THE HISTORY OF H-CLASS SUBMARINES AND ARCHAEOLOGY OF THE SUBMARINE USS *H-1* (EX *SEAWOLF*) (1913-1920)

A Dissertation

by

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ABSTRACT

The 1864 sinking of the USS *Housatonic* by the Confederate submersible *H. L. Hunley*, during America's Civil War, accelerated the race to develop a mechanically powered submarine capable of sinking enemy shipping.

The development of internal combustion engines, improvement in electric motors and storage batteries, and invention of the locomotive torpedo, coupled with enhancement of submersible designs, changed the face of naval warfare. Iterative improvements in submarine designs and associated technologies enabled the transformation of submarine warfare from its original mission of blockade breaking, through coastal defense and denial of freedom of the sea, to its modern role of strategic power projection.

The United States Navy purchased its first 'modern' submarine in 1900, and over the next 11 years several different classes of American submarines were developed, with expanding size, range, and lethality. Each of these classes exhibit designers' attempts, some more successful than others, to improve the vessel. The overall success of a class of boats can be measured by the number of vessels produced, by the number of countries which built and operated them, and by the length of time that they remained in service. Of these early submarines, the H-Class boats and their simple yet effective design stands out.

Early development of American submarines was costly; more submariners died and more submarines were lost in the years leading up to the First World War than were

lost in combat during that war. Submariners lived in conditions best described as hazardous squalor. When running on the surface, the boat was often filled with gasoline vapor and exhaust fumes; fires, explosions, and carbon monoxide poisoning were common. Submerged, the boat was cold and dank, and the air quickly became low in oxygen and saturated with carbon dioxide. Men slept on cold steel decks, ate poorly, and used buckets for toilets. Understandably many of the improvements in submarine design came from the men that operated them.

This dissertation places manned submersibles in historical context and presents a summary of the technological advances in submarine design and construction leading to the development of the H-Class submarine; presents the historical and archaeological record of *USS H1*; and draws conclusions regarding the H-Class submarines' contribution to development of undersea warfare.

DEDICATION

To all submariners who made the ultimate sacrifice in service to their country.

ACKNOWLEDGEMENTS

I would like to express my deep gratitude to my committee chair, Dr. Kevin Crisman, and my committee members Dr. Donny Hamilton, Dr. Filipe Castro, and Dr. Jonathan Coopersmith for their guidance and help throughout the course of my studies, research, and writing.

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Contributors

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This dissertation was supported by the research and experiences of countless individuals, While the work was for this dissertation was completed by the student, it would be disingenuous to state that it was done independently, I was privileged to stand on the shoulders of some incredible scholars and submariners alike.

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NOMENCLATURE

BUORD	Chief of the Bureau of Ordnance
CO	Commanding Officer
COB	Chief of the Boat
HMAS	His Majesty's Australian Ship
HMS	His Majesty's Ship
INA	Institute of Nautical Archaeology
INAH	*Instituto Nacional de Antropología e Historia*
NARA	National Archives and Records Administration
NHHC	Naval History and Heritage Command
SECNAV	Secretary of the Navy
USS	United States Ship

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CHAPTER I

INTRODUCTION AND HISTORICAL BACKGROUND

USS *Seawolf* was the inaugural vessel of the United States Navy's H-Class coastal defense submarines. Prior to its commissioning, the Navy changed the naming convention for submarines, referring to them by an alphabetical class designator and a numerical designator indicating their position within that class; hence USS *Seawolf* became USS *H-1*. The initial submarines of the class, *H-1* through *H-3,* were built by the Union Iron Works shipyard in San Francisco (*H-1* and *H-2*) and the Moran Brother's shipyard in Seattle (*H-3*). Construction of the vessels began in the spring of 1911; *H-1* and *H-2* were commissioned in December of 1913; *H-3* would be commissioned the following month.

The H-Class submarines were designed by the Electric Boat Company under the guidance of lead naval architect Lawrence Y. Spear. Known as design EB26 or (design 602 for foreign sales), this class was the product of decades of technical development and would prove very successful with 71 vessels (including the British H-21 derivation) constructed. These submarines would serve in the navies of nine nations; a comprehensive accounting is provided in Appendix A.

The terms submarine and submersible are often used interchangeably; however, for the purpose of this writing, the word submarine, when used as a noun, will define armed warships capable of operating both on the surface and under the water. The term submersible will define unarmed vessels capable of operating in the same environments. When referring to these vessels collectively, the term subs shall be used.

