# ***SUBMARINES, AND THEIR COMBAT SYSTEMS.***

**CAPTAIN RAYMOND B. WELLBORN, US NAVY (RETIRED)** **SEPTEMBER 7, 2004.**

***ABOUT THE AUTHOR.*** Over a 30-year Navy career, Captain Wellborn served some thirteen years in submarines. He graduated with a BSEE from the US Naval Academy in 1959, a MSEE from the Naval Postgraduate School in 1969, and a MA from the Naval War College in 1976. He had two major commands at sea, *USS MOUNT BAKER* (AE 34), 1976-1979, and *USS DETROIT* (AOE 4), 1984-1986; and two ashore, the Naval Sea Systems Command's *Director of Surface-Ship ASW Systems*, Washington, DC, 1981-1983, and the *Naval Electronic Systems Engineering Center*, Charleston, SC, 1986-1989. After retirement in 1989, he was the Director of Programs for *ARGOTEC, INC.*, for advanced development models of large ELF acoustic projectors. From 1992 to 1996, he was a senior lecturer for Marine Engineering at Texas A&M University, Galveston. He now is a retired consultant for Maritime Safety and Training, and resides in Galveston County near the Houston Ship Channel at Dickinson, TX. Once a year he teaches a three-day course for the Applied Technology Institute entitled:

***"INTRODUCTION TO SUBMARINES, AND THEIR COMBAT SYSTEMS."***

For more information regarding this course, call ATI in Clarksville, Maryland, 21029, toll-free at 1-888-501-2100, or visit their website:

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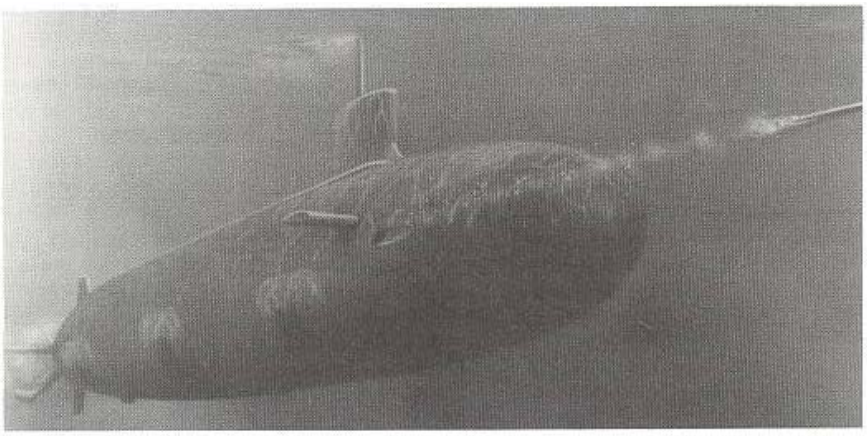
# ***THE EFFICACY OF SUBMARINE WARSHIPS.***

**CAPTAIN RAYMOND B. WELLBORN, US NAVY (RETIRED)** **SEPTEMBER 26, 2004.**



An official U.S. Navy painting shows *Seawolf* operating submerged, with her hull plane extended. The ridge visible above the hull must accommodate a thick-line towed array (TB-16), dispensed through the extra tail plane. Note also the fairing (sail cusp) at the forefoot of the sail, adopted for quieting. The painting does not show the acoustic window, near the top of the sail, for the MIDAS (BQS-24) mine and obstacle-avoidance sonar.

***SUBMARINE TASKING.*** So, what are submarines task to do?

Pursuant to mission accomplishment in support of national policies, and in particular for a duly delineated national armed-force objective to "Project National Power," submarines can be tasked to launch land-attack cruise-missiles from international waters-- as directed unilaterally by our *National Command Authority*, ***NCA***.

Submarines can be tasked to conduct surveillance and reconnaissance operations inside and outside the battle space, covertly. In that same vein, submarines can be tasked to insert, and, or retract *Special Operating Forces*, ***SOF***, on the littoral shores of the world's oceans-- covertly.

In more poignant warfare scenarios, submarines can be tasked to mine sea-lane choke points as well as enemy harbors.

