all of the blame for torpedo problems on fleet boat personnel. As a result, the Bureau of Ordnance reaffirmed their position that the Mark XIV torpedoes ran at their set depth. (Blair, 1975, p. 170)

At this point I need to add one other thing that brings me back to the original fleet boat requirement. The fleet boat, being designed to fight alongside the battleships, had only a secondary mission as a commerce-raider in its strategic role of strangling the enemy by cutting its sea line of communication. That concept was knocked in the head shortly after the Washington Naval Conference of 1921 and its resultant treaty. The intent behind the treaty was to try and stop a growing naval arms race, and it was only reluctantly agreed to by the Japanese, who it turned out never lived up to it anyway. The treaty restricted battleships and some other capital ships to a 5-5-3 ratio. For every five battleships that the U.S. and Great Britain were allowed, the Japanese were allowed to have three. The Germans were not allowed to have any battleships under the Treaty of Versailles.

The U.S. had two battle cruisers under construction at the time of the Washington Naval Conference of 1921. Under the terms of the treaty, the U.S. was not only going to have to scrap some old battleships but also it was going to have to scrap the two battle cruisers that were still under construction. Battle cruisers are now a defunct class of ship, but an anecdote about a British battle cruiser will help me illustrate what they were.

The HMS Hood (the pride of the British Navy between WWI and WWII) was as large as a battleship. The Hood carried guns almost as large as those carried by a battleship, except the Hood was much more lightly armored, and that weight savings allowed it to have a much higher speed. The idea was that if it could reach 35 knots when regular battleships could only achieve about 20 knots, then its speed would make it very difficult to hit and would enable it to quickly escape out of range, meaning that it also did not need that thicker armor. In 1940, a couple of salvos from the German battleship Bismarck proved otherwise, and the Hood went down with a loss of a couple thousand men; there were only three survivors.

The U.S. Navy decided to convert their two partially built battle cruisers into another class of ship. The Navy decided that since it had developed an embryonic air arm, it would convert these two battle cruisers into aircraft carriers because the latter were not limited under the treaty signed at the Washington Naval Conference of 1921. Those two battle cruisers became the aircraft carriers Saratoga and Lexington. These two aircraft carriers had bows that were not squared off, but instead were tapered and rounded. They also had huge “islands” set to the starboard side of the ships that contained the facilities to operate the ships and conduct flight operations. Mounted next to them were several turrets of dual-purpose 5-inch guns that were used both for anti-aircraft purposes and against surface targets.

Because the Saratoga and the Lexington retained the engines of the original battle cruisers, they had fully loaded speeds of 33–35 knots, much faster than 1920s battleships. During war games in the late 1920s, the carrier battle group simulated a Japanese attack on the Panama Canal; even with their contemporary biplanes, they were able to sneak up during the war games and attack the canal by simulating bombing the locks and ruining the canal, closing it so that it would not have been available for use in time of war. That seriously alarmed the Navy, and it decided that it had better increase the speed of the battleships so that they could accompany the carriers. Budgets were very limited between the wars; however, they did design the North Carolina class, which had a speed of 27 knots; she was launched in 1939 and commissioned in 1941 and became known as the “show boat” because the Navy took her around to all the port cities on the East and West Coasts. She was specifically designed to go through the Panama Canal, which today we call being a "Panamax," the maximum size that will go through the locks. Her sister battleship, the Washington, was commissioned in late 1941. (Sumrall 1988)

Later U.S. battleships of other classes were slightly larger and slightly faster than the North Carolina, culminating in the Iowa-class battleships: the Iowa, the New Jersey, the Missouri, and the Wisconsin, all of which could achieve over 33 knots. The four were all reactivated for the Korean War; some of them were reactivated for the Vietnam War; and President Reagan brought all of them out of mothballs during his administration. The updated New Jersey was still active for Desert Shield and Desert Storm in 1990 and 1991, respectively. They are all back in mothballs again, or, in many cases, they have become monuments. The Missouri, of course, is now a monument and moored next to the Arizona Memorial in Pearl Harbor.