This author seeks, through archival research, to provide historical context for subs, an explanation of the success of this early class of submarines and a concise record of each class member's place of construction, country of service and final disposition. Further, the author will detail the experience of service on the H-Class through historical sources including first person accounts. Finally, the author will present the history and archaeology of the lead boat of the class, USS *H-1,* highlighting its pre-war operations and wartime service and culminating with its loss off the western coast of Mexico in 1920.

The *H-1* wreck site provides an amazing opportunity to witness the effects of the site formation process on early submarines. Recent images of the site and a description of the processes acting on the wreck as well as recommendations for its protection will be presented.

Today H-Class submarines are easily dismissed as crude; to understand how ingenious this complex amalgamation of technology was in its own day; however, one must understand its genesis.

Conceptual Foundation

Human fascination with, and exploitation of, the underwater world surely predates written history. We will never know when the first swimmer dived under the water or when the first tools to sustain life underwater were invented. However, a pearl found in an excavation at Marawah Island in the United Arab Emirates dates, by radiocarbon analysis, to ca. 5800-5600 BC.[1] While we cannot be certain that the pearls found at the site were harvested by divers it is most probable. Early Greek literature describes diving for pearls, sponges and warfare, and the use of tools such as snorkels, weights and inverted caldrons to improve depth and dive duration.[2] This desire to exploit the depths eventually led to the development of manned submersibles.

The earliest known documentation of the concept of powered manned submersibles dates to the Renaissance and is found in Leonardo da Vinci's *Codex Atlanticus*, Folio 881R.[3] A 3D model, constructed based on da Vinci's drawing, may be viewed at www.leonardo3.net/en/l3-works/machines/1467-mechanical-submarine.html. Although lacking a pressure hull, da Vinci's submersible design possesses many of the functional systems that would become hallmarks of future subs, these being: directional control (diving planes and rudder), buoyancy control, and propulsion (Figure 1). There is no evidence that da Vinci's design was ever built, let alone successfully tested, but it merits mention as a springboard for future designs.

[1] Beech et al.,'Excavations at MR11 on Marawah Island', 28.
[2] Frost, 'Scyllias: Diving in Antiquity'.
[3] Da Vinci, *Codex Atlanticus*.

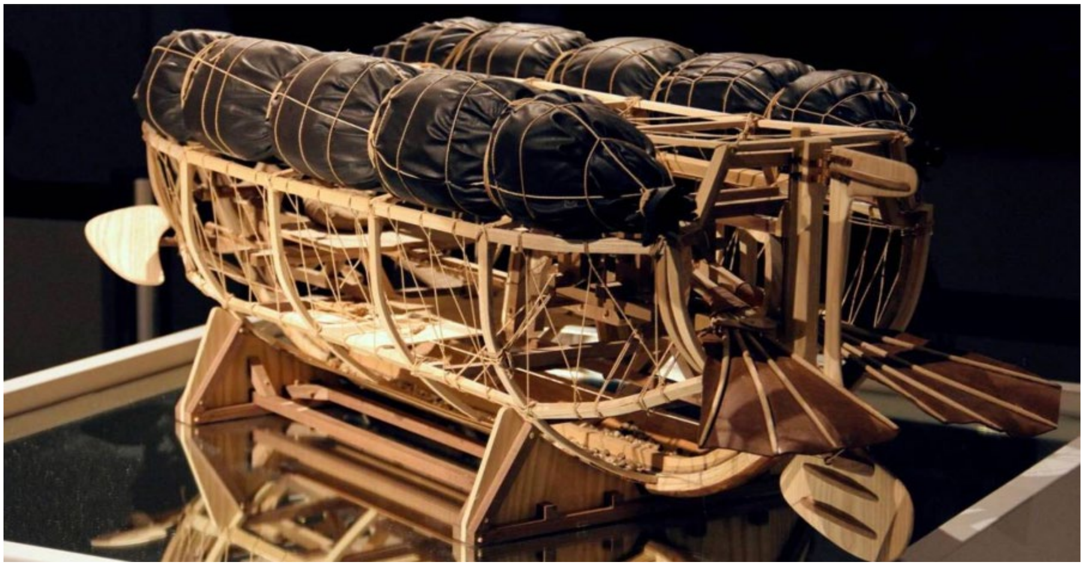

Figure 1. da Vinci inspired mechanical submarine model.
Courtesy of: Leonardo3 Museum, Milan, Italy. All rights reserved.