Moreover, and perhaps most particular, submarines can hunt and kill other opposing submarines in the same undersea medium with them. Besides the deep ocean, that undersea medium includes the shallow waters for our coastal defense as well as that for projecting US national power by amphibious forces in foreign waters.

Notwithstanding the brassy jingoism above, submarines were first procured to sink threatening warships by surprising them from below the sea with the numbing sting of a torpedo.[1] For over a hundred years now, submarines have been so tasked; and, since WWI, submarines have been tasked to interdict sea lanes and sink unarmed merchant ships to deny re-supply. Yes, ***VIRGINIA,*** an economic strangler lurks in the sea-- *Submarines Sink Ships!*

When ***SEAWOLF--*** conceptualized in the painting above—was launched in 1995, there were some 24,000 merchant ships of over 1,000 gross-registered-tons plying the sea lanes of the world for international trade and transport. For national comparison, a table of ***Merchant Fleets of the World,*** ranked by number of oceangoing vessels, is provided below delineating a grand total of their displacements as about 657-million dwt (deadweight tons).

Table M-4

**Merchant Fleets of the World**

January 1, 1993 Rank by Number of Vessels (Oceangoing Vessels 1,000 Grt & Over)

| Rank | Flag of Vessel | No. Ships | (1,000) Total dwt | dwt Rank |
|---|---|---|---|---|
| 1 | Panama | 3,171 | 79,387 | 2 |
| 2 | Liberia | 1,568 | 97,167 | 1 |
| 3 | Russia | 1,363 | 13,367 | 13 |
| 4 | Cyprus | 1,251 | 35,627 | 4 |
| 5 | People's Rep. of China | 1,231 | 19,392 | 9 |
| 6 | Japan | 913 | 32,567 | 6 |
| 7 | Greece | 904 | 46,109 | 3 |
| 8 | Bahamas | 818 | 32,160 | 7 |
| 9 | Malta | 752 | 17,980 | 10 |
| 10 | Norway (NIS)[1] | 737 | 35,372 | 5 |
| 11 | United States[2] | 603 | 22,462 | 8 |
| 12 | Philippines | 534 | 13,413 | 12 |
| 13 | Singapore | 493 | 15,386 | 11 |
| 14 | Italy | 468 | 9,754 | 17 |
| 15 | Saint Vincent | 431 | 7,114 | 21 |
| 16 | South Korea | 422 | 10,247 | 15 |
| 17 | Federal Rep. of Germany[3] | 419 | 5,666 | 24 |
| 18 | Netherlands | 367 | 4,266 | 27 |
| 19 | Indonesia | 365 | 2,507 | 40 |
| 20 | Turkey | 339 | 6,594 | 22 |
| 21 | India | 296 | 10,044 | 16 |
| 22 | Denmark (DIS) | 281 | 6,311 | 23 |
| 23 | Romania | 255 | 4,110 | 28 |
| 24 | Spain | 222 | 3,902 | 31 |
| 25 | Brazil | 220 | 8,778 | 19 |
| 26 | Taiwan | 215 | 9,145 | 18 |
| 27 | Honduras | 215 | 1,008 | 53 |
| 28 | Poland | 212 | 4,048 | 29 |
| 29 | Hong Kong | 200 | 11,979 | 14 |
| 30 | Malaysia | 185 | 2,781 | 37 |
| 31 | Sweden | 172 | 3,156 | 34 |
| 32 | Thailand | 169 | 1,151 | 51 |
| 33 | United Kingdom | 154 | 3,076 | 35 |
| 34 | Antigua & Barbuda | 148 | 888 | 54 |
| 35 | Egypt | 128 | 1,503 | 42 |
| 36 | Iran | 124 | 8,229 | 20 |
| 37 | Vanuatu | 119 | 3,026 | 36 |
| 38 | Latvia | 118 | 1,319 | 45 |
| 39 | Bulgaria | 117 | 1,884 | 41 |
| | All Other | 3,054 | 63,716 | |
| | Grand Total | 23,753 | 656,591 | |

[1]Norway (NIS) established in 1988.
[2]Includes United States Government-owned ships.
[3]Includes Germany (East).

Source: Department of Transportation, Maritime Administration, Office of Maritime Labor and Training.

