Radar and the American Submarine War, 1941 -1945: A Reinterpretation

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Cet article examine la guerre sous-marine entreprise par les Américains contre le Japon en 1943, année cruciale car c 'est à ce moment-là que, signe d'une performance sous-marine accrue, le tonnage coulé par mois augmenta considérablement. On attribue traditionnellement cet accroissement à la correction de problèmes de torpille, à l'expansion de la flotte sous-marine, aux améliorations de doctrine et à l'impact du décryptage sur les patrouilles sous-marines. Bien que ces facteurs aient certainement joué un rôle dominant, cet article soutient qu'ils n 'expliquent pas complètement le redressement rapide de la performance. C'est plutôt l'intégration d'un radar de veille de surface efficace qui unifia ces autres facteurs et permit au commandant en poste de patrouiller plus énergiquement et efficacement.

At 2105 on 15 April 1943, the silent, shadowy form of the USS *Seawolf* broke the surface of the East China Sea after slowly rising from a depth of 250 feet. Since 1954 she had been avoiding a minor depth charge attack brought on by her ambush of a two ship convoy earlier that evening. The first attack on the convoy was launched at 1952 when four torpedoes were fired at a large freighter. The first of those torpedoes detonated prematurely, about fourteen seconds after being fired, which alerted the convoy to the presence of the *Seawolf* and allowed them to avoid two of the three remaining Mark XIV torpedoes. The fourth torpedo hit the freighter and caused minor damage. The subsequent counter attack by the escort started at about 1954, but it was not as severe as would have been expected. Shells were fired at the periscope and four depth charges were dropped some distance away from the submarine. The *Seawolf* nonetheless remained submerged for just over an hour before surfacing to pursue the convoy.

Seawolf immediately reacquired her targets using her SJ surface search radar at a range of 15,000 yards and proceeded to manoeuvre around the port flank of the convoy. By 2304 the *Seawolf* had gained a good attack position 10,000 yards (based on radar ranges) ahead of the ships. As the convoy approached the *Seawolf* the range decreased rapidly until the submarine was forced to dive at 4,200 yards and launch a submerged attack due to the

***The Northern Mariner/Le marin du nord,* XIV No. 3, (July 2004), 27 - 40.**

bright surface conditions. During this second attack three more torpedoes were fired at the damaged freighter at a range of roughly 1,650 yards. Set for a depth of sixteen feet with an eight second spread, two of these torpedoes were heard to hit the target which promptly stopped but remained afloat. Because the escort refused to leave the area, the *Seawolf* was forced to make another submerged attack at 0152 on 16 April. Two more torpedoes, fitted with the secret Mark VI influence detonators, were fired at a now stationary target at a range of 1,400 yards. One torpedo exploded just below the stack of the freighter and the second torpedo either ran erratically or was defective and failed to detonate. Despite this third hit, which broke away the forward partition of the freighter, most of her remained afloat. Later that day, following a periscope observation of the scene the *Seawolf* finally withdrew because of the continued presence of escorts and aircraft. She left a crippled freighter missing a portion of her bow and with a severe list to port: a meagre result for the nine torpedoes fired, almost 40 per cent of her torpedo load, and all the risks taken in the attack.[1]

Seawolfs attack on 15 April 1943 encapsulates a critical period for the American submarine effort to destroy Japanese merchant shipping during the Second World War. *Seawolf's* difficulty is obvious. Silent and almost untraceable, a submarine is nonetheless most vulnerable to detection and counter attack during an approach and an attack on a ship. The need to use the periscope and the tell-tale torpedo wakes reveal the location of the submarine even if the torpedoes miss their target. In the case of the *Seawolf* the return for a series of such skilful and daring attacks, and the expenditure of expensive ordinance, was paltry at best.

In fact, the United States expected much more from its submarine fleet by 1943. Following the shock of Pearl Harbor, the United States Navy was forced to rebuild its surface force which had been savaged in the early hours of 7 December 1941. In an effort to strike back at the Japanese, American commanders turned to the submarine fleet, unleashing it in an unrestricted attack on the Japanese Navy and merchant marine. Unfortunately these attacks failed miserably in 1942. Although ordered to "Execute against Japan unrestricted ...submarine warfare" shortly after the attack on Pearl Harbor, the relatively untouched submarine fleet was severely hampered by a variety of difficulties.[2] Prior to the attack on Pearl Harbor, the American submarine fleet was seen as an adjunct to the main battle fleet, an almost ideal scouting force with a devastating capability to attack the Imperial Japanese Navy. With the loss of the battle fleet at Pearl Harbor, the submarine fleet was forced to take a leading roll in the war against Japan.

The transition from the pre-war scouting force to a strong and effective anti-

[1] Chief of Naval Operations, Communications Division, "The Role of Communication Intelligence in Submarine Warfare in the Pacific January 1943-October 1943," SRH-11, November 1945, National Archives, Washington, DC, (hereafter NA), as found in *U.S. Submarine War Patrol Reports and Related Documents, 1941-1945: Reference Documents on Submarine Operations and Submarines,* Scholarly Resources Inc., Reel 7, Vol IV, 86-87.

