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MERCHANT SHIP ATTRITION

A Historical Perspective

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Prepared by:

Information Spectrum, Inc.
1745 S. Jefferson Davis Hwy.
Arlington, VA 22302
(703) 892-9000

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Traces the history of sealift protection, with primary concentration on World War II. Examines ship types, exploited advantages and constraints through seven phases of the war, statistical data which indicates attrition rates, and analysis of submarine action against independent shipping and convoys. Extensive references and notes. Concludes that attrition rates are highly dependent on the values of such factors as tactics, sensors, weapons, communications, intelligence, speed, experience and training, season, and area.

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CONTENTS

EXECUTIVE SUMMARY

War is dynamic, with each party to the conflict seeking an advantage to achieve his own ends, frustrate those of the enemy, decisively defeat or demoralize the enemy's battle forces, or prevent the enemy from gaining a decisive advantage. An anti-SLOC campaign is basically a war of attrition, except in a few cases of vital, timely, or irreplaceable military cargo. It presumes a strategy which makes provisions for a long, drawn-out struggle involving the classic move and countermove of tactics, technology, and forces.

In the historical examples, as well as analytical models, a great deal of attention is usually focused on the early high rates of attrition inflicted by predeployed, and hard-to-find, submarines upon unarmed merchant ships. However, it is in the interplay of multiple engagement opportunities that the detailed effects of the battles for the sea lines of communication (SLOC) have been revealed. If one side's opportunities are closed down, while increasing the other's within a reasonable time frame, the first loses the initiative and the second gains time to anticipate the next move.

Convoying valuable merchant ships has been one of the primary means of defense in the recorded history of warfare at sea. Three views are generally taken regarding the proper management of SLOCs: 1) that timely delivery is worth the risk

of loss, particularly for an aggressive and wily master; 2) that the appropriate role of battle forces is to blockade enemy commerce raiders, or to seek out and destroy them; and 3) that the percentage of safe arrivals is increased by drawing enemy raiders to the known location of the ships, whereupon they are dispatched by a sufficiently strong escort force. The popularity of this last view is enhanced during times of extended conflict, meager escort resources, numerous enemy raiders, and roughly equivalent technology. The second view is popular in times of offensive naval ascendancy or momentary technical advantage. The initial view is bound up with complex assessments of the risk and the uniqueness or priority of particular cargo in relation to the land campaign which strategic sealift supports.

In most cases the appropriate sea lane defense measures are influenced by the strength of the defensive forces rather than by the importance of the ships/cargo to be defended. If the defending force is small, its immediate success is small. Eventually, the defending forces may produce a cumulative attrition among the attacking forces which results in a decrease in the intensity and/or frequency of attacks - but only if the defenders are not the object of attack. As a general rule, if an element of strategic sealift is so important that no damage can be permitted, that assessment must be backed with a massive defense force. In that event, it is best to strike the first blow before being attacked.

Merchant ship attrition in World War II varied by area, national enemy, season, time period, and tactics. Various "lessons" have been drawn from its statistics, particularly for the Battle of the Atlantic. Perhaps foremost among these "lessons" is the view of SLOC defense which accompanies the current expressions of the Maritime Strategy by the U.S. Navy leadership: "As the battle groups move forward, we will wage an aggressive campaign against all Soviet submarines [to ensure] that we prevent such losses as the Germans inflicted on allied shipping between January and July of 1942 when 14 of 50 then-operational German U-boats sunk [sic] 450 ships..."* This view neglects to mention the special circumstances which enabled so few submarines to sink so many ships.

Another view of World War II is articulated in the pages of the official publication of the Navy League of the United States: "The contemplation of such a deployment pattern [10 submarines on station from an anti-SLOC force of 50] is not particularly comforting to those Western naval leaders who recall that from September 1939 to May 1941, when an average of only about eight Nazi U-boats were on patrol at any one time, the Allies lost about 60 ships or so per month .... it is most unlikely that losses of similar magnitude could be long sustained [today]."**

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* James D. Watkins, "The Maritime Strategy," U.S. Naval Institute special supplement, January 1986, page 11.

** James J. Tritten, "Defensive Strategy and Offensive Bastion," Seapower, November 1986, page 68.

Once again, a period of unique weakness on one side versus deliberate exploitation by the other was chosen as the characteristic of World War II. The article also states that today's USSR mine warfare capability would force NATO to convoy or use circuitous SLOCs, neglecting to cite WW II statistics showing only about 10% of the Allied merchant ship losses were due to mines (some of them Allied mines).***

Attrition rates varied during the World Wars. Some representative rates were:

May 1917 - Nov 1918	Atlantic Convoys	0.9%
Sep 1941 - Apr 1942	Tripartite Convoys (U.S./U.K./ Can.)	0.3%
Dec 1941 - Dec 1942	Convoys with U.S. Escorts	1.4%
early 1942	North Atlantic Convoys	5.5%
early 1942	Independents from Halifax and Freetown	14.6%
2 Jan 1943	Bari, Italy Air Raid	56.7%
Jan 1943	Convoy TM-1	77.8%

During World War II, the overall attrition rate for all merchant ships sailing through combat areas averaged 3%. However, as noted, results from individual encounters ranged from nil to virtual annihilation, depending upon strategy, area, season, tactics, training, technology, and forces present.

*** George R. Lindsey and S. W. Roskill, The War at Sea, 1939-1945, vols. 1-4, HMSO, London, 1960.

MERCHANT SHIP ATTRITION - A HISTORICAL PERSPECTIVE

I. INTRODUCTION

Our historical perceptions form a mosaic which is experienced as truth, as lessons learned, or as guidelines for future behavior depending on how the large set of data, from a series of engagements by a multitude of participants over a long period of time, is illuminated and examined. There are also shibboleths such as "History is bunk" or "Those who ignore history are doomed to repeat it." 1/ In the business of strategy, however, it is probably closer to the mark that "the greater danger than a complete ignorance of history is its misapplication." 2/ Despite a great deal of oversimplification derived from the accounts of maritime strategy of the past, there seems to be general agreement on the desirability of robustness of a strategy with respect to enemy strategy, escalation in the war's intensity, length of the conflict, and the outcome of the initial warfighting. Indeed, the historical accounts of merchant shipping in wartime display these desiderata in an almost classical sense of move and countermove.