[1] Note that the word torpedo comes from the Latin *torpidus*, or from *torpere* meaning "be numb," like the numbing sting of an electric ray fish.

As capital-intensive assets—meaning their annual amortized construction cost and operating expense well exceed the cost of labor to operate them—their collective loan-value, without any consigned cargo, can be estimated parametrically to total about $1.5-trillion. Moreover, the annualized value of their consigned cargo that they deliver each year can be estimated to total about $3.0-trillion.

Ask yourself which of these national economies today could stay afloat with the *sunk cost* of its *Merchant Fleet?*

And today, with near instantaneous news around the world, when the first explosion from a submarine-launched torpedo plumes brusquely, so will ocean-shipping insurance rates.

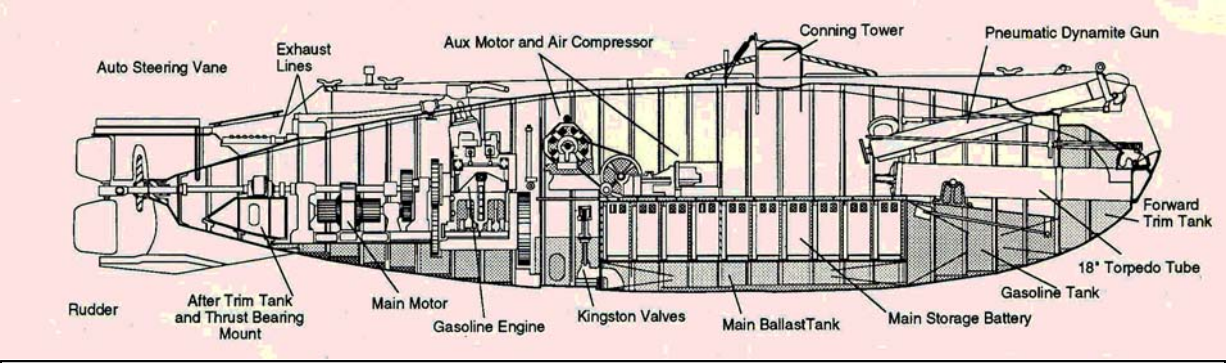
In regard to fleet operations, submarines can be tasked to provide *INDIRECT*, *ASSOCIATED*, and *DIRECT* Battle Group support. For deployments, *Time-On-Station* for modern nuclear-powered submarines is dependent only on the amount of food they must carry to feed their crew—like, a 90-day supply, without replenishment.[2]

Some submarine-patrol stations literally are *On the Far Side*. For instance, our forward submarine base on Guam in the western Pacific is about 12 days of submerged steaming from San Diego. Then for a submerged transit from Guam to a patrol station in the Gulf of Oman via the Java Sea and the Lombok Straits thence across the Indian Ocean could take as long as 16 days.

For all warfare, speed-time-distance parameters are factors to consider, inclusive of:

***LOGISTICS-- THE BRIDGE!***

[2] After a couple of weeks, dreams of the taste of fresh milk become as persistent as others. Moreover, submarine chow has been judged by the *Ney Memorial Foundation* to be some of the Navy's best.




The First: On April 11, 1900, the US Navy purchased Holland-VI for $150,000; and, on October 12, 1900, *USS HOLLAND* (SS 1) duly was commissioned.

***THE EVOLUTION OF A SUBMARINE—AS A WARSHIP.*** At the close of the 19th century, the hail heard around the world was *Britannia Rules the Sea.* Ships of the Royal Navy were high profile targets for their enemies—both foreign and domestic.

Douglas Porch, in his book *The Path to Victory* published in 2004, by Farrar, Straus, and Giroux in New York, revealed that Irish revolutionaries in 1876, known as the *Fenian Brotherhood,* contracted John P. Holland, an Irish-American who had immigrated to the US in 1872, to develop a way to sneak up on British ships from underwater, and sink them.