[2] This order was issued by the Navy Department six hours after the attack on Pearl Harbor. Clay Blair Jr., *Silent Victory,* (New York, 1975), 106.

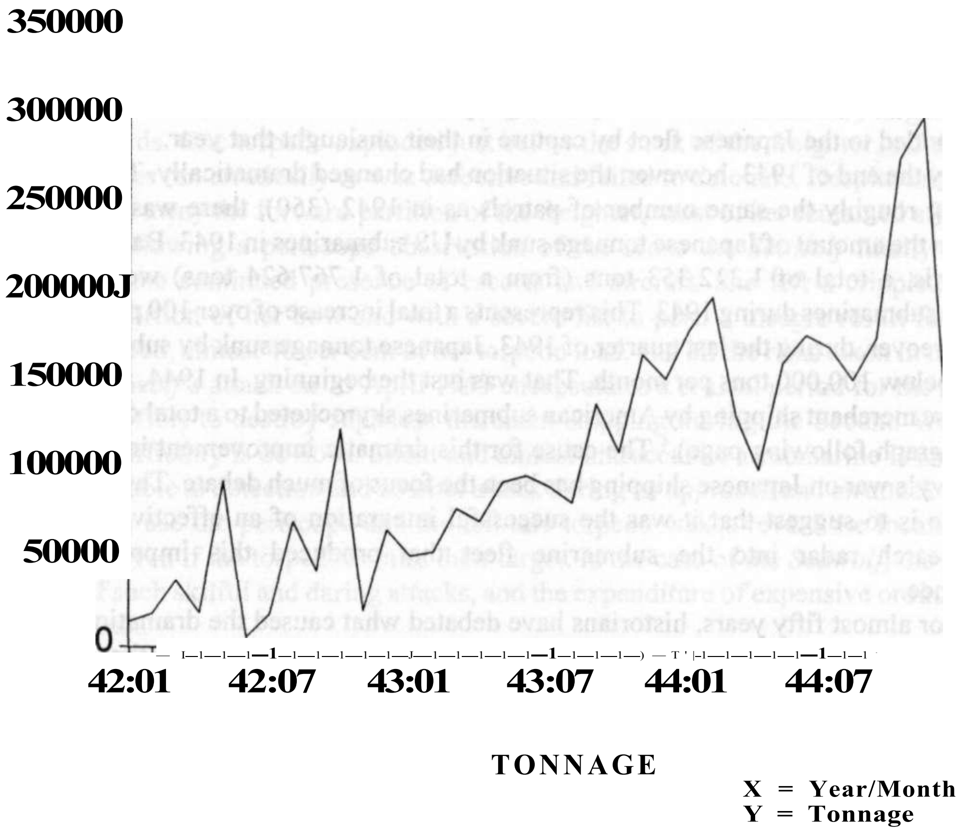
shipping fleet was not easy for the submarine fleet. The expectation of many American officers in 1941 was that the submarine fleet would inflict severe losses on Japanese merchant shipping and on the invasion forces expected to be sailing towards the Philippines. As the first months of the war demonstrated, this expectation was never realized. Total Japanese merchant ship losses for 1942 were 977,927 tons, of which American submarines accounted for 612,039 tons.[3] This was just slightly less than the 661,800 tons of merchant shipping added to the Japanese fleet by capture in their onslaught that year.

By the end of 1943, however, the situation had changed dramatically. Though only conducting roughly the same number of patrols as in 1942 (350), there was a dramatic increase in the amount of Japanese tonnage sunk by US submarines in 1943. Based on post-war records, a total of 1,312,353 tons (from a total of 1,767,624 tons) were sunk by American submarines during 1943 .This represents a total increase of over 100 per cent over 1942. Moreover, during the last quarter of 1943, Japanese tonnage sunk by submarines did not drop below 100,000 tons per month. That was just the beginning. In 1944, the sinkings of Japanese merchant shipping by American submarines skyrocketed to a total of2,3 88,709 tons (see graph following page).[4] The cause for this dramatic improvement in the United States Navy's war on Japanese shipping has been the focus of much debate. The purpose of this article is to suggest that it was the successful integration of an effective system of surface search radar into the submarine fleet that produced this improvement in performance.

For almost fifty years, historians have debated what caused the dramatic increase in American submarine performance during 1943. The result is a consensus that has been both espoused by the key authors in the field and accepted by most historians. Although authors like Admiral Charles Lockwood (CINCPAC 1943-1945), Theodore Roscoe, Samuel E. Morison and Wilfrid J. Holmes have presented basically the same arguments, the current consensus is best described by Clay Blair Jr. Blair, in probably the most detailed account of the submarine war, presented what has become the accepted explanation for the improvement in submarine performance. According to Blair, the submarine fleet suffered three important problems in 1942. First there was an insufficient number of submarines to

[3] It is difficult to assess exactly how much tonnage was actually sunk by the submarine fleet. The figures given by various authors differ substantially. Parillo, in the most recent work on the subject, presents several different figures himself and these differ from other authors like Blair. Parillo states two different figures for tonnage sunk by submarines in 1942. The first is 612,039 tons (Table A.9) and the second in the text of 884,928 tons. No explanation for the differences is given. Parillo also states two different figures for total losses in 1942: 1,095,800 tons and 977,927 tons. The lower figures from table A.9 are used here. See, Mark P. Parillo, *The Japanese Merchant Marine In World War II,* (Annapolis, 1993), 37-38, 204, 242 Table A.8., 243 Table A.9.