II. THE ERA OF SAIL

The protection of merchantmen has been a recurring theme over the centuries, whether the danger was pirate, belligerent state, or privateer. Deceptive routing, point defense, area protection by a Navy, and superior speed were all tried, but only convoying was made compulsory under law in the principal trades. 3/ Belief in the system was underscored by a 30-50% reduction in insurance premiums offered by the underwriters "when a warranty to sail in convoy was inserted in the policy," but critics "asserted that its advantages were counterbalanced by the massed target presented to attack and the heavy losses sustained when an escort was overpowered." 4/ After seventy-five years on the books, the British Compulsory Convoy Act was repealed in 1872 in response to two principal arguments: that 1) independent shipping could more favorably compete for trade which would be snapped up by neutrals while British ships were waiting to make up into convoys, and 2) warships would be released from direct protection roles to blockade commerce raiders and patrol the sea lanes. 5/

III. WORLD WAR I

The introduction of steam propulsion partially removed the principal objection of older critics to the convoy system, by enabling merchant vessels to disperse in all directions when an escort was overpowered. However, the objections arising from delays in sailing were enormously multiplied. Thus, "for all the North Atlantic convoys [in WWI] the speed was fixed at 8 knots, and no vessel over 12 knots speed were included, as it was considered that the diminution of risk to such ships would not compensate the delays entailed. Ships of less than 8 knots speed, which were excluded in order to avoid too great a lengthening of the voyage for faster vessels, sailed individually on special routes indicated by the Admiralty..." 6/

The Admiralty had resisted introducing ocean convoys up to May 1917 because of an insufficiency of destroyers and patrol craft to serve as escorts. This situation was then ameliorated by assistance from the U.S. Navy so that, by the end of 1917, a bit over half the total overseas traffic of the United Kingdom sailed in open ocean or short-sea convoys. The success of the convoys was unmistakable and the Admiralty made greater efforts to increase the available escorts. By the end of the war in November 1918, 90% of overseas traffic was in convoy. The equation of time and attrition was less than 1% attrition versus a 25% increase in the average round trip (equivalent to having 20% fewer ships) for almost 16,700 sailings in 1134 convoys. Only 102 of the 154 losses were due to enemy submarine action

while actually in a convoy. An additional 1610 ships over 1600 gross register tons were lost to various enemy actions while sailing independently during the entire war. 7/

A large part of German U-boat losses in the latter part of World War I, after the Germans realized their value against enemy shipping and geared up to unrestricted submarine warfare in February 1917, was due to mines. Of 178 U-boats lost during the war, about 30% were sunk by mines, compared with 23% which were sunk by depth charges, 22% by gunfire or ramming, 10% by Allied submarine torpedo, and 15% by other causes. About 220 U-boats were under construction at the end of the war, testimony to continued German belief in their effectiveness. 8/

IV. WORLD WAR II

The British learned from World War I that the ocean convoy system reduced losses best, that it worked best in open water where evasive maneuver is possible, that effective evasion depended on an efficient tracking system, and that convoy escorts in sufficient number and with effective offensive weapons had to be provided. 9/ The Germans learned that "against the massed ships of a convoy ... the only right course is to engage them with every available U-boat simultaneously." 10/ This tactic would ensure a reasonable ratio of ships were sunk per opportunity. Both sides, however, had difficulty in implementing these lessons because of other priorities.

On the allied side, "It had been one thing to decide the form of protection which would be given to our merchant fleet in time of war; quite another to extract from an unwilling Parliament and nation the funds to provide the warships and aircraft needed to implement it." 11/ The Admiralty also failed to take the submarine threat seriously because of the few in operation and its overconfidence in the Asdic sonar. 12/ American unpreparedness was just as severe. The U.S. focus on the Pacific, our assignment of escorts to the critical North Atlantic convoys to Britain, and lack of long-range aircraft because of deliveries to Britain directly contributed to the German U-boat successes against the independent sailings along our East Coast and the Caribbean in Operation Paukenschlag ("Drum Roll") in early 1942. The number of coastal losses was further

exacerbated by a lack of wartime radio discipline and coastal blackout. 13/

The Japanese started the war with about seventy-five submarines operating in the Pacific and Indian Oceans. Although nine Allied merchant ships were lost to Japanese submarines in the Pacific in December 1941, and nine submarines harassed shipping close to the California coast early on, Japan never mounted an extensive anti-shipping campaign. 14/ 15/ Most merchant ships in the Pacific sailed independently.

On the German side, the small number of ocean-going U-boats available in September 1939 "suggests that Germany, possibly not anticipating that England would enter the war at that early date, had given higher priorities to the building of tanks and aircraft for land warfare than to the building of U-boats." 16/ This, despite a clear understanding that "the strategic task of the German Navy was to wage war on trade.... The sinking of ships was the only thing that counted." 17/

With this as prologue, several factors which influenced merchant ship attrition in World War II can be examined.

A. The Ships

"When the war broke out most of the ships of the American Merchant Marine had been built prior to or around World War I. One torpedo was enough to blow most of them apart and they sank rapidly. The condition of the ships and their equipment was a major cause for the heavy loss of life..." 18/ Nevertheless, there are many accounts of ships which, although being very seriously damaged, were able to deliver their cargoes

before putting in for extensive repairs. Additionally, of more than academic interest, are the cases of groundings, capsizings, and collisions loosely grouped under the heading of "marine hazards" in the statistical roll calls of ships lost and damaged beyond repair. One historian has noted that, though no official figures were ever released, "the total damage done by Allied ships to their column neighbors and the escorts surpassed the losses suffered in enemy action." 19/

On the other hand, accounts from the British experience make note of extraordinary damage done by enemy attack, and yet the ships were still brought into port. Several cases will illustrate the merchant saying that "so long as she keeps most of the ocean on the outside she'll be all right:"

- A torpedo hit broke her in two. The stern 2/3 was sailed at 3 1/2 knots into port.
- Sailed 720 miles at 4-7 1/2 knots with a 76 foot long hole in her hull.
- After her stern and rudder were blown off by a torpedo in high seas, she steered by her engines some 700 miles to deliver her cargo, then another 2700 miles home.
- Shelled and holed above the waterline in the forward tank, three tanks and the pump room damaged by a torpedo, she caught fire and was down forward with the forecastle awash, but came into port.
- A torpedo hit set her afire and she lost steering; part of an enemy plane fell on deck; her boiler blew; and a bomb destroyed her engine room. Towed into port. 20/