In terms of an interwar fleet boat, if the Navy were going to have fleets of aircraft carriers accompanied by fast battleships, the fleet boat submarine simply could not keep up. The physics of getting the diesel engines of the time large enough for submarines to keep up at 30 knots would have left no room for the electric batteries required for the boat to work as a submersible; therefore, achieving the new battleship speed just was not practical. The mission for the submarine in the late 1920s and early 1930s had to change from being an auxiliary to the battleship versus battleship battle. When the speed of the fleet increased to the point that the submarines could not keep up, then the main mission of the submarine became a strategic one as a commerce raider, and the Navy did not need a high-risk magnetic exploder in a torpedo being used to defeat relatively fragile enemy merchant ships.

In reality, the extra expense of the magnetic exploder probably was neither required nor necessary. However, the U.S. Navy, for whatever reasons, simply did not adjust the torpedo requirement. Therefore, the Mark VI magnetic exploder remained part of the Mark XIV torpedo design. The Navy did not test the Mark XIV any further and, therefore, when the war started, the Navy had terrible problems with torpedoes not sinking ships. In 45 separate attacks during the first weeks of combat in the defense of Luzon, at least 96 Mark XIV torpedoes were fired for a total of only three Japanese ships sunk (Bridges & Weiss, 2000). The submarine community in the Pacific was deeply disappointed by their failure to sink more ships. The below quote is from a History Channel documentary and highlight the frustration of the submariners: (Bridges & Weiss, 2000)

> Submarine commanders blamed the lack of success on two primary causes: Faulty torpedoes that ran too deep and torpedoes that were hitting the targets but not exploding. There were a lot of reports of deep-running torpedoes or suspected deep-running torpedoes because proving that they are running deep is difficult. And the Bureau of Ordnance was saying well, you guys are not shooting straight.
>
> Well in those days, they took an attitude that well maybe you are right or maybe you are wrong, and we lost a lot of good skippers of submarines because they were disbelieved. We pretty much believed the sound operator—that 80% percent believed the sound operator who would say that he can hear them hitting the target. So most of what we thought was tremendous frustration. Not only that, but we felt that we were taking such great risk with our own lives for nothing. It was bad on morale.
>
> At Pearl Harbor, Rear Admiral R. H. English sided with the Bureau of Ordnance in placing the blame on the submariners' lack of initiative. To be Commander of the Bureau of Ordnance was very important and was a stepping stone to even higher commands of flag rank so the power of the Bureau of Ordnance was considerable and that is one of the reasons not to challenge its favorite submarine weapon, the Mark XIV torpedo.
>
> In Western Australia, however, Rear Admiral Charles Lockwood took his submarine captains' complaints seriously. On June 20, 1942, outside the harbor in King George Sound, in southwest Australia, RADM Lockwood test fired torpedoes against moored fishing nets. Although more than 800 torpedoes had been fired in combat, this was the first controlled test since 1926. The firing proved to Lockwood's own satisfaction that the Mark XIV was running on average 11 feet deeper than set. Washington ridiculed the test. The immediate reaction from the Bureau of Ordnance was that you did not have the torpedoes trimmed right. The weight distribution wasn't right. Furious, RADM Lockwood repeated the test. The results were the same. Finally, the Bureau of Ordnance ordered its own investigation into the depth problem. On August 1, 1942, almost 8 months after Pearl Harbor, Newport

> conceded that the Mark XIV depth control mechanism had been improperly designed *and tested* [emphasis added]. (Bridges & Weiss, 2000)

The task of incorporating the necessary modification was given to the fleet, but even with torpedoes now running at the proper depth, sinkings did not dramatically increase. Further complaints about premature detonation, erratic runs, and defective torpedoes fell on deaf ears. The magnetic exploder became the primary suspect in the minds of the crews and captains. The following quote is from also from the History Channel documentary and highlights the frustration of the submariners and the various flag officers as the Mark XIV continued to be defective: (Bridges & Weiss, 2000)