[4] Parillo again provides slightly differing figures from Blair. According to Parillo, a total of between 2,065,700 and 1,767,624 tons of shipping were lost by the Japanese in 1943. Of this total, 1,312,353 tons was sunk by the United States submarine fleet. This represents a doubling of the average monthly sinkings from 1942-1943: 51,003 tons per month to 109,363 tons. The 1944 losses to American submarines was more than the total losses during 1942-1943 combined. Blair gives the total sunk as exceeding 1.5 million tons in 1943. These losses were offset by the addition of 1,067,100 tons of shipping in 1943. See, Parillo, 243 Table A.9., 242 Table A.8. Blair, 551-554,816-819.



Tonnage Sunk Per Month[5]

cover all the patrol areas and fulfill all the secondary missions assigned to them. Second, the submarine fleet was suffering under a doctrine which was not aggressive or flexible enough for an effective submarine war. This problem was exacerbated by the poor pre-war training of submarine commanders that resulted in overcautious captains. Finally, the submarine fleet's main weapon, the Mark **XrV** torpedo was seriously flawed. It ran deeper than the depth for which it was set, it was fitted with a magnetic detonator which tended to activate prematurely, and its contact detonator was poorly designed causing a large number of dud torpedoes. Over the course of 1942-1943, the combined problems of insufficient numbers,

[5] Based on data taken from, John Alden, *U.S. Submarine Attacks During World War II,* (Annapolis, Maryland, 1989).

a weak doctrine, and defective torpedoes were corrected, Blair argued, so that by the end of 1943 American submarines were able to attack Japanese shipping effectively. Blair maintains as well that American code breakers were able to read the Japanese merchant marine codes and to direct submarines to patrol areas with the best potential of locating targets, thereby increasing submarine effectiveness.

All of what Blair says is true, but he and others have missed the crucial element in reassessing submarine effectiveness by late 1943. To date, there exists no detailed account of the impact of radar on submarine operations in the Pacific. Even though the role of radar in the Atlantic war is well known, the lack of understanding with respect to the Pacific submarine war is surprising considering the large volume of work written on the Pacific war. A wide range of work still needs to be done with respect to the relationship between submarines and radar in the Pacific during the Second World War. Even though this work represents a step forward, it is at best a case study looking at some specific examples. Nonetheless, it illustrates the importance of radar and the need for further research.

More important than any of the conventional reasons for dramatic improvement in tonnage sunk was the integration of an effective surface search radar into the operations of the submarine fleet. Although not completely ignored by the historiography on submarine warfare, radar is often discussed only very briefly. Morison, Lockwood, Blair and Holmes all refer to the installation of radar as important, however its importance has never been fully explored. At best, most authors only mentioned the installation of radar in the submarine fleet but they considered it of secondary importance behind the three key problems faced by the submarine fleet. Only Edward Beach stands out for his emphasis of the role of radar in the submarine war. "At night, radar coverage was at its best and enemy air surveillance at its poorest," Beach wrote. "We, in the submarine, could cover a swath of sea forty miles wide, and all ships picked up by our radar ... were enemy."[6] Radar provided the crucial tactical edge that allowed all the other factors - new, young captains, a more aggressive doctrine, good torpedoes and code breaking identified as ULTRA intelligence - to achieve maximum effect. In all weather conditions, a radar search provided the vital information of range and convoy disposition. It allowed the captain to keep track of the enemy escorts while using accurate range information to close and attack the selected target. It is now clear that Beach's personal conclusion is supported by the evidence. Radar was central to the improvement of submarine warfare against Japanese shipping.

The year 1942 saw the introduction of two different radar sets in the submarine fleet. The first radar was the SD air search radar. Omnidirectional, this radar first appeared in early 1942. Because it was very close to Japanese radio and radar frequencies, the SD radar was highly susceptible to direction finding, attracting anti-submarine warfare forces. Thus, the SD was considered as much a liability as a benefit. The second set was the surface

[6] Edward L. Beach, "'Culpable Negligence' A Submarine Commander Tells Why We Almost Lost the Pacific *Wax," American Heritage,* Vol. 32 (Dec. 1980), 47. The maximum range of detection for submarines prior to the development of radar was six to nine miles; with radar this was extended to over twelve miles so long as the submarine was surfaced.