Because over 2700 liberty ships were built during World War II, this class offers a special opportunity to compile a statistical sample of loss and damage sustained during wartime. 21/ Before the United States entered the war the British had ordered 60 of these ships to be built in two U.S. shipyards. The prototype was a British 10,000-ton freighter, modified for mass production and with reciprocating steam engines for which production facilities were available. Seven watertight bulkheads divided the ship into five holds, with a central machinery and boiler space under the midship deckhouse. It was capable of 11 kts and was classed at 10,865 deadweight tons by American Bureau of Shipping (ABS) standards. However, some changes from the basic British design turned out to have unexpected consequences. These, combined with inexperience, poor welds, unusual loading and ballasting, and austere outfitting all combined to make the ships vulnerable to environment and enemy action. 22/ A survivor's account is instructive:

> "It was well known by the men who sailed these Liberty ships that the section of the hull in a vertical alignment with the face of the midship house was an overly weak point. I'm sure that the German skipper knew this as well as we did, and that,,two torpedoes would do the job like a can opener. In addition to their well-known fragility, these ships were natural torpedo bait. They had been designed with speed and maneuverability sacrificed for cargo capacity. Their blunt bows and flat bottoms allowed

them to carry more cargo but, in such cases as ours, made a critical difference in speed. This design also created a built-in weakness which showed up in stormy weather. One of our shipmates was making an Atlantic crossing in a Liberty when she broke into three pieces during a storm without any help from a torpedo - forward and aft of the midship section, leaving it floating around without a bow or a stern. [In partial defense of the designers, the writer, having worked at shipbuilding, noticed that in many cases production welding did not follow tack welding, leaving critical weaknesses between plates.] These weaknesses were intensified by the extreme strake between the midship and the bow, creating a powerful shearing stress where the forward section joins the midship house. This weak point was further agitated by the flat bottom; when a wave lifts up a ship and drops it down again on a following wave, the strain on the hull plates is greatly increased by a flat design. Proof of this is that after the war some of these ships were strengthened by reducing the forward strake; others had steel girdles (production-welded) around their middles." 23/

Each of the 17 yards on three coasts which built the Liberty's used slightly different methods. Some ships were 100% welded, others had riveted frames, seams, and deckhouses. Some plates were riveted just enough to hold them in place for

welding. Overall, about 12.5% had weld defects, 10% developed cracks, and one in thirty had major fractures. 24/ The steel sometimes fractured in the extreme cold of the Arctic routes. One ship developed an 18-inch hull crack running from the main deck into the engine room. The captain coolly ordered cables rigged on deck between bits and used winches and turnbuckles to hold the ship together until it reached port and received a welded patch. 25/

Many losses resulted from non-fatal hits which caused a ship to drop out of convoy and become vulnerable to further attacks. Most ships on the Murmansk runs carried ammunition or TNT and were blown to bits if hit in a hold by a bomb or torpedo. Although fitted with fire extinguishing systems, most had no fire detectors and no emergency diesel generators for powering pumps. The head of the Maritime Commission, Admiral Emory S. Land, remarked of the Liberty: "It was produced to be expendable if necessary." 26/

Altogether, 2624 dry cargo and 86 tanker/collier Liberty's were built for the U.S. Merchant Marine during the war. No colliers (EC2-S-AW1) were lost and only one tanker (Z-ET1-S-C3) was lost to a Kamikaze attack. 272 dry cargo ships (EC2-S-C1) were put out of action by all hazards as follows: 27/

submarine	124
marine hazards	55
aircraft	44
mines	40
surface ship	6
unrecorded enemy action	3

B. Exploited Advantages and Constraints

"The United States Navy participated in no fleet actions in the Atlantic... The Battle of the Atlantic was, by and large, a fight for the protection of shipping, supply and troop transport waged by the United States Atlantic Fleet and Allied Navies against Axis submarines, supporting aircraft and a few surface ships." 28/ The story of this fight proceeds in fits and starts, through at least seven distinct phases, and recounts the seesaw nature of results influenced by the introduction of forces, sensors, weapons, tactics and strategy on both sides. The end came as a result of land actions, not because the Battle of the Atlantic was decisively won. The Type XXI U-boat was never used in battle and the Type XXVI U-boat was never completed, but their high submerged speeds (18 and 24 knots, respectively) and endurance could have drastically changed the sealift picture. 29/

1. Phase One: 9/39 - 6/40

For the majority of the war, submarines were really surface ships capable of disappearing from view by diving. Submerged, they had restricted mobility and were similar to mines. The main problem the Germans had to solve was how to locate the convoys formed by the British. 30/

Both sides experienced a lack of long-range air reconnaissance. Without it, the Germans had difficulty locating convoys and the British could not force patrolling submarines to submerge.

U-boats attacked the closely-spaced, 45- to 60-ship convoys in daylight at periscope depth. They found it relatively easy to

maneuver into attack position on the 6.5- or 9-knot convoys protected by close-in escorts. Electric wakeless torpedoes did not betray the attackers. The slow convoys steamed straight ahead, zigzagging only if submarines were suspected in the immediate area. 31/

An unarmed straggler or independent merchant ship was usually attacked by surface gunfire. Troop convoys sailed at 12-15 knots and were better protected and, thus, harder to attack.

Because of the transit distances from their bases in Germany, the U-boats did not venture too far into the Atlantic and preferred to attack independent ships. Losses of ships in the lightly escorted convoys, however, were enough for the British to change established routes.

2. Phase Two: 7/40 - 3/41

U-boats moved to French bases after France fell. Aircraft reconnaissance also was facilitated. Night surface attacks on convoys were begun, evading Asdic detection, and a full spread of five torpedoes was usually fired. Problems with the effectiveness of torpedoes, however, were so severe that multiple salvos were required for a single kill. Thus, "U-boats often found themselves unable to engage subsequent targets because of lack of torpedoes." 32/

The British opened the spacing between ships in convoy, moved the escorts out, and used night illuminating devices to counter the U-boats.