The early history of submarine and submersible development (ca. 1620 -1900) has been documented by numerous authors and, with the exception of vessels significantly contributing to the genesis of submarines, will not be reiterated here.[4] As with most complex technical inventions, successful development of these vessels resulted from the amalgamation of multiple inventions which advanced the end product through innovation, improvement of the designs of others, and a great deal of trial and error.

Several factors needed to be addressed before safe, functional, effective subs could be built. Of primary importance, the vessel must provide an enclosed environment

[4] Texts detailing early development include: Compton-Hall, *Submarine Pioneers*; Roland, *Underwater Warfare*; and Swinfield, *Sea Devils*.

which allows the operators to survive underwater: the hull must protect the crew from hydrostatic pressure, breathable air must be maintained, and accommodations and victualing must be provided consistent with mission duration. The vessel must be controllable in all axes of movement in a three-dimensional underwater environment, and it must have a propulsion system capable of providing sufficient operational range and speed to meet its mission requirements. In the case of submarines intended for naval service, an effective weapons system must be developed. Managing to meet all these factors in a single vessel would prove challenging.

The first functional subs would be developed in the closing years of the 18th century and were the product of conflict. These early vessels were hampered by stability and control issues compounded by awkward arrangements for mechanical propulsion, that were initially powered by their human crews. The resultant craft were practically so slow and unmanageable as to be utterly ineffective. Additionally, the underwater weapons systems developed for use by the early boats proved both dangerous and unreliable.

With the idea of undersea warfare came the moral question of its employment; skulking unseen upon an enemy with the intent of sinking his ship, killing him and his crew was not the way of gentlemen. This argument would hamper the development of submarines and undersea warfare but in the end the desire for victory would overcome chivalry.

Early Inventors and their Human Powered Submersibles

David Bushnell and the Turtle

Research has not uncovered evidence detailing how David Bushnell (1740-1824), first conceptualized building a submersible, but we know from a letter between Bushnell and Thomas Jefferson that the idea for *Turtle* and its explosive charge emerged in 1771 while Bushnell was attending Yale University.[5] Historians postulate that Bushnell formulated his plans for *Turtle* after reading of French inventor Denis Papin's submersible design published in the December 1747 edition of *Gentleman's Magazine,* a copy of which may well have been available in Yale's library. Papin's and Bushnell's designs share common features that make the argument plausible.[6]

A product of the American Revolutionary War, *Turtle* was built in 1775 in the town of Saybrook, Connecticut for the purpose of sinking British warships lying in American harbors. Bushnell like many inventors, lacked the technical skills necessary to singlehandedly bring his concept from the drawing board to fruition, and it would take a team of skilled individuals to make *Turtle* operational. Bushnell's team included his brother Ezra Bushnell, clockmaker and brass founder Isaac Doolittle, and ships carpenter Phineas Pratt.

Our understanding of the design and construction of *Turtle* is based on multiple primary documents. Bushnell provided a detailed description of the endeavor in a letter written in October 1787 in response to an inquiry by Thomas Jefferson; this description

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[5] Bushnell, 'General Principles and Construction of a Sub-Marine Vessel', 312.
[6] Roland, 'Bushnell's Submarine: American Original or European Import'.

of *Turtle* was later published in the 1799 volume of *Transactions of the American Philosophical Society*.[7] *Turtle's* pilot, Ezra Lee, described both his participation in the venture and the boat in a letter written to David Humphreys that was published in *The Magazine of American History*.[8] Dr. Benjamin Gale, who lived near Bushnell, and personally viewed *Turtle,* provided a description to Benjamin Franklin in a letter written in August 1775; the letter is published in *Naval Documents of the American Revolution*.[9] Additional corroborating documents include letters between Dr. Gale and Silas Deane. Deane, a Connecticut representative to the Continental Congress, served on a committee to protect colonial trade.[10] These letters, published in *The Collections of the Connecticut Historical Society, Vol II.*[11]*,* were written during the construction of *Turtle* and substantiate the enterprise and its participants. Each of the source documents, as well as secondary sources (letters between George Washington and Benjamin Franklin) are re-published in the appendices of *Turtle: David Bushnell's Revolutionary Vessel.*[12] These easily accessible versions are faithful to the originals and recommended to the reader.