Holland's work began in Paterson, New Jersey, on the Passaic River, and then moved to New York harbor. The *Fenian's*, however, withdrew their support of Holland's research when he failed to meet their timetables. Private investors though kept Holland afloat. By 1898, Holland had produced his sixth prototype—and, the US Navy was ready to buy. On April 11, 1900, the US Navy purchased Holland-VI for $150,000; and, for the record, the US Submarine Force was born. Then, on October 13, 1900, *USS HOLLAND* (SS 1) duly was commissioned, Lieutenant H. H. Caldwell, US Navy, Commanding.

*HOLLAND* was 53.3 feet overall, with a maximum beam of 10.3 feet, a cruising draft of 8.5 feet, and a submerged displacement of 75 deadweight tons, dwt. *HOLLAND* was constructed with fitted steel-plate attached to angle-iron rib-frames that had been forged into perfect circles starting at 10.25 feet for the central one, and then decreasing to end-closures to form a parabolic, spindle-shaped hull. Safe test-depth was set at 80 feet to correspond to an external, water-head, crushing pressure of 35 psi, pounds-per-square-inch.

*HOLLAND* featured an ingenious dual-propulsion system. A 50-horsepower *Otto* (gasoline) engine was geared to drive a propulsion-screw-- a propeller-- directly, or by a friction clutch could be connected as a dynamotor for charging *HOLLAND's* electric battery. This battery then could be switched to provide electrical energy to an electric motor that by friction clutch could be connected to the propulsion shaft.

*HOLLAND's* maximum speed on the surface by gasoline-powered engine was rated at 7 knots; and, when topped-up with fuel, *HOLLAND* had an endurance-range of about 1500 nautical miles, nm, at her engine's maximum continuous rating for making turns for 7 knots. When submerged, *HOLLAND's* fully charged battery discharging at the six-hour rate had the ampere-hour capacity for electric motor propulsion at a rated maximum submerged speed of 5 knots for a submerged endurance-range of about 30 miles!

And, *to go in harm's way*, *HOLLAND* had a single internally loaded 18-inch diameter tube that extended through the pressure hull in the bow for launching the new, improved Whitehead diving-torpedo Mark-III that was 11.65 feet in length, and rated at 30 knots for a run of 2000 yards. Moreover, *HOLLAND* was designed with space-and-weight accommodation for two torpedo reloads. ***Submarines were now stand-off warships***.

***SUBMARINE WEAPON DEVELOPMENT***. The British, however, lagged in early submarine development. The Admiralty apparently thought submarine attacks were dishonorable; and, declared that captured submariners would be treated as pirates, and be hanged, accordingly.

After Britain's rivals at sea commissioned Holland to build submarines for them, the Admiralty changed its tune. As what could be expected, Holland later profited from selling submarines to that same Admiralty whose fleet he once had been paid to sink.

It is interesting to note that it was the US inventor Robert Fulton who in 1805, after studying the design of Bushnell's *Turtle*, positively demonstrated in a weapon-trial the feasibility of sinking a ship by detonating an explosive charge against its underwater hull.

Some sixty years later in 1866, two years after the submarine *CSS H. L. HUNLEY* was lost detonating a torpedo attached to a bow-sprit spar that sank *USS HOUSATONIC* in Charleston harbor, Robert Whitehead, a Scottish inventor, demonstrated his advanced development model of an *auto-mobile* torpedo—to the Germans.

At the behest of officials representing the German Kaiser's government in Austria, Whitehead demonstrated an unmanned, underwater vehicle that was a self-propelled, lighter-than-water dirigible—a "diving submarine." It essentially was an automated-mobile—an *auto-mobile*—underwater vehicle that could deliver a "numbing" explosive charge—a torpedo—to detonate against the underwater hull of a target-ship, and sink her—from a stand-off distance!