Although attacks were taking place farther into the Atlantic, the few U-boats available on station (about 10, since

two had to be used as weather ships farther to the West), and the continued lack of long-range air reconnaissance kept the U-boats from intercepting many ships before they reached the North Channel between Iceland and Scotland. 33/

At this point in the war, Germany suspended radar research for two years; Hitler required that all research have a one-year payoff. 34/

To counter the British Asdic and compensate for lack of air reconnaissance, 3-5 U-boats began to operate in fixed areas with some coordination with land-based bombers. Torpedo fuzes were changed from magnetic to impact and the new, faster Type VIIC U-boat was introduced. 35/

In November 1940, the pocket battleship, ADMIRAL SCHEER, attacked convoy HX-84. It sank the lone armed merchant cruiser, sank five merchant ships, and severely damaged another. The British faith in the existing convoy system was severely shaken and battleships were diverted to convoy escort duties. 36/ Convoy frequency was also reduced in order to provide more escorts per convoy.

3. Phase Three: 4/41 - 12/41

Because of inadequate escort numbers and problems in fueling those which were available, there was a gap in coverage southeast of Greenland. German wolfpacks gathered in this area and in the Freetown/Azores area, and coordinated with the Luftwaffe against the Gibraltar-to-Britain convoys off Spain and Portugal.

The British began using HF/DF to locate U-boats closing on the convoys and were able to shift escorts to threatened sectors. 37/

In May, U-110 was captured. Before it sank, the Kurzsignale short report and "officers only" codebooks were recovered. 38/ In August, the capture of U-570 provided the British with a wealth of technical details. 39/

In September, a tripartite force of U.S., U.K. and Canadian escorts began end-to-end escort on the Halifax-to-Britain routes (this before official entry of the U.S. in the war). While U-boats sank an average of 34 ships per month during September - December 1941, and 98 ships per month during January - April 1942, the tripartite convoys lost only 8 out of 2600 ships escorted during the same periods. A contributing factor was the tactic of stationing escorts in the areas the U-boats needed to occupy to trail and fire torpedoes. 40/

On 18 June the minimum speed for independently routed ships was raised from 13 to 15 knots. Independent loss rates had been running 13.8% from Halifax and 15.4% from Freetown. Convoys averaged about 5.5% attrition on both routes. Even 15-knot independents had losses approaching convoy loss rates. Only the giant 30-knot liners had an adequate speed defense. 41/

On 22 June, Germany invaded Russia, ending the threat of invasion of England and releasing British air and surface craft for the ASW battles. German aircraft were diverted to the Eastern Front. 42/

U-boats began attacking escorts and shooting salvos from outside the screen. Escort policy was then changed to have them patrol in sectors, 2000-5000 yards out. Escorts were also fitted with new SG radar near the end of this phase. 43/

4. Phase Four: 1/42 - 9/42

As the United States entered the war, aircraft depth charge depth settings and spacing were changed to be more effective against U-boats which were caught submerging. Escorts were moved out to three miles to capitalize on radar detections.

A change in the German Enigma code machines hindered the Allied Ultra code-breaking effort during this period.

The German B-Dienst decoding service broke the Admiralty Naval Cypher in February. 44/ It did not affect the anti-shipping campaign much, however, since Admiral Doenitz moved as many subs as he could to the U.S. East Coast. With the U.S. coastal waters practically undefended, no coastal convoy system, and no wartime radio and coastal blackout disciplines in effect, Operation Paukenschlag took a heavy toll of East Coast shipping. One can only surmise the devastating effects if Doenitz had been able to keep more than 6 U-boats on station in the Western Atlantic. 45/

When coastal convoys were finally started, the U-boats moved to the easier hunting in the Caribbean.

Much of the German success in Operation Paukenschlag derived from their use of large (over 1000 ton) "milch cow" replenishment submarines stationed about 300 miles east of Bermuda. From the end of March, 12 Type VII boats could be supplied for 4 weeks or

5 Type IX for 8 weeks by a single "milch cow" without replenishment. 46/

When U.S. air coverage increased in the Caribbean and Gulf/Caribbean convoys were established, the U-boats returned to the North and South Atlantic.

Meanwhile, fuel shortages and the reduced numbers of U-boats had caused the North Atlantic convoys to sail on the shortest routes, making it easier for the remaining U-boats to locate them. The German Naval Operations Staff and Grand Admiral Raeder felt that only the fully-laden eastbound convoys should be attacked, but Doenitz's arguments prevailed. He pointed out that, while stopping cargo was the object, this goal could also be served in the long run by sinking ships in ballast and that this tactic was also the best use of limited U-boat on-station time. 47/

The PQ/QP convoys between Britain and Archangel and Murmansk had their own problems in the Norwegian and Barents Seas. Foul weather resulted in stragglers which were picked off by submarines, warships, and high- and low-level bombers. German air reconnaissance, flown from bases in Norway, was extensive, so that fog became a mixed blessing for the beleaguered merchant ships. Ships were even subjected to bombing attacks entering the Kola inlet and offloading in Russia. In one recorded instance the Naval Armed Guard aboard ship broke out two tanks secured on deck and used their 37mm guns to help fight off air attacks. 48/ In another instance, however, 350 bombers hit a large convoy and

sank a fourth of the ships. Some of these convoys had up to 75 escorts. 49/

5. Phase Five: 10/42 - 6/43

The Battle of the Atlantic peaked during this period. Despite the Germans having the greatest number of U-boats at sea, the weight of Allied submarine countermeasures finally took its toll. This phase contained the interactions which centered on Operation Torch, the Allied landings in North African in early November; concentrated attacks on independent shipping in the Capetown, South African and Brazilian areas; diversion of shipping bound for the Indian Ocean/Red Sea to a trans-Pacific route; and withdrawal of the U-boats from the North Atlantic.

Wolfpack operations against the North Atlantic convoys were hampered by newly available long-range aircraft operating against them in the Atlantic and during transit of the Bay of Biscay. When the U-boats were equipped with radar receivers they had ample time to submerge before being detected, though there were instances of the GSR receivers reradiating the radar beams and causing the U-boat to be detected. 50/ This advantage was lost when 10cm S-band radar was installed in aircraft. Because of their previously noted suspension of radar development, the Germans were unaware of S-band. Therefore, the U-boats were fitted with heavier anti-aircraft armament and began to stay on the surface to fight. With a 25-foot depth setting on their depth bombs, the aircraft were able to sink many of these subs. 51/

The U-boats also seriously underestimated or ignored shipborne HF/DF. Once contact on a convoy was made, subsequent radio chatter to coordinate the wolfpack enabled the escorts to triangulate and localize them.