Contemporaneously with the development of *Turtle,* Bushnell experimented with underwater ordnance, beginning with a small charge of powder encased in a wooden canister. Once he was able to successfully detonate the small charge, he moved to successively larger ones. Gaining confidence that his devices would regularly detonate,

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[7] Bushnell, 'General Principles and Construction of a Sub-Marine Vessel', 303-312.
[8] Lee, 'Lee's 1815 ltr. To Gen. Humphreys describing *Turtle*', 262-266.
[9] Clark, *Naval Documents of the American Revolution*, 1088-1089.
[10] Ibid, 872.
[11] Trumbull, *Collections of the Connecticut Historical Society*.
[12] Manstan and Frese, *Turtle*, 276-310.

he arranged a demonstration for a select group he referred to as ‘some the first personages in Connecticut’.[13] The device, referred to as a magazine, was detonated with good results.

Turtle’s magazine was built of two pieces of hollowed out oak which were joined with iron bands, much like a barrel, and the seam was caulked and payed with tar. The magazine contained approximately 68 kgs of black powder and the firing mechanism, which incorporated a clockwork and a gun lock.[14] The magazine was mounted above *Turtle’s* rudder and connected by line to the attaching screw mounted on top of the vessel. Interior controls for the weapons system included the crank for turning the attaching screw, and a releasing mechanism for the explosive charge.

Turtle’s design, while rudimentary by modern standards, incorporated many innovations which contributed significantly to the development of the modern submarine. These innovations included: a time-detonated underwater mine, bladed propellers, variable water ballast, a rudimentary snorkel, and a depth gauge.

There are no extant design drawings from the construction of the original vessel. A drawing prepared in 1875 by Lt. Francis Barber USN follows the general description provided by Bushnell but has some inaccuracies (Figure 2).[15] Barber incorrectly depicts the propeller as being of a helical design, instead of bladed, and shows enclosed ballast tanks which were not mentioned in any description of the vessel.

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[13] Bushnell,‘General Principles and Construction of a Sub-Marine Vessel’, 308.
[14] Ibid. 307-308.
[15] Barber, *Lecture on Submarine Boats*.

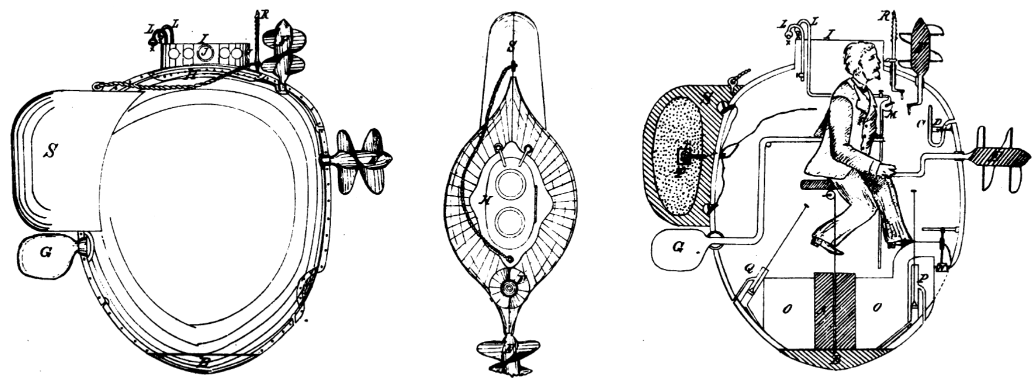

Figure 2. Bushnell's *Turtle*. From: Barber 1875.

Descriptions of *Turtle* in primary sources are remarkably consistent. The hull, shaped like two turtle carapaces joined edge to edge, was constructed of wood. The species of wood, thickness of the hull, as well as the actual method of construction, are not documented but *Turtle* was likely constructed utilizing shipbuilding materials and techniques of the day. Charles Griswold, who interviewed Ezra Lee, notes that it was constructed of several pieces of oak, tightly joined, the seams caulked, the hull tarred and bound with iron bands.[16] The hull was reinforced with an interior athwart-ships timber which also served as the operator's seat. Approximately 318 kgs of lead ballast were permanently fixed to the bottom of the hull, with another 91 kgs of lead ballast which could be dropped by the operator in the event of an emergency.