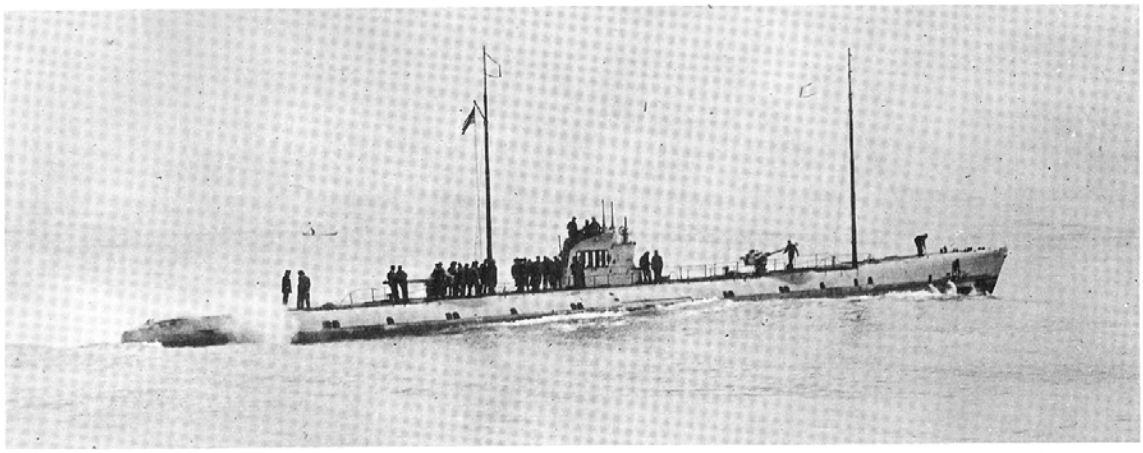
As the world turned into the 20th century, a booming *Industrial Revolution* seemingly elevated science and technology as if they were its King and Queen, their supreme overseer. It was like there had been a royal *CORONATION OF SCIENCE & TECHNOLOGY*.

Figuratively, a silver spoon was placed in the mouth of each new steamship born in modernized shipways. They indeed were capital-intensive assets. This was big financing—*Big Time!*

With the continuing evolution of submarines as reliable warships, torpedo advancements burgeoned to keep pace with them. For instance, by the onset of WW-I, US submarines had the new Bliss-Leavitt Mark-X torpedo, which weighed in at a hefty 1,628 pounds with a 326-pound warhead, stood 17.1 feet in length with an 18-inch diameter-girth, and ran 6,000 yards (3 nm) with a rated speed of 35 knots.

Now, enter the most efficient, the most cost-effective, the most peerless shipping interdictor, the most devastating business-loss inflictor, and most menacing national economic strangler of them all:

***Der Kriegsmarine Unterseebooten!***



U.S. submarine designers were much influenced by German U-boat practice, largely as revealed by U-boats like this one, taken briefly after World War I. *U-111* is shown in American service.

***THE ENEMY BELOW.*** During WW-I the word "U-boat" entered the world's lexicon as a contraction of *Unterseeboot*, the German labeling of their new submarine warships. U-boat also entered the world's consciousness as an offensive instrument of warfare that devastated commercial shipping.

Contrary to popular belief, the crews of Germany's feted *Ubootwaffe* were not all volunteers. Once committed though, each German submarine-sailor soon came to understand that he must take pride in being a member of a unique undersea brotherhood. Thus, the sailors of this brotherhood-- this *Ubootwaffe*-- became bound together by an intense camaraderie, by ever-present dangers, and by a unity of purpose more powerful than any known to other sailors.

U-boats were armed with a German version of an advanced Whitehead torpedo that very effectively—very cost-effectively-- delivered an explosive charge to a target-ship at a stand-off distance that typically was less than a mile even though the torpedo had a maximum run of three miles.

So, with over-extended capital investments, the British built new, capital-intensive, ocean-going steamships to bolster their colonized trade—strategic imports—from overseas. And, the strategic plan of the Germans—Britain's "new" continental rival-- was to interdict British capital-intensive, economic assets that sailed those seas, and do so from a hidden position deep below the sea when in actuality they were just below its surface.

Thus, the German's set-out to build and crew cost-effective U-boats whose individual tactical ship-sinking combats could be managed strategically to achieve their national goal of *Economic Equality* with their rival *Great Britain*.

These U-boats featured a dynamo with an innovative design of an internal combustion engine that was not fueled with gasoline—and, did not require an ignition system. Thus, this "rational heat engine" was more efficient, and safer, than gasoline-fueled ones. In 1897, after a major re-design of the lubrication system for this coal-dust fueled, single cylinder, four cycle pump-engine for flooded mineshafts, the first successful engineering development model of a liquid-fueled, "*coal-oil*," engine was completed by its then-bankrupt inventor in collaboration with the Krupp firm and an Augsburg-Nuremberg machine shop, *Maschinefabrik Augsberg Nürnburg*-- ***MAN***.