In February 1942, the U-boats had begun using a new cipher on their Enigma code machines which the Allies were unable to break for 10 months. In December 1942, a steady flow of decrypted messages was once again available. In March, a new four-rotor system was used on Enigma, but the British code breakers managed to crack it in only three weeks. By May of 1943, the steady stream of Ultra intelligence could be acted on by the increasing numbers of escort ships, aircraft, and newly formed hunter/killer groups. Meanwhile, the Germans were still privy to the British and Allied Merchant Ship (BAMS) code, which was not changed until mid-1943 despite the warning available in 1942 through decoded U-boat signals. 52/

Several weeks before the North African Allied landings, the North Atlantic convoy escort groups were reduced by half to provide escorts for the invasion force. As the invasion force approached Africa, two other convoys drew the U-boats' attention. They sank 27 ships from these convoys--a cheap price in the long run for the safety of the invasion fleet, but of little consolation to the chance "decoys". 53/

Weather also became a significant factor as January 1943, set a record for storms over the North Atlantic. Storms of gale force or greater were recorded on 116 out of 140 days from December to March, hindering the U-boats more than the convoys.

Superimposed on a battle of wits between opposing commanders, a raging storm slowed convoy HX-223 on 22 January and the waiting U-boats were drawn out of position because of the speed change. 54/

In February, Convoy SC-118 was a victim of several factors: a broken cypher revealed its routing, a merchant seaman survivor from a torpedoed ship in the convoy ahead had confirmed it, an illumination device was accidently set off and revealed its location, and an evasive course change was only received by half the merchantmen and none of the 11 escorts. Only superb air and escort work held down losses to 1 ship against 20 U-boats for three days. Then, a superb U-boat commander found the convoy. Korvettenkapitan von Forstner sank seven ships and enabled two other U-boats to sink five more. Three U-boats were sunk and four others heavily damaged. Neither side had "won". 55/

In March, Doenitz became increasingly concerned with the Allied ability to located surfaced U-boats by radar. He ordered new tactics of 30 minutes submergence when detecting a radar transmission; to shadow at maximum visibility, moving around the convoy to a position ahead; and attacking submerged. One of the first convoys to encounter these tactics suffered heavily, due in large measure to lack of maintenance and consequent sensor failures on the escorts. This was brought about by the shortage of escorts and the decision to sail even diminished-capacity escorts with every convoy. 56/ The convoy system was at the breaking point and the British Naval staff considered abandoning it.

At this point, six support groups of destroyers and escort carriers were formed to hunt down and kill U-boats wherever detected. They erased the "air gap" and, along with greater numbers of very long-range Liberator bombers, forced the U-boats from the surface. Allied confidence improved so much that a deliberate attempt was made to engage remaining wolfpacks in the vicinity of a heavily escorted "decoy" convoy. 57/

In May 1943, Allied radio codes were changed and Allied HF/DF became unusually accurate. After several violent clashes during which 31 U-boats were sunk, Doenitz recalled all U-boats from the North Atlantic on the 22nd. The following factors contributed: 58/

- HF/DF ashore and on escorts
- microwave radar on escorts and aircraft
- formation of special support groups
- air coverage
- allied training, ability and teamwork
- operations research techniques
- improved weapons (hedgehog, depth charge, rockets)
- persistent hold-down tactics by Allied ASW forces.

6. Phase Six: 7/43 - 5/44

Despite the setbacks in the previous phase, the U-boat war continued. Perhaps anticipating a rich harvest by striking at comparatively lightly defend areas such as the Caribbean, Brazilian, and Freetown areas, they attempted to regain the initiative even as the Allied invasion of Sicily took place in July without any losses to U-boats.

Other factors which influenced the decision to resume the U-boat campaign included:

- confidence in new antiaircraft guns
- new detection devices and a pattern-running torpedo
- improved anti-escort homing torpedo
- development of Schnorchel and the Type XXI submarine
- ability of relatively few U-boats to tie up Allied forces useful for invasion of the Continent
- demands of the Allies for unconditional surrender. 59/

Special Intelligence position reports were used by the Allies to locate and destroy 8 of the "milch cow" replenishment submarines in July and August, usually by aircraft from the escort carriers of the support groups. 60/ Aircraft activity over the Bay of Biscay made the U-boats much more cautious in transiting. Shore-based aircraft sank 9 U-boats in the Brazilian and Caribbean areas, forcing a withdrawal from areas Doenitz had considered safe.

In September, the Italian Fleet surrendered, removing 29 U-boats from the threat. In that month, also, German U-boats adopted the tactic of attacking the convoy escorts first with acoustic homing torpedoes. In May 1944, they sank the escort carrier USS BLOCK ISLAND and one of her escorts. This fulfilled the prophecy of British Commander Howard-Johnston, who had remarked earlier on the relative risks to convoy escorts: "There is no risk yet. The U-Boat is out to sink merchantmen. You are a confounded nuisance to its Captain, not a target. When the first escort vessel is torpedoed deliberately you will know that

the Hun is beaten and the war is won. Everything else after that date is just a mopping up operation." 61/

Small wolfpacks, coordinated with air reconnaissance, tried again to stop the North Atlantic convoys, but Allied land-based air and stronger escort groups beat them down. The losses of supply submarines noted earlier also affected wolfpack effectiveness, which had been based on high-speed surface operation (and high fuel consumption) to close with the convoys.

Analysis of U-boat operations indicated a strong correlation between independent ship speed and attrition. A 12-knot ship ran about 3 times the risk of a 14-knot ship, given an identical threat environment. This was linked to the 17- to 18-knot surface speed of the U-boats, which had to sprint into attack position in most cases. 62/

The convoy program was kept flexible during this phase in order to balance risk of loss with urgency of cargo delivery. A greater percentage of shipping was permitted to sail independently until the danger of a U-boat attack appeared imminent.