Operator access was provided via a single elliptical opening on the top of the vessel. The opening was surrounded by an iron band, inlet into the hull, and was secured

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[16] Griswold,'ART. VIII. Description of a Machine.', 95-96.

with a cupola-like hatch likely made of bell metal. The hatch had three round vents and numerous glass portlights, providing air and light; each could be covered securely. Two air pipes fitted with external float mechanisms, to seal them shut on diving, were installed in the hatch.

Propulsion of *Turtle* was provided by the first documented use of bladed propellers. These propellers were described in several documents as two oars in the shape of a windmill which rotated on a central axle; Lee notes that the oars measured 'about 12 inches long & 4 or 5 inches in width'[17]. Forward or reverse propulsion was provided by a propeller mounted on the forward edge of the hull. It was turned by hand crank and foot treadle mechanism. Changes in depth were achieved by a propeller, of similar design but likely of smaller dimensions, mounted on the top of the hull and turned by hand crank. Turtle was steered by a rudder mounted on the after edge of the hull and controlled by an internal tiller. The multiple hull penetrations were achieved by brass tubes or bushings surrounding machined iron rods; the fittings were filled with oil to create a watertight seal.

Turtle was slightly positively buoyant; internal lead ballast was added or removed to compensate for the weight of the operator. When ready to submerge, the operator depressed the foot valve, allowing water to enter the bilge until slight negative buoyancy was achieved. When cruising submerged or at night the operator depended on a compass and depth gauge, illuminated by a bioluminescent fungus found in decaying

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[17] Lee, 'Lee's 1815 ltr. To Gen. Humphreys describing *Turtle*', 263.

wood. Once ready to surface, water ballast was discharged via the installed forcing pumps.[18]

In August 1776, following the completion of construction and trials of *Turtle,* its intended operator, Bushnell's brother Ezra, fell ill and was replaced by Ezra Lee. One evening in early September, following a period of training and maintenance, *Turtle* was towed on the surface through the waters of New York Harbor, its target a British warship anchored near Staten Island. Once the tow was cast off, *Turtle* submerged, and Lee made a successful approach. The attack failed; Lee reported that he was unable to drill into the hull of the ship. After several failed attempts, he retreated and in doing so was spotted and chased. Lee armed and released the magazine, and its subsequent explosion allowed him to escape.[19]

Two subsequent attacks were conducted, each of them unsuccessful. *Turtle* was lost when British forces sank its support vessel; Bushnell salvaged *Turtle* but made no further attacks.[20] *Turtle* may have been lost to history, but the first half of the 19th century would see several submersibles designed and constructed as a variation on its theme.

Several working replicas of *Turtle* were constructed over the years based on the replicator's interpretations of the historical descriptions.[21] One such replica was built by the students of Old Saybrook High School (OSHS), under the direction of Fred Frese

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[18] Ibid. 263-264., and Bushnell, 'General Principles and Construction of a Sub-Marine Vessel', 303-307.
[19] Lee, 'Lee's 1815 ltr. To Gen. Humphreys describing *Turtle*', 264.
[20] Bushnell, 'General Principles and Construction of a Sub-Marine Vessel', 310-311.
[21] See Manstan and Frese, *Turtle*., and Handshouse Studio, 'Carving the Bushnell Turtle Submarine.', both replicas, while slower than the primary sources indicate, functioned as designed.

and Roy Manstan and with the exceptions of a few modern safety improvements made to facilitate the vessel's in water testing is consistent with the historical descriptions (Figure 3).

Figure 3. OSHS replica of *Turtle.* Courtesy of: Roy Manstan.

Frese was the Industrial Arts teacher at OSHS and Manstan an engineer at the Naval Undersea Warfare Center (NUWC). This interpretation utilized period shipbuilding practices resulted in a more hydrodynamic hull than others replicas reviewed. The project began in 2003 and culminated with operational testing in 2008 (Figure 4). The construction and testing of replicas faithful to the description of Bushnell and Lee proved that *Turtle,* while likely slower than described, functioned as described.

Figure 4. OHHS *Turtle* replica during testing. Courtesy of: Jerry Roberts.