> Rear Admiral Ralph Christy, who took over command of submarines in Australia when Vice Admiral Lockwood was transferred to Pearl Harbor, adamantly refused to consider magnetic exploder defects. Not surprisingly, as RADM Christy had been responsible for its design while in the Bureau of Ordnance. He specifically ordered his submarine crews not to tamper with the magnetic exploder. (Bridges & Weiss, 2000)
>
> Finally, in June 1943, Fleet Admiral Chester Nimitz, Commander of the Pacific Fleet, ordered the deactivation of magnetic exploders on all torpedoes. But the submarine's success rate did not improve. Instead, the number of torpedo failures seemed to increase.
>
> The Bureau of Ordnance in the meantime had corresponded with Albert Einstein at Princeton University on a variety of issues including torpedo detonation. Einstein was paid $25/day as a consultant and quickly understood the problem. The contact exploder's firing pin located in the very front warhead was deforming on impact before it could detonate the explosion.
>
> Einstein's immediate suggestion was to add a space at the front of the warhead providing an additional cushion to absorb the initial shock. The Navy never pursued Einstein's suggestion and once again the submariners had to find their own solution.
>
> The torpedo controversy came to a head in July 1943 when the USS Tanosha received intelligence that a large Japanese tanker would pass through her patrol area the next morning. They fired four torpedoes from 1,000 yards. The sound man could hear them hit, but no explosion resulted.

The skipper was about to cry and the XO and I said ‘Captain, this ship was tracking right on course with the speed and course we got it exactly right.’ He said ‘We will fire two more torpedoes at its stern and I will angle my periscope.’ We fired at it at 4,000 yards which is two miles with one miss and one that hit its stern and blew its stern up and it could not move again. Well, he sat there. We fired, over the next three to four hours, 12 more—one at a time. We fired one side; we would go round to the other side. Consternation and frustration was extreme.

None of the 12 torpedoes exploded. The Americans were finally chased away by Japanese ships sent to help the beleaguered tanker. Dan Daskey, Tanosha’s Captain, saved his last torpedo as conclusive evidence that something was very wrong.

Now Vice Admiral Lockwood had to accept that yet another component of the Mark XIV, the contact exploder, was also defective. The sheer cliffs on uninhabited Kavalai Island southwest of Maui provided the final piece of the exploder puzzle. On August 31, 1943, as a Navy patrol plane circled overhead, three torpedoes were fired against Kavalai’s underwater cliffs. The first and second torpedoes detonated; the third was a dud. A Navy diver went down in probably one of the most under-heralded and most heroic things that had been done in the course of the war. He went down and put a line on a live warhead that had not exploded and they fished it up and then they took the damn thing apart.

Finally, they found out what was causing the trouble. There was a little ring that was just too light and if you hit too hard it would just crush, but if you hit it a glancing blow it was just right. Well all they did was make a little change in that and they turned out a couple on the lathe, and tried it out, and it worked like a charm.

The problems that had plagued the Mark XIV torpedo since the start of the war had finally been corrected. The date was October 1943. The first two years of WWII were the most frustrating of times for the silent service. But by the end of 1943, torpedo performance had improved dramatically.

During the entire war, approximately 15,000 torpedoes of all kinds were fired. Despite a disastrous beginning, US submarines while comprising less than 2% of the Navy’s wartime commitment essentially accounted for over 5 million tons of shipping and 55% of all Japanese vessels lost. (Bridges & Weiss, 2000)

It took 21 months into WWII before the three root cause defects in the Mark XIV were finally identified and corrected. In all seriousness, God only knows how many submariners died as a result of those defective torpedoes, which until the

Mark XVIII electric torpedo became available, had very prominent wakes that showed where the submarine was when it fired the torpedo. Then, because the submarines could not adequately defend themselves, they were sunk. It just boggles my mind that it took as long as it did.

RADM Christie had to receive an order directly from the Chief of Naval Operations (CNO) to deactivate his magnetic exploders because he was not going to do it even with Fleet Admiral Nimitz's order. He had also refused Lockwood's orders. Some admirals might risk refusing to obey another admiral's orders, but nobody dared to cross Fleet Admiral King, the CNO.

Production finally met demand in 1944 with the activation of not only commercial industry sources but also the reopening of the Alexandria factory and the inauguration of the new Keyport torpedo station.