A British aircraft, shot down over German-occupied territory, crashed with its X-band, 3cm microwave radar sufficiently intact for the Germans finally to realize the reason for Allied aircraft detection successes against the U-boats. They rushed to install detectors and increased the percentage of submerged time. 63/ They also realized the effectiveness of the escort HF/DF and tightened up on their communications. 64/ In February 1944, the first Schnorchel was installed.

Allied countermeasures included the Bearing Deviation Indicator for sonar, magnetic airborne detection (MAD) for aircraft, Asdic depth predictor, magnetic proximity fuzes for depth charges, a faster-sinking depth charge, and introduction of ahead-thrown depth charges (Squid).

7. Phase Seven: 6/44 - 5/45

The U-boat war, as in Phase One, became subsidiary to, and influenced by, military operations in Europe as the Normandy invasion approached. Sufficient Schnorchel-equipped U-boats were available to create the threat of a massed attack on the invasion force. The Allies concentrated ten escort groups (54 ships) and three escort carriers to block off the cross-Channel area and guard the convoy routes in the Western Approaches.

The U-boats set up defensive patrols off Bay of Biscay ports, but were forced to maximum submergence by Coastal Command aircraft. It was not until late June, three weeks after D-day, that U-boats succeeded in even penetrating to the invasion area.

The Allied breakthrough on land in August forced the U-boats to head for Norwegian ports. The Allies countered by routing convoys to the south of Ireland. Gaining confidence in the Schnorchel, however, the U-boats soon learned how to transit inshore waters without serious risk. Counter-detection was difficult due to reverberations, use of towed noisemakers by escorts, and the large number of wrecks on the bottom. 65/

Coincident with the German land offensive on the Western Front (Battle of the Bulge) in December, the U-boats began a

steady increase in operations in an attempt to impede military supplies and troops. A few merchantmen were sunk in the Western Atlantic, one by a U-boat which had landed agents in Maine in November.

In the Spring, some U-boats shifted back to the lightly defended mid-Atlantic area. One U-boat, homeward bound from the Indian Ocean, sank two ships in the Brazilian and Caribbean areas. "With remarkable determination the enemy maintained his U-boat offensive in inshore waters to the very end of the war. No relaxation of effort or hesitation to incur risk was apparent until the German surrender on May 8, 1945." 66/

Allied aircraft used the X-band radar and sonobuoys effectively against Schnorcheling U-boats. An FTC circuit also was added to the radar to reduce sea return. German developments of a new pattern-running torpedo (LUT), high-speed HF communications (Kurier), and directional radar search receivers (Tunis) came too late to produce much of an effect. The new Type XXIII U-boat, designed for inshore waters and short cruises, was moderately effective. The high-speed, 18-knot (submerged) Type XXI encountered problems during trials and, though several were ready in Norway, were never engaged before V-E day. 67/

8. Epilogue

The various histories of the war identify numerous factors which influenced the course of the anti-shipping campaign by the Axis powers. They ranged from strategic employment of available resources, to struggles with the environment, intelligence and counterintelligence, scientific and technical

developments, tactical employment involving communications and maneuver, and to force expansion priorities. The Allied problem has been described as being like "lifting an immense jellyfish." 68/ Only through the most extraordinary cooperation and dedication was the tide turned, as a variety of "solutions" were proposed, implemented and modified to meet the circumstances - which were largely controlled by the enemy until mid-1943. Convoying, dispersal, improved weapons, night illumination, better radar and sonar, better gunnery control, use of aircraft, building faster warships and merchantmen, and strategic bombing of submarine bases were all tried.

C. Statistics

A great wealth of statistical data has been compiled on World War II. Much of it was compiled from original reports and files not available to the average researcher or so voluminous as to present a problem of immense magnitude. Some accounts were made during and immediately after the war, when records had not been carefully verified and compared to enemy records. Other accounts had to await a long records declassification process before access by historians and researchers was possible. Much of the summary data available is not internally compatible due to such differences as choice of time periods or tonnage classification criteria. Since "there appears to be little virtue in the extremes of complete description of the intractable or rigorous analysis of the trivial ... we are forced to accept approximation in both description and analysis. However, it is dangerous to believe unreservedly that what is plausible is also

true." 69/ The data must be considered in the context of the events which produced it.

1. Liberty Ships 70/

Number built during war for the U.S. (including 86 tankers/colliers)		2710
Number put out of action		273 (10.1%)
submarine	124	
maritime hazards	55	
aircraft	44	
mines	40	
surface ship	6	
unknown enemy action	3	
shore battery	1	

2. Allied Merchant Ships

• Number of merchantmen sailed in British-controlled Atlantic convoys (9/39-5/45)		75,000
Number of ships lost		574 (0.8%) 71/
• U.S. merchantmen lost (1000 GT or over, 12/7/41 - 8/14/45)		674
Number lost while escorted		163 (24.2%) 72/
• Allied merchantmen lost (1000 GT or over, 9/39-5/45)		5,150
Causes: submarine	2,828	
aircraft	820	
mine	534	
ship	336	
other	632	73/

- Transatlantic convoys with U.S. escorts (12/41-12/42) 250
  Number of ships convoyed 9,481
  Number of ships lost 132 (1.4%) 74/
- Transatlantic convoys in U.S. area of responsibility (1942-1945) 1,134
  Number of ships convoyed 47,997
  Number of ships & escorts lost 275 (0.5%) 75/
- North Atlantic Trade Convoys (HX/SC/ON/ONS) ships sailed 12/41-4/45 30,330
  Number of ships lost 242 (0.8%) 75/
  (84 sunk as stragglers; 29 others were damaged but arrived)
- North Atlantic Trade Convoy attrition rates (in U.S. area only 12/41-4/45):
  fast convoys (9 knots) 0.4%
  slow convoys (6.5 knots) 1.6%
  westbound (longer) 0.9%
  eastbound 0.7% 75/

3. World War I Comparison 76/

- Number of merchantmen convoyed (5/17-11/18) 16,693
  Number of convoys 1,134
  Number of ships convoyed 17,111
  Number of ships lost 154 (0.9%)
  to submarines 102
  to marine perils 16

as straggler or

after dispersal 36

- Number of merchantmen 1,600 GRT and over (7/14-10/18)

sunk by enemy	1,764
marine perils	248
captured/interned in port	46

D. Analysis

The anti-shipping offensive in World War II was primarily conducted by German and Italian U-boats in the North Atlantic and littoral seas. However, U-boats, ships, and aircraft all have to accomplish three tasks: 1) obtain contact on desired target ships through intelligence or long-range detection; 2) approach to attack range by moving to intercept a firing position based on predictions of target movements; and 3) select the weapon and target attack solution parameters. The primary aim of sealift protection is to reduce the effectiveness with which the attackers carry out these steps.