Robert Fulton - Nautilus

In 1797, Robert Fulton (1765-1815) an American gunsmith, painter, engineer, and inventor, left England, where he had been living since 1786, and moved to Paris. Having recently published *A Treatise on the Improvement of Canal Navigation,* he was keen to market himself as a canal engineer in France.[22] Arriving in Paris, he found himself under the patronage of the American businessman and poet Joel Barlow. Barlow and Fulton formed a close relationship with Fulton taking up residence with Barlow and his wife in their home. Barlow facilitated Fulton's continuing education, providing him introductions in the French government and working with him on scientific experiments and inventions. Barlow also provides a plausible link between David Bushnell and Robert Fulton as Barlow and Bushnell both studied at Yale, with Barlow graduating in 1778.[23] Historians speculate that Bushnell traveled to France around 1787 where he met with Fulton, and proposed the use of submersibles to break an ongoing British Naval blockade of France.[24] While some Bushnell-Fulton link may have resulted in the transfer of information on submarine construction, available evidence neither conclusively proves nor disproves the theory.

In December of 1797, Fulton presented his plans for a submarine called *Nautilus* to the French government as a weapon to defeat the British Navy and bring lasting peace by making surface warships obsolete. His proposal was considered, tabled, turned down,

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[22] Fulton, *Improvement of Canal Navigation*.
[23] Todd, *Life and Letters of Joel Barlow*. Barlow's letters document the Fulton-Barlow relationship.
[24] Barber, *Lecture on Submarine Boats*, 9.; Compton-Hall, *Submarine Pioneers*, 42.; Harris, *The Navy Times Book of Submarines*, 40.; Parsons, *Fulton and the Submarine,* 40.; and Roland, *Underwater Warfare,* 86-89.

reconsidered, resubmitted by Fulton, and finally, following General Napoleon Bonaparte's *coup d' état* and the appointment of Eustace Bruix (1759-1805) as Marine Minister, the project went forward.[25]

Bruix appointed a commission to study Fulton's proposal; their description of the vessel, accompanied by a drawing, provides the most complete depiction of *Nautilus.* Details of construction materials and methods are scant. Historians have speculated that the hull was constructed of copper plates secured by iron fasteners over an iron framework.[26] A letter by Fulton describing breaking up *Nautilus* brings the use of copper hull plates into question; he reports selling its iron, lead and cylinders but copper is not mentioned.[27]

Nautilus initial design and major components are illustrated in Figure 5. The submarine was a composite vessel, with components of iron, lead and cupreous metal as well as wood.[28] It was at least partially fastened in iron as Fulton later noted the fasteners caused rust damage.[29] Like *Turtle*, *Nautilus* had a metal conning tower mounted atop the hull fitted with an access hatch and deadlights. Submerged propulsion was provided by a human-powered propeller. New in *Nautilus* was a separate method of

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[25] Dickinson, *Fulton, Engineer and Artist*. Chapters five and six presents Fulton's motives and provides translated versions of his correspondences proposing and negotiating terms for construction and employment of *Nautilus.*
[26] Delgado, *Silent Killers*, 25.
[27] Dickinson, *Fulton, Engineer and Artist*, 123.
[28] Delpeuch, *La Navigation sous-marine,* 90-91, 103.
[29] Dickinson, *Fulton, Engineer and Artist*, 118.

surface propulsion: it was fitted with collapsible mast and sail. Hull dimensions were 21.3 feet (6.5 m) in length and 6.6 feet (2 m) in beam.

Diving, or plunging as Fulton referred to it, was accomplished by flooding the ballast tanks, located in the metal keel. Once slight negative buoyancy was achieved, the bow was driven down by utilizing forward motion and stern-mounted diving planes. Surfacing was accomplished by pumping the water out of the ballast tanks with a manual forcing pump while driving the bow up in the same manner. Directional control was via a stern-mounted vertical rudder. Fulton proposed to attach an explosive charge (that he referred to as the torpedo) to the hull of an enemy ship by employing the "Horn of the *Nautilus*" (Figure 5, detail O). This method was much the same as the concept Bushnell used in *Turtle*, but it employed a spike instead of a screw to fix the charge to the target and the torpedo was towed behind instead of mounted directly on the vessel.