search radar, called the SJ. More than any other single factor, the SJ had the greatest impact on the submarine war. Although not fool-proof, it gave the submarine fleet the technological advantage necessary to dominate the Pacific. Captain Richard O'Kane, in the second war patrol report for the *Tang,* described the importance of radar. "Except for internal failures, which will undoubtedly be ironed out by installation of more substantial parts, the SJ at present is a near ideal search and attack radar."[7]

The SJ radar had a 10-cm wavelength and initially utilized an "A" scope for measuring range. It later included a Planned Position Indicator (PPI) which provided a tactical picture for the commanding officer. The SJ affected all four stages, detection, positioning, attack and escape, of a submarine attack. In the first stage, the submarine was concerned with locating its target. An SJ radar working in ideal conditions could detect a single merchant ship at roughly 17,000 yards and a single warship at 10,500 yards (depending on the size of the ships and the weather conditions). A convoy of merchant shipping was detectable at 19,000 yards and a large escorted warship could be detected at 25,000 yards.[8] O'Kane found that the SJ more than doubled the normal visual search range of a surfaced submarine using its elevated periscope alone.[9] Thus, SJ equipped submarines could cover their patrol area more effectively, finding more contacts than would be expected without radar. Thus, interception rates went up in late 1943.

In particular, SJ radar allowed submarines to use the information provided by ULTRA[10] to setup those intercepts more effectively. With signals intelligence providing "position and intended movement" of enemy ships, the submarine could search, on the surface, a wide area with a high possibility of detection. SJ radar and this intelligence

[7] ComSubPac Patrol Report No. 426, USS *Tang,* Second War Patrol 16 March 1944-15 May 1944.NA, Record Group (RG) 38, Fiche 010747, 25.

[8] Norman Friedman, *Submarine Design and Development,* (Annapolis, Maryland, 1984), 51 ; Norman Friedman, *U.S. Submarines Through 1945,* (Annapolis, Maryland, 1995), 241. *These are the theoretical maximum ranges.* The fleet manual listed the reliable range as being 75 per cent of these figures. The size of ships, and weather conditions and the height of the radar detector above the surface, directly affected these ranges. These figures are consistent with reported contact ranges from war patrols. The fifth war patrol of the *Trigger* and the second patrol of the *Tinosa* indicated contacts at slightly lower ranges for both warships and merchant shipping of various sizes. See ComSubPac Patrol Report No. 203, USS *Trigger,* Fifth War Patrol 30 April 1943 - 22 June 1943, NA, RG 38, bx2816/370/6/30/5, 20-21; ComSubPac Patrol Report No. 231, USS *Tinosa,* Second War Patrol 7 July 1943-4 August 1943, NA, RG 38,bx2831/370/6/31/1, 22.

[9] Richard O'Kane, *Wahoo: The Patrols of America's Most Famous World War II Submarine,* (Novato, California, 1987), 39.

[10] ULTRA refers to intelligence generated from intercepts and code breaking. These intercepts were in either the Japanese Naval Code (JN-25B) or the Merchant shipping codes (Maru Code). These were hand cyphers that converted information into a number sequence and added additional security via adding random numbers from a code book. These should not be confused with the diplomatic codes known as PURPLE. The PURPLE code refers to a machine encryption system used for diplomatic traffic broken by the US government prior to the outbreak of war. PURPLE intercepts had no bearing on naval operations.

significantly increased the likelihood of an intercept." Detection of a particular target at a longer range gave the submarine time to manoeuvre into a good attack position.

Having detected a target, in the second phase of an attack the submarine had to manoeuvre into the best firing position, normally well ahead. Radar allowed the submarine to close with more assurance. The tactics initially used in the first year of the war were overcautious, resulting in a poor performance. However, over the course of 1942 new tactics like the "end run" were developed for the periscope and used extensively for manoeuvring ahead of the target. The submarine would keep track of the target visually while she circled ahead at the edge of visual range to gain a the best attack position. Radar, after its introduction, helped to limit the risks of operating on the surface by increasing the distance between the submarine and the target and by warning of any threats. A "textbook" example occurred during the third patrol of the *Sawfish.* On the afternoon of 22 July 1943 a convoy of six ships with escort was sighted. Though forced to dive deep by the convoy escorts, at 1739 that evening the *Sawfish* surfaced and pursued. At 1914 the convoy was re-acquired by radar and followed till dark. After dusk the *Sawfish,* while using her SJ radar to keep track of the convoy, commenced to run around the convoy at a range of 18,000 yards. Without being detected, the *Sawfish* gained a position ahead of the convoy and worked her way into a firing position. At 2347, from a range of 6,700 yards, six torpedoes were fired at the *Asama Maru.* Three hits were observed and at 0001 on 23 July the target vanished from the *Sawfish's* radar screen.[12]

The SJ radar did more than help the submarine gain an attack position. In the third stage of submarine attacks, radar provided a wealth of information that was vital to success. Ahead of the convoy in an attack position, aggressive submarine skippers began to remain on the surface at night to utilize fully the potential of radar. The PPI provided captains an accurate tactical picture, that included ranges, bearings, the formation of the convoy, and the position of escorts. With this information, the submarine captain was able to manoeuvre for both the optimum firing position possible and, (the final phase), the best possible chance to escape. Two excellent examples of this are the second patrol of the *Snook* and the tenth patrol of the *Sailfish.*