Some fifteen years later, in 1912, a year before the death of the engine's impoverished inventor, the US Navy procured a number of them from New London Ship and Engine Company, *NELSECO,* teamed with Vickers who was a British shipbuilder licensed by this German conglomerate. These engines were the coal-oil fueled, four cycle version having four cylinders with a 12.75-inch bore and a 13.5 stroke that was rated 275 BHP at 400 RPM. They were scheduled for installation in *E-1 Class* (ex-SKIPJACK) US-submarines to replace the scheduled gasoline-powered prime movers for the dynamos in their dual-propulsion hybrid system.[3]

In 1908, the German Navy favored the lighter pounds-per-horsepower, two cycle version; but, in preparatory expediency for their inevitable war plans, they proceeded to fit all their U-boats with a six-cylinder, four cycle version of this now-feted engine as designed by its fatherly inventor whose name they bear-- ***Rudolf Diesel***, 1858-1913.

The rest of the story is legendary.

***DIESEL BOATS FOREVER!***

[3] On March 5, 1912, a month before *SS TITANTIC* sank, President Taft established the Atlantic Submarine Flotilla, Lieutenant Chester W. Nimitz, US Navy, Commanding.


***USS HARDER* (SS 568) entering the Baltic port of Kiel, Germany, in June 1961.**

***THE ADVENT OF SUBMARINE WARFARE***. The epoch for ***Submarine Warfare***, for all intents and purposes, opened with the brusque plume of an exploding torpedo launched by a German U-boat sinking *SS LUSITANIA*, a British passenger liner, off the southwest coast of Ireland on May 7, 1915, leaving 1154 dead, including 114 Americans.[4]

Patently, the submarine evolved from a very awkward beginning into a very versatile, very cost-effective, and very stealthy warship. The following Benefit-to-Cost, B/C, analyses compare the costs of ships sank by warships to the costs of those warships lost in the effort, and statistically portray the efficacy of the submarine warship as a very cost-effective, ship-sinking interdictor of ocean sea-lanes.

In WW-I, German U-boats sank 5,708 merchant ships, and 62 warships. To absorb the magnitude of those considerable numbers, you may have to read them twice-over so as not to trivialize their significance—or, their economic significance. These sinking numbers equate to some 11,018,865 dead-weight tons (dwt) of merchant-ship hulls plus their consigned cargo, and 538,535 dwt of warships.

[4] Notably, also in 1916, a year after a U-boat sank *SS LUISITANIA*, *USS E-1* (SS 24), which was 135 feet in length with a submerged displacement of about 400 dwt, became the first submarine to cross the Atlantic under her own power, that is, the first trans-Atlantic crossing by a *coal-oil-powered* submarine.

This figurative "*sunk cost*" can be estimated parametrically to be $39.4-billion—at the time-value of money for 1918. Then, dividing that "Benefit" by the "Cost" of the lost of 178 U-boats estimated parametrically to be $1.3-billion, yields a ***B/C*** ratio of **30.5!**

Note that a ***B/C*** of 1.0 is breakeven, and a 2.0 is considered a beneficial venture. There was a lot to be learned in the two intervening decades between WW-I and WW-II. Ardent studies of the technologies and techniques associated with Anti-Submarine Warfare (***ASW***) were lessons that had to be learned by the "Hunter," and the "Hunted."

Inevitably, as if portended by the foreboding *Winds of War*, German U-boats in WW-II sank 23.4-million dwt of allied shipping plus their cargo, which together is estimated to be $78.5-billion. Dividing that by the lost of 781 U-boats estimated to be $5.7-billion yields a ***B/C*** of **13.8.**

In comparison to the greater ***B/C*** ratio in WW-I, one deduces that ***ASW*** in the Atlantic apparently helped to cut this telltale ratio by more than half. I doubt though that this lesser ***B/C*** was any solace to those having to stomach the lost of $78.5-billion-- at the time-value of money for 1945.

Meanwhile, *On the Far Side*, how did US submarines fare in WW-II against the Eastern island empire of Japan in the Pacific?