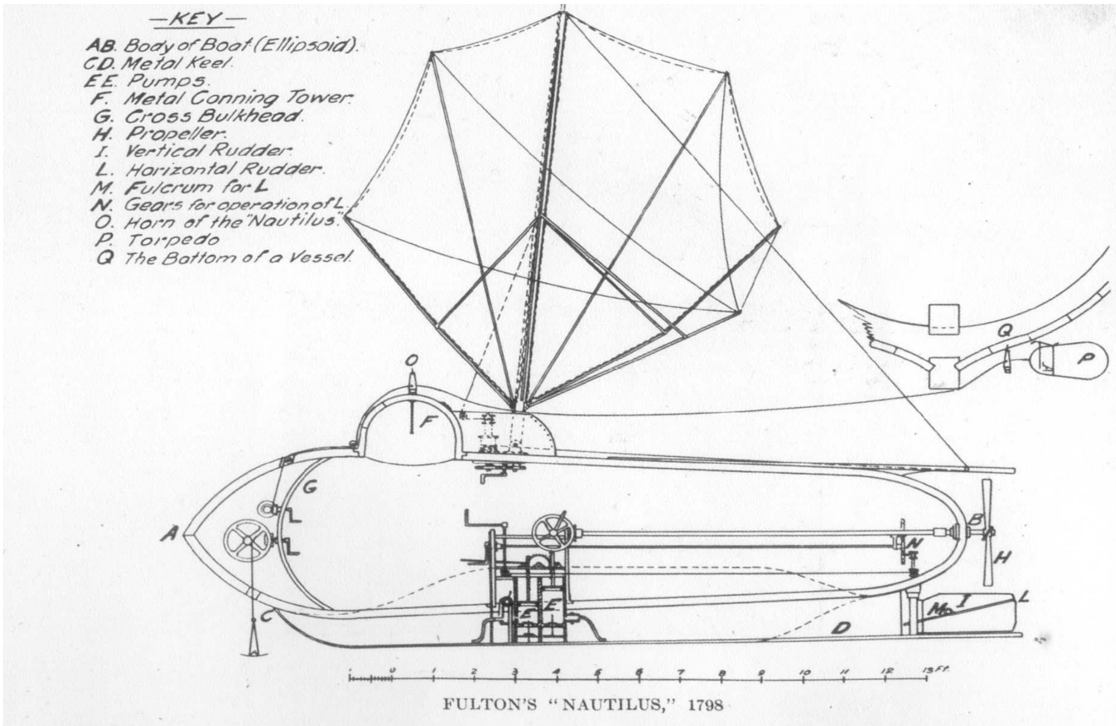

Figure 5. Drawing of *Nautilus.* Courtesy of: NHHC.

Sources disagree on the date and location of *Nautilus*' launch and sea trials. Several historians cite Rouen as the launch site; however, evidence presented by Holden Furber points quite convincingly to a launch and initial trials in the Seine River occurring in mid-June 1800 at Paris.[30] In letters to Minister Pierre Forfait, Fulton describes testing conducted in July and August 1800 in the sea off La Havre. He reported that his experiments with *Nautilus* were successful and during one test the boat and its crew remained submerged for an hour.[31]

[30] Furber, 'Fulton and Napoleon in 1800'.
[31] Dickinson, *Fulton, Engineer and Artist*, 102-103.

Fulton made several modifications to the plan shown in Figure 5, adding a wooden deck for the crew to stand on while sailing, a jib to improve sailing capability, a vertical propeller to improve depth control and altering the horizontal propeller to improve submerged speed.[32] The designer's concept of a vertical propeller is seen in plans by Fulton (Figure 6, detail B) for an improved submersible that was not constructed.