Post-WWII analyses found that the Japanese surface-launched, 24-inch, Long Lance torpedo had double the warhead weight and range of the Mark XIV, and at a much higher speed—almost double the speed. The Japanese achieved that by using a more volatile (at least the Bu Ord called it volatile) liquid hydrogen peroxide fuel. The Navy had repeatedly rejected this as too dangerous because it was worried about fumes affecting the crew. However, there was no post-WWII record found of any Japanese incident due to the use of hydrogen peroxide as torpedo fuel.

As fallout from the Mark XIV root cause analysis process, the Chief of the Bu Ord, Admiral Blandy, signed and published the following rather remarkable memorandum in early 1944:

> Even with the relatively meager funds available in the time of peace, much of the work now being done after more than a year and a half of war could, and should, have been accomplished years ago. That the work was not accomplished during peace, or earlier during the war, or so far as the Bureau's records disclose that no one either at the Bureau or at Newport apparently questioned the inadequacy of the design without such tests, shows a lack of practical appreciation of the problems involved which is incompatible with the Bureau's high standards and reflects discredit upon

both the Bureau of Ordnance and the Naval Torpedo Station, Newport. The Chief of the Bureau therefore directs that as a matter of permanent policy, no service torpedo device ever be adopted as standard until it has been tested under conditions simulating as nearly as possible those which will be encountered in battle.[1]

[1] One of my students from the Keyport Undersea Warfare Center obtained this for me.

Lessons Learned

Generically speaking, the project manager (PM) and the user promulgating the requirement need to constantly reassess the required capability and make sure that what they are building is what is actually needed. For example, in the case of the Mark XIV, in most instances, the magnetic exploder with its complexities, risk, and expense was no longer needed because the submarine was no longer a main element in the combat operations between capital ships. Due to their shortfall in surface speed, fleet boats were now essentially commerce raiders with the strategic mission of strangling Japan for fuel, materiel, and food. They performed this mission very well once the Bu Ord finally fixed all three major faults in the Mark XIV torpedo.

Adequate developmental testing should have found all three failure modes prior to full-rate production. The lack of adequate empirical testing was unjustifiable, but I am not sure Bu Ord realized that they were failing to conduct accurate tests and I am not sure they realized how much testing they really needed to do. The inherent arrogance of the Gun Club and the “not invented here” syndrome, have been cited by some critics. (Bridges & Weiss, 2000) Yes, a full-up Mark XIV torpedo did cost $10,000 in then-year dollars, but there certainly were ways that Newport could have had surrogates, engineering development models, and so forth to test the features of systems and subsystems. They could have done a contact exploder test with a crane dropping a dummy warhead from a height that would match the momentum of an actual perpendicular impact of a torpedo against the hull of a ship. VADM Lockwood actually had this done at Pearl Harbor to confirm the results of the cliff tests and to develop an interim solution. There were a lot of things they could have done, but they did not.

The arrogance of the Gun Club, particularly the Newport Torpedo Station, at least as viewed by much of the rest of the Navy, was legendary. They simply believed that they were the experts and did not take seriously the reports from their inferiors in the fleet. The result was disastrous in terms of the lives unnecessarily lost in submarines that could not defend themselves because of defective torpedoes.

If there had then been an operational testing law and if the Navy had been forced to do adequate, independently evaluated operational testing, the Mark XIV would not have gone to war in 1941 with its three root cause deficiencies. Today's operational testers may sometimes over test equipment, but inadequate testing risks disaster. Good operational testing that is intelligently applied and that does not also create requirements is very necessary.

Another thing that the Navy has today with our readiness reporting and our logistics assessments is a system that forces equipment defects found by the fleet to surface early on. Because submarines were so secret in WWII and because their patrol reports were need-to-know, there was not wide dissemination within the Navy of the seriousness of the torpedo problems that occurred early in the war. If the Navy had had today's formal post-deployment logistics assessments, and if it had had follow-on operational test and evaluation, the Navy probably would have discovered much earlier that it had a serious torpedo performance problem. The Gun Club would have been overridden by the CNO, and the Navy would have solved this problem much earlier—if not prevented it altogether, assuming the resources could have been garnered in the late 1920s and early 1930s to actually do what needed to be done in order to absolutely prove the operational effectiveness and suitability of the Mark XIV torpedo.

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