US submarines sank 4.9-million dwt of Japanese warships, and merchant ships plus their cargo, which together is estimated to be $16.3-billion. Dividing that *Benefit* by the *Cost* of the lost of 52 US submarines materially estimated to be $355.3-million yields a ***B/C*** of **45.9!**[5]

[5] Notably, this B/C was higher than that for German U-boats because by my deductive reasoning the US tactics of submarine approach and attack were with more stealth, and that ASW by the Japanese Navy was less intense and less effective.

At the beginning of 1943, as another statistical example, over the sea-lane between Taiwan and the Philippines at the *Bashi Channel* choke-point for the Luzon Straits connecting the South China Sea with the Philippine Sea, Japanese oil-tankers were transporting some 1.5-million barrels of crude oil per month for Japan's refineries to make distillate fuels for their war-machines. That sea-lane was interdicted by US submarines, literally torpedoing Japan's oil-imports. By the end of 1944, this crude-oil supply had been reduced by 80 percent to something less than 300,000 barrels per month.

US submarines, with only 2% of all US Navy personnel, were credited with sinking 55% of all Japanese merchant ships, and 29% of all Japanese warships.

This era of submarine warfare, however, is still a "work-in-progress." It began auspiciously on May 7, 1915, when a German U-boat torpedoed and sank *SS LUSITANIA* off the southwest coast of Ireland. For the moment, its log's tab is set on May 21, 1982, when a British nuclear-powered attack submarine, *HMS CONQUEROR*, torpedoed and sank Argentina's battle cruiser *BELGRADO* off the Argentine coast in the approaches to the Falkland Islands—a 150-year-old British colony that occupying Argentine armed forces two weeks later surrendered back to British armed forces on June 4, 1982.

The lead-in photo for this section is a subtle depiction of the forebodingness of such *Submarine Warfare* for several significant reasons. First, it could be said to be a chilling photo because of where it was taken in showing a submarine entering a German port.

Second, it was somewhat ironic that the entering submarine was US; and, moreover, that this US Submarine, *USS HARDER* (SS 568), was a post-WW-II TANG-Class submarine, which was a US-copy of a WW-II Type XXI German U-boat.

Third, is that *HARDER's* ingress to Kiel that day had been through the once mined approaches to Kiel in *Kieler Bucht* after a 600-nm transit from a NATO exercise in the North Sea that included rounding the top of the Jutland Peninsula through the *Skagerrak* and the *Kattegat* thence southerly into *Kieler Bucht* leaving *Kobenhavn* to the east. As yet another ironic transpiration for that week leading up to Midsummer's Night of 1961 was how the Germans subtly facilitated the queuing for comparable ship-visits by mooring *HARDER* just across the pier from *WILHELM BAUER*, a Type XXI German U-boat that just had been raised and refitted to be part of a memorial to German submariners lost in WW-II. Being qualified in *HARDER* and then walking through *WILHELM BAUER* was an experience seemingly like having stepped through a looking glass.

A week later though, at the end of *Kieler Woche*, *HARDER's* egress was through the *Nord Ostesee Kanal* (Kiel Canal), which was only a 50-nm transit across the neck of the Jutland Peninsula to the mouth of the *Elbe* River, some 40 nm seaward of *Hamburg.* Moreover, from the mouth of the *Elbe* back to our previous position in the North Sea, it comparably was only 150 nm, whereas it was 600 nm around the top.

In 1936, Chancellor Adolf Hitler officially opened the Kiel Canal, and relegated the inaugural passage to one of ***Der Kriegsmarine Unterseebooten***. So, the *Third Reich's* construction of the Kiel Canal may have been for *other means* to bolster Germany's maritime economy. Thus, *HARDER's* transit of the Kiel Canal at the end of *Kieler Woche* could be deemed to have been some surrealistic scheme to top-off the Kiel Canal's twenty-fifth anniversary with a transit of a Type XXI U-boat. But perhaps, I just consider this photo to be significant because I am the young submarine officer pictured on deck with the Anchor Detail as *HARDER* stood in to Kiel that day. Nevertheless, it remains that ***SUBMARINES SINK SHIPS!***