Late in the evening of 3 July 1943, the *Snook* picked up a convoy on radar at a range of seven miles. Using her radar to find an opening in the escort screen, and her surface speed and concealment to exploit it, the *Snook* gained a firing position within the convoy. At 0112 on 4 July, three torpedoes were fired at a large ship. Two torpedoes hit their target. The

[11] The submarine was furnished with ULTRA information in two ways. The first consisted of patrol orders generated from intercepted transmissions. These orders provided detailed information on the location of targets, speed and routes of advance. With this information a submarine could then have a chance of intercepting a target. This was done for the most important targets only. Traffic analysis refers to the careful monitoring of Japanese signals to determine the locations and patterns in enemy activities. Briefed on shore concerning these issues, the submarine's captain could use such information to guide him with respect to the best patrol areas within his zone and thus the highest likelihood of an intercept.

[12] USS *Sawfish,* Third War Patrol. Post war assessment was unable to confirm this sinking. Alden, 52.

Snook then used her radar to escape from the counter attack. Roughly an hour later the *Snook* was again in a firing position on what appeared to be a flat topped ship, possibly an auxiliary carrier. Six torpedoes were fired at 0251, of which three were seen to hit. This ship was claimed as a probable sinking as it was not detected by radar later. Despite the efforts of the escorts, the *Snook was* again able to evade detection and began to hunt two other ships of the convoy that was now breaking up. A third attack was launched at 0334 on these two ships at a range of 2,400 yards using five torpedoes. Two confirmed hits were seen on these targets.[13] The first endorsement of this patrol by Leo L. Pace, Commander of Submarine Division 141, stated, "the series of attacks carried out on the convoy on the Fourth of July is very remarkable. The courage, intelligence, ability, dogged determination and clear sighted vision displayed by the commanding officer combined with the brilliant cooperation of his officers and crew was outstanding."[14] It was radar that gave the commanding officer of the *Snook* the "clear sighted vision" needed for this devastating night action by keeping track of both the merchant shipping and the escorts to allow for both surface approaches and escapes. The *Snook's* use of radar at night was so well done, it became one of the examples used to train other captains.

In what became one of the most incredible attacks of the war, the ability of a radar equipped submarine was further demonstrated on 3-4 December 1943 by the *Sailfish.* The *Sailfish,* while braving a typhoon, attacked a large target first tracked by SJ radar at a range of 9,500 yards on the surface. At 0012 on 4 December the first four torpedoes were fired, of which two hit, from a range of 2,100 yards. Forced deep by an escort, the *Sailfish* surfaced at 0158 and pursued. After tracking on SJ radar again, a second attack was launched at 0552 from a range of 5,200 yards with two of the three torpedoes fired seen to hit. It was only realized, after sunrise, that the target repeatedly attacked that evening was an aircraft carrier now stopped in the water. A third attack was launched at 0940 on the carrier. Two of the torpedoes hit but before another attack could be launched a heavy cruiser, probably part of the original convoy, showed up to charge the submarine. Unfortunately, the convoy was never re-acquired after that. The post-war analysis credited the *Sailfish* with sinking the 22,500 ton carrier *Chuyo.*[15] With examples like these, the submarine fleet quickly realized the value of employing radar during night surface actions.

These highly successful tactics had evolved as submarine commanders learned to use radar. An alternate was to keep the submarine partially submerged in order to allow the radar, which was mounted on the conning tower, to function. Commonly known as "radar depth," this tactic was not overly popular; nonetheless, it was used with moderate success. An excellent example of this was demonstrated by the first patrol of the *Sawfish.* On 17

[13] ComSubPac Patrol Report No. 220, USS *Snook,* Second War Patrol 9 June 1943-18 July 1943, NA, RG 38, Fiche 00974,4-5. Post war assessments revealed that only two ships were sunk and one suffered heavy damage. Alden, 50.

[14] FB5-141/A16-3 Serial 0143, First Endorsement to War Patrol Report 220, 20 July 1943, USS *Snook,* Second War Patrol, NA, RG 38, Fiche 00974.

[15] SS192/A16-3 Serial 01, USS *Sailfish,* Tenth War Patrol, NA, RG 38, Fiche 00804, 2-6. Alden, 72.