First, the enemy's contact rate can be reduced by evasive routing after determining threat areas through surveillance or intelligence. Movement security denies the enemy knowledge of ship position and movements. Under some circumstances, convoying will reduce the threat exposure of individual ships. Offensive area operations force the enemy away from desired transit areas, force him to concentrate on his own survival, and prevent his use of optimal tactics.

Second, hindering closure rate depends on restricting the enemy's relative mobility. Obscuring one's own intended movement makes it difficult for an attacker to arrive at an optimum weapon release point. Interposing escorts forces the attacker away from direct closure courses. High speed reduces the relative closure rate for attackers approaching from all sectors other than ahead.

Finally, in order to interfere with or degrade the successful attack rate, a knowledge of weapons effectiveness and operation is necessary. Knowledge of enemy weapon release parameters permits proper positioning of appropriate sensors and deployment of countermeasures, and requires the defender to maneuver rapidly or unmask counter-fire batteries. Preventing accurate weapon release requires timely use of deceptive measures or vigorous offense to disrupt the chosen attack solution.

Additional considerations which play significant sealift protection roles include denial of rearm/resupply opportunity at fixed or mobile depots, offensive operations against attackers transiting to operational areas, disruption or exploitation of enemy central coordinating communications, and restricting the effects of weapon detonation through damage control and ship construction.

1. Independent Shipping versus Submarines [77/]

The expected number of detections on a single transitor, N,

is $N = DQ\ (L/v)$

where D = Number of subs per square mile of operating area

Q = square miles per hour searched by the sub (sweep rate)

L = ship track length in threat area

v = ship speed

Detections can be reduced by using many routes (forcing subs to search a larger area); sinking subs (reducing density); forcing the sub to slow or operate in acoustically poor water (reduce sweep rate); decreasing own speed (reduce sweep rate); or reducing time in the sub operating area ($^{L}/_{v}$). Detections of a particular ship could also be reduced by increasing the number of widely dispersed ships in the area simultaneously, assuming the sub interrupts its search to investigate each contact in turn.

Reducing the rate at which submarines are able to maneuver to an ideal weapon release position depends upon several factors: the ability of the sub to predict future ship positions, the closure rate, and the degree of target identification required.

In World War II, a visual sighting was required to attack a merchant ship. Often, however, course changes by ships caused the intercepting submarine to miss the rendezvous. In many cases, the speed of some merchant ships - generally those capable of speeds in excess of 15 knots - seriously hindered the submarines'ability to close to an attack position in the forward sector of ship movement or to conduct re-attacks if initially in a favorable position. Higher submarine speed and offboard or extremely long-range sensors will tend to reduce the importance of

ship speed, but there will be complex relationships involving speed, detectability, detection/tracking ability, and target signature. The presence in the submarine operating area of combatant platforms capable of counter-detection may inhibit the use of high submarine speed.

Knowledge of enemy weapon types and firing doctrine assisted in developing countermeasures during World War II. Point defense anti-torpedo nets, used to protect the midship area, were somewhat effective, but could not be properly rigged in bad weather and were not routinely used except when an attack was expected. They were capable of stopping about 85% of the electric torpedoes, but only 20% of the air-propelled torpedoes. 78/ Acoustic decoys were towed by some escorts, but they degraded detection ability. After the Germans corrected the torpedo fuzing problem, merchant ships were usually attacked with a salvo of two straight-running, non-homing torpedoes. Ship construction and loaded stability were important factors in survivability, given that hits occurred.

2. Convoyed Shipping versus Submarines 79/

The expected number of detections by submarines will be less when ships are concentrated in convoys, since there are fewer opportunities (a convoy is one opportunity) for detection (factor = $1/n$). However, the collection of ships will tend to be detectable at longer ranges (factor = $n^{1/3}$). The WW II rule of thumb for contacts on convoys, Nc, was:

$$Nc = Ni/n^{2/3}$$

where, Ni = expected number of contacts on the same ships sailing independently

n = number of ships in convoy

Thus, a convoy of 64 ships was expected to reduce the total contact opportunities by a factor of 16 (Nc = Ni/16), while a convoy of 27 ships only reduced submarine contact opportunities by a factor of 9.

Another advantage of the convoy was the ability of shore-based intelligence centers to warn the convoy of known submarines so the convoy could maneuver to avoid detection. One of the most difficult problems in WW II was that of wolfpacks. A great deal of ASW effort was eventually devoted to preventing submarines from making convoy position reports to draw in other subs for massed or sequential attacks. The analysts estimated that a pack of 3 had 1.7 times as many contacts and a pack of 6 had 6 times as many contacts as developed when searching independently. German U-boats formed some packs as large as 10-20.

The approach to firing position on a convoy included the additional factor of escort avoidance. Since the typical convoy was large, slow and unmaneuverable, the effect of ship/convoy speed had to be offset by the escort factor. Aircraft escorts were used to force submarines in the surfaced approach and tracking zones to submerge, lose contact, and fall astern. The surface escorts were used to detect submarines in the submerged approach zones (or, in the absence of aircraft, to use HF/DF, radar, or illumination to detect and force the subs under) and attack before the subs did. The rule of thumb was that, all factors considered, the number of successful approaches on a convoy would be about 1/4 - 1/2 of those on independent ships.