February 1943, the *Sawfish* sighted a white light on the surface and closed on it. At a range of 15,000 yards, the SJ radar picked up the ship, but it was decided not to close the target directly but rather manoeuvre ahead due to the "brilliant moon." Once ahead of the ship, the *Sawfish* dove to radar depth and closed to a range of 5,000 yards before completely diving. During the subsequent attack two of the three torpedoes that were fired hit and the target sank.[16]

This method allowed the submarine to reduce her silhouette, but the radar depth approach placed the boat at a marked disadvantage. In order to ensure that the main induction valve was not flooded, the submarine was forced to rely on batteries only which made her slow and sluggish to respond to helm control. According to the commanding officer of the *Pompano* during her fifth patrol, the use of radar depth had only limited value. "Going to 35 feet (5 feet of radar out and bridge rail awash) to finish a radar approach has its disadvantages. The ship does not handle well at this depth in much of a sea, a few degrees down angle throws the stern out and, from exercises with the *Litchfield,* any thing over 1/3 speed makes a very noticeable froth and spray. Radar has a problem to track both the target and escorts and water noises makes sound less effective so close touch with the escort is not always possible."[17] The degraded handling characteristics meant this method was preferred only on bright nights. Although helping to conceal the submarine, radar depth did not give the same shelter as full submergence. When combined with the fact that the submarine was also dependant on the radar for virtually all the information on ships in the area due to the poor performance of sonar so close to the surface, it is clear why this was not a popular tactic. During 1943-44, only seventy-one submerged radar approaches were made.[18]

With the SJ radar the submarine had the advantage of being able to attack both at night and in fog when its ability to approach unseen was highest. Prior to the use of radar, night attacks proved exceedingly difficult because of the poor night vision equipment available to the submarines.[19] Radar solved this problem and by 1944, the average number of night attacks increased from approximately 20 per cent of all attacks in early 1942 to about 80 per cent in 1944. In a very real sense, radar placed the submarine in the most advantageous position possible.

The all-weather ability of the radar when combined with its ability to track surface

[16] ComSubPac Patrol Report No. 162, USS *Sawfish,* First War Patrol 21 January 1943-25 March 1943, NA, RG 38, Fiche 00832,2-3. See also ComSubPac Patrol Report No. 203, USS *Trigger,* Fifth War Patrol 30 April 1943 - 22 June 1943, NA, RG 38, bx2816/370/6/30/5, 4-5.

[17] ComSubPac Patrol Report No. 153, USS *Pompano,* Fifth War Patrol 16January 1943-28 February 1943,NA, RG38, Fiche 00660, 15.

[18] Submarine Force, Pacific Fleet, *Submarine Operational History,* Reel 1,11,576. See also, O'Kane, 191. Radar depth was used not only to attack but to patrol as well. In the Yellow Sea, this technique was used to maximize the area patrolled.

[19] At numerous points in the patrol reports, complaints about the poor optics for night attacks exists. See ComSubPac Patrol Report No. 203, USS *Trigger,* Fifth War Patrol 30 April 1943 - 22 June 1943, NA, RG 38, bx2816/370/6/30/5, 2,4,9.

targets accurately gave the American submarine fleet a distinct advantage over Japanese shipping and its escorting forces. However, air cover, surface escort and visibility did limit the ability of submarines to remain on the surface in their patrol areas during the daylight hours. Whenever a submarine was patrolling near Japanese islands it was assumed that aircraft were present, and this naturally limited performance. Although the SD radar provided some air warning, the submarine on patrol was constantly forced to react to the threat.[20] This is illustrated by the third war patrol of the *Sawfish,* when she was repeatedly forced down by both known aircraft and the threat of air cover.[21] Nonetheless, over the course of the war, the combination of the SJ/SD radars greatly increased the number of days spent on the surface during patrols. Early patrol reports by the *Sawfish* in 1942 and 1943, for example, showed that most of the time on station was spent below the surface, using sonar and periscopes to patrol. By 1944, the *Tang* spent most of her time on the surface using not only periscopes but radar as well despite greatly increased Japanese anti-submarine measures, such as more escorts and air patrols. Only when close to shore, and thus visible to those on land, did the *Tang* patrol submerged.[22]

Through the careful use of radar, submarines were able to trail and then run ahead of their targets with the assurance that it was unlikely that they would be surprised on the surface or even detected. Some captains, having used radar to close with their target on the surface, preferred to dive at the last possible minute to make a submerged attack. This almost exactly duplicated the daylight submerged attack, and the night periscope attacks that had dominated the early stages of the war.[23] As combat experience increased, commanding officers were more willing to make surfaced attacks on targets at night. Theodore Roscoe stressed that this increase in night attacks only really began in 1943. According to Roscoe, approximately 30 per cent of the attacks conducted in 1942 were done at night on the surface. By 1944 this number reached 57 per cent.[24]

The impact of these night surface attacks was telling. By the end of 1944, Japan had begun changing her shipping practices. Japanese shipping was increasingly sailed only by day in an effort to avoid the night surface attack. Edward Beach described it. "Anything to make the night surface attack less likely. Statistics backed up Japan on this, for by far the

[20] Examples of the need to adjust patrolling patterns to the possibility of aircraft are numerous. The *Snook's* first patrol provides several examples of a submarine being prevented from pursuing on the surface during daylight. See, ComSubPac Patrol Report No. 190, USS *Snook,* First War Patrol, 11 April 1943-23 May 1943, NA, RG 38, Fiche 00974.

[21] ComSubPac Patrol Report No. 235, USS *Sawfish,* Third War Patrol June-August 1943, NA, RG 38 Fiche 00833.

[22] USS *Sawfish,* First-Fourth war patrols. USS *Tang,* First War Patrol, NA, RG 38, fiche 00833.

[23] Submarine Force, Pacific Fleet, "Submarine Operational History of World War II," Unpublished Manuscript 14 May 1947, (Washington Naval Yard, Operational Archives Branch), Reel 1, II, 553-555.

[24] Theodore Roscoe, *United States Submarine Operations In World War II,* (Annapolis, Maryland, 1949), 172. See also, Submarine Force, Pacific Fleet, *Submarine Operational History,* Reel 1, II, 552-553. Friedman, *US Submarines Through 1945,* 235. According to Norman Friedman, a post war official naval research and development history credits the SJ radar with the "dramatic shift from day to night submarine attacks."

greatest damage to her shipping during those climactic last two years of the war came from submarines attacking on the surface at night."[25] The reasons for this were twofold. First, radar allowed for the discovery of targets otherwise missed in dark or poor weather. Second, by the end of 1943, American captains had more experience with radar and had realized its potential. Rigid doctrine that had characterised pre-war tactics was being replaced by a more flexible system based on radar.

The submarine could now be utilized to its full potential. Able to see at night and use this information, the submarine fleet concealed itself in a way not wholly appreciated in 1941. While using either night or foggy conditions, the submarine, a creature belonging neither below the surface nor on it, was able to ride the edge of these two worlds. Hidden from the Japanese, who lacked an effective surface search radar[26] and who had only limited numbers of radar detectors, the submarine on the surface was able to move faster both during the attack than its target and during its escape than the slower escorts. In probably the clearest statement on the importance of radar to the submarine fleet, Richard O'Kane, in his second patrol report for the *Tang* in 1944 expressed his concern that the advantage that radar gave to the submarine fleet was in danger of being lost: "We are still enjoying, though on the waning edge, an immense tactical advantage over him because of speed and radar... he is catching up. It will then be just a matter of time until submarines are again the 'submerged vessels of opportunity' we used to believe them to be."[27] It is clear for O'Kane that radar changed how submarines were used, thus revolutionizing the submarine war. With radar providing the vital information for the creation of a firing solution, the submarine found itself in the most advantageous situation.

It was radar then that provided the dramatic improvement in the submarine fleet's performance in late 1943. The importance of night surface attacks was reflected in the revised *Current Tactical Doctrine Submarines, February 1944.* Besides cautioning that radar should be swept across the entire area periodically to ensure that all the escorts are accounted for, the new orders stressed the importance of attacking at night. "In reduced visibility the attack may be carried out undetected with the submarine on the surface. This is more desirable and more effective than a submerged attack as the submarine retains the

[25] Beach, 54.

[26] The Japanese only began research into radar in 1941. By 1944 the surface search radars began to appear in the escort fleets. Though airborne radar was becoming available after 1943, it was extremely rare and like all other vital equipment it was usually sent to the Combined Fleet first. Japan did have excellent sonar and an early form of the Magnetic Anomaly Detector but these were dependant on the submarine being submerged. At its best, Japanese airborne radar could detect targets roughly twelve nautical miles away and surface search radar at ten miles. This radar was usually used at night only since it could be detected by the Americans. The Japanese radar detector was one of the earliest in use and proved very effective especially against the SD radar. Parillo, 101 -120; Roscoe, 24-212; Friedman, *Naval Radar,* 96-97.

[27] ComSubPac Patrol Report No. 426, USS *Tang,* Second War Patrol 16 March 1944-15 May 1944, NA, RG 38, Fiche 01047, 25.

advantage of mobility and high speed."[28] Relatively silent on the surface, especially if the final stages of an approach were conducted on battery power, the low silhouette and night camouflage, also adopted in 1943, helped to conceal the submarine.[29] It is not surprising that the number of these attacks dramatically increased in 1944. An example of this can be seen in the first patrol of the *Tang* in early 1944. Of the six attacks made during the patrol, five of them were night surface attacks and the fifth attack, a dawn periscope attack, was made after a night of repeated attacks on a convoy detected by radar.[30]

To understand the importance of radar to the effectiveness of the American war on Japanese shipping, it is only necessary to examine the results. During the latter half of the war, for example, radar became the single most important factor that affected attacks. This was certainly evident in October 1944, when the *Drum,* commanded by Maurice H. Rindskopf on her eleventh patrol, conducted five separate attacks off Luzon Strait. Three were night surface engagements using radar. Three separate ships were sunk, the largest was 6,886 tons for a total of 18,754 tons. Two daytime submerged attacks were also performed. These attacks were considerably less successful, with only one damaged vessel of 3,210 tons.[31] The startling difference in results is important. In the same waters on the same day, with only the method of attack being different, two sets of results can be seen. Clearly the ability to use radar when surfaced had an important impact on the performance of the *Drum?[1]*

Despite the apparent importance of radar, it has been difficult to assess how much of an impact it had on the effectiveness of the submarine campaign. Indeed, much of the evidence for its importance has been anecdotal. Fortunately, John Alden's recent compilation on submarine attacks, when combined with a careful examination of submarine patrol reports, indicates that radar played the dominant role in improving submarine effectiveness in 1943. The traditional explanation for the improvement in submarine performance has rested on increases in submarine numbers, younger captains and improved submarine doctrine, the influence of signals intelligence, and the correction of the three faults that plagued American torpedoes. Collectively, these factors go far in explaining the rapid increase in tonnage sunk during late 1943-1944, but not all the way.