Firing at a convoy ship may produce damage even if a torpedo misses, since interior ships are also at risk. Simplisticly, the probability of hit, P:

$$P = 1 - (1 - L/r)^c$$

where L = length of ship

r = row spacing

$$c = \text{number of columns crossed} = \left| \frac{Rm - Rf}{s} \right|$$

where Rm = maximum torpedo range

Rf = firing range from main target

s = column spacing

Example: 5000 yard torpedo is fired 1800 yards abeam a ship 420 feet long in a convoy spaced 800 yards bow to stern and 1000 yards abeam.

$$c = \left| \frac{5000 - 1800}{1000} \right| = 3$$

$$P = 1 - \left(1 - \frac{140}{800}\right)^3 = .44$$

If a salvo of 4 torpedoes is fired, the expected number of hits is 1.76. One reason many large convoys were formed with a broad front was to reduce the likelihood of interior ships being hit by torpedoes aimed to cross the convoy course at the preferred 90 degree angle.

The effects of convoy size (m), number of escort ships (c), and number of U-boats (n) in a wolfpack were analyzed for WW II

data. For about 15-70 ships per convoy, there was no statistically significant effect of convoy size on the number of ships lost per attack. The number of ships sunk (k) and U-boats sunk (g) were observed to be about:

$$k = 5\ (n/c)$$

$$g = nc/100$$

$$\frac{g}{k} = \frac{c^2}{500}$$

Thus, a convoy of about 30 ships, attacked by a wolf pack of 8 U-boats, and protected by 6 escorts, would be expected to have about 1/10 the contacts made on it as if the ships were independent; 1/2 the number of successful approaches; and would sustain about twice the hits, for a relative loss factor of 1/10 compared with independent shipping. The wolfpack effect would produce about 7 kills and result in one U-boat sunk in every two attacks on convoys.

Problems encountered in a convoy system include communications difficulties (particularly, in ensuring that all ships are informed), decreased maneuverability, vulnerability of stragglers, congestion in the port approaches or vulnerability in dispersal areas, and delays involved in making up and sailing convoys. Data collected for U.S. coastal convoys revealed

% of time spent at sea

independent - 67%

convoyed - 57%

Loss rates per month at sea

independent - 20%

convoyed - 4%

The implication, in a general sense, is that the total cargo delivered safely by independent ships is greater up to about 6-7 months, when convoying surges ahead.... IF the percentages preceding do not change by either side adjusting their strategy, tactics, weapons, sensors, or intelligence.

With regard to escorts, the analysis indicated that the number of escort groups, G, required to operate a convoy system should be

$$G = \frac{W + P}{I}$$

where W = round trip time

P = port time (both ends)

I = sailing interval

The number of escorts per group, by one rule, should be at least 1.5 times the expected number of attackers per encounter plus a 2-ship search/attack unit. Other considerations include the length of perimeter to defend and detection range of each escort. By another rule, the number should equal 1/10 the number of merchant ships plus three. 80/ Thus, a 40-ship convoy proceeding through an area reported to contain up to 6 U-boats should have 7-11 escorts.

E. World War II Summary

Each encounter was nearly unique, with a particular combination of factors which determined the outcome. Generally, the victory went to the side which was able to keep ahead in tactics, sensors, and weapons simultaneously, but communications

and intelligence were often the deciding factors where neither side or a clear numerical and technical advantage. Relative speed was a great tactical advantage, with a differential of 2-4 knots often making a decisive difference in the ability to engage. Aggressive attacks by experienced and well-trained crews usually paid dividends for both sides, and these were more likely in the cases of commanders and crews which had survived several engagements.

Convoying worked because it made the best use of limited escort resources by drawing the enemy to where it could be engaged with massed firepower. Its effectiveness was facilitated because enemy submarines were funneled into approach sectors by the limitations of relative speed and because the mere presence of aircraft was enough to force submergence and effective loss of mobility. The convoying advantage disappeared when the attacking force was overwhelmingly strong relative to the defenders.

Several other factors were more difficult to quantify from the written accounts. The strain of engaging convoys over a period of several days exhausted most U-boat crews after two or three such operations and "made it imperative that the boat should return to base for a period of rest and recuperation." 81/ Sometimes this was no more than withdrawal to an open ocean haven for sunbathing and swimming. Some of the convoy battles were also exhausting for the escort crews, who rarely had the opportunity for R&R. Initially, the expenditure of fuel and weapons in these engagements severely restricted defensive efforts and the escorts

were forced to develop an ability to refuel and rearm from merchant ships in the convoy.

Convoy routing had its own problems. "During the war, one-fourth of all ship losses were due to collision, foundering, and marine casualties not directly attributable to enemy action." 82/ Some causes involved ship construction, loading and ballasting, and weather, but it was not until 1944 that standard convoy routes could be established in the Altantic to eliminate the danger of collisions between convoys on converging courses. Collisions within convoys remained a problem which bad weather and evasive steering exacerbated and which opened intervals did not eliminate (a consequence of no radar, lack of crew training and discipline, and steering problems). Submarine concentrations made some routes so dangerous up to mid-1943 that cargo for the Persian Gulf area was first diverted around Cape Horn via the South Atlantic, then via the Panama Canal and the West Coast of South America, and finally via the South Pacific and Indian Ocean. Timeliness, of necessity, became subordinate to assured arrival. 83/

The overall World War II attrition rate over 72 months was about 3%, but this included sailings of independents and convoys which suffered attrition ranging from zero to 78%. 84/ It included the extremely low attrition in the Tripartite convoys in 1941-42, the 5.5% attrition on the Murmansk/Archangel runs from August 1941 through May 1945, 85/ the 20% losses of U.S. coastal shipping to Operation Paukenschlag in early 1942, the 17 out of 30 ships sunk or damaged beyond repair in a 20-minute air raid at Bari, Italy, on 2 December 1943, and the strange case of two

Liberty ships loaded with gasoline and ammunition which were hit by aircraft torpedoes - one blew up, the other survived. 86/ Attrition in an isolated encounter was always captive to the dynamics of strategy, tactics, training, technology, and forces present.

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82. Waters, p. 16.

83. C-in-C U.S. Fleet, pp. 19-21.

84. Morrison, p. 326. Convoy TM-1 lost 7 of 9 tankers to 9 U-boats, 3-10 Jaunary 1943, which were being escorted by 4 British corvettes from Trinidad to Gibralter.

85. Winton, p. 303. 78 convoys, composed of 1489 ships, suffered 84 losses. 32 U-boats and many aircraft were destroyed. Includes losses from convoy PQ-17, which suffered most of its losses after being scattered.

86. Bunker, p. 123.

87. Ibid.