The easiest explanation for increased submarine performance rests with an increase in the number of submarines on patrol. However, during 1942-1943, only eighty-four submarines were added to the fleet. Since only at best one third of operational submarines were on patrol at any one time, the simple increase in operational boats cannot account for

[28] Submarine Force, Pacific Fleet, "Current Doctrine Submarines, February 1944," (USF-25 A), *U.S. Submarine War Patrol Reports,* Reel 4, 22, paragraph 2403.

[29] Originally, submarines were painted a dull black in the belief that this would conceal the submarine best. By July 1943, experiments revealed that a smoky grey paint was more concealing at night. By the end of 1943, all submarines were painted in the new paint scheme which greatly aided their surface operations. See, Submarine Force, Pacific Fleet, *Submarine Operational History,* Reel 1, II, 568-9.

[30] USS *Tang,* First War Patrol, 10-22.

[31] Alden, 148.

[32] For another example of a successful night surface attack see, Beach, 50-54.

the substantial improvement in fleet effectiveness in late 1943. Given that the number of operational patrols did not significantly increase over the period under review, the increase of tonnage sunk does not reflect a large increase in the number of submarines assigned to operations. The submarines new to the fleet would have allowed for replacement of older submarines, and perhaps increased maintenance and training periods for the remainder.

It has also been suggested that the captain's age when coupled with improved doctrine impacted submarine performance. A major factor in Clay Blair Jr. and other authors' interpretations of why submarine performance improved rested with the replacement of older captains with younger, more aggressive, and flexible officers. However, the influence of the captain's age is not pronounced in the documents. Likewise, signals intelligence has also been indicated as a major cause for improvements in submarine performance. Unfortunately, this argument is problematic at best. Information generated by studying Japanese communications and shipping patterns helped target submarines at areas of higher shipping activity. This allowed captains to use their time at sea far more effectively. However, the actual use of information generated from code breaking was less effective. Targeted at military targets which were harder to intercept and sink, there is no evidence that code breaking significantly improved submarine performance.

Only the correction of the three flaws found in the Mark XIV torpedo holds a level of credibility. The faulty depth control, flawed magnetic detonator, and improperly designed contact detonator combined to make the Mark XIV a very imperfect weapon. At its worst, it was like firing solid shot at enemy ships, at best its performance was erratic. Certainly, the correction of these problems produced a viable weapon, which was necessary for a war against shipping. However, the torpedoes were useless if shipping could not be located or the captain could not close with it to attack. Of all the significant variables, in terms of locating and attacking shipping, radar had the largest impact. Radar was the most important factor in locating and attacking shipping. Its ability to increase the area searched by each submarine directly influenced the amount of shipping attacked and how it was attacked. Night surface attacks became the preferred method of attack because it exploited the submarine's stealth and speed to best advantage. Radar gave the submarines the ultimate advantage at night. The impact of radar was even more pronounced as captains became more skilled in its use. Experience taught them what was effective and how to use the radar most effectively. The result was a learning curve which led to a greater improvement. Radar affected the amount of tonnage sunk in two different ways. First, in the case of the number of attacks, radar increased the likelihood of contact being made. As the number of ships on patrol increased over the course of the war, the number of radar sets available also increased resulting in more contacts and thus more attacks and sinkings. Second, radar information improved the submarine's approach, attack, and the escape. This value of radar during an attack can be seen in the second patrol of the *Snook* discussed earlier. Thus, radar acts as the bridge between the various factors. It helped find more targets for the improved torpedoes, gave information vital for a successful attack, and allowed the submarine to escape more easily. Radar was the glue that united these forces into an effective submarine war on Japanese merchant shipping.

A submarine trades armour and the ability to sustain damage for stealth. Pre-war American naval planners, caught up with the Mahanian concept of the decisive battle, placed a great deal of emphasis on the role of the submarine as a scout, with the duty of observing the enemy in home waters and then attacking where possible. The belief that the submarine was easily susceptible to damage and loss from aircraft and escorts led to a very passive doctrine prior to the war. Even though paying lip-service to the idea of night surface attacks, the lack of effective night vision optics and the belief of submarine vulnerability combined to eliminate any effective night training for the fleet. The submarine was expected to fulfil its duties from below the surface. Radar shattered this notion. The submarine was now able to hide both above the surface and below it, attacking in the manner that best suited her and at the time of her choosing. The impact on the Japanese merchant marine, once this system was perfected, was devastating.