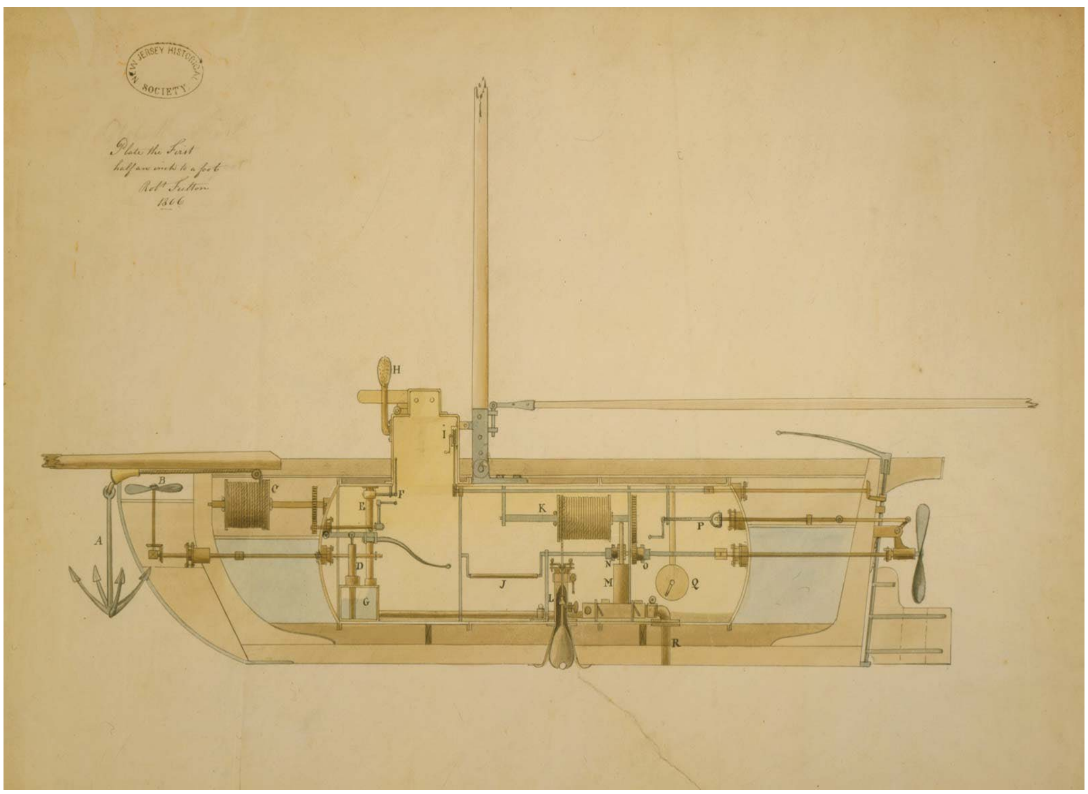

Figure 6. Fulton's improved submersible. Courtesy of: NARA.

[32] Ibid, 101,107, and 119.

Following initial trials at Le Havre, in September of 1800 *Nautilus* departed from that port bound for Saint-Vaast-la-Hougue, a voyage of approximately 65 nautical miles (120 km) (Figure 7). After making Growan Harbor, near Isigny-sur-Mer, Fulton twice attempted attacks against anchored British ships. The British were forewarned of Fulton's plans and set sail, handily escaping.[33] *Nautilus* was simply too slow and ungainly to press home a successful attack. The onset of winter forced Fulton to return to Paris and wait for better weather.

Figure 7. *Nautilus* operating area Courtesy of: Google Earth Pro.

In February 1801 Fulton was issued a letter of marque conditioned on his conveying *Nautilus* from Isigny to the port of Brest. The boat needed repairs, making overland transport more likely than a sea voyage. Refit work took approximately two months and *Nautilus* returned to service in July 1801. Fulton continued to experiment

[33] Ibid, *108-109*.

and improve the vessel, adding a compressed breathing air tank to improve submerged duration, but any attempts to attack British shipping failed. *Nautilus* was broken up and its valuable components sold in the late summer or early fall of 1801.[34]

Fulton shifted his focus away from submarines and worked toward developing practical steam driven vessels and undersea mines. He was eventually lured back to England to work on projects. It is probable that the British were more concerned with depriving France of Fulton's destructive capacities than it was with altering its naval strategy to include Fulton's inventions. The British eventually dismissed him and in October 1806 he returned to America where he successfully built steamboats and unsuccessfully tried to sell the concept of undersea warfare to the U. S. Navy.[35]

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[34] Ibid, 113-123.
[35] Harris, *The Navy Times Book of Submarines*, 56-64.

Wilhelm Bauer - Brandtaucher and Seeteufel

The late 1840s was a time of considerable tension in Europe and Great Britain over what became known as the Schleswig-Holstein question. Which nation, Germany or Denmark, owned and governed the duchies of Schleswig and Holstein?[36] These border areas, located on the Jutland Peninsula, are sandwiched between Denmark to the north and Germany to the south (Figure 8).

Figure 8. Map of Europe, 1849. S. Mitchell, Courtesy of: Library of Congress.

[36] von Wenckstern, *Constitutional Rights of the Duchies of Schleswig and Holstein*., presents the historical arguments.

During the conflict, the Danish government imposed a naval blockade of the ports of Schleswig-Holstein. Sebastian Wilhelm Bauer (1822-1875), a Bavarian artillery engineer, designed and constructed a submersible with which he hoped to break the blockade (Figure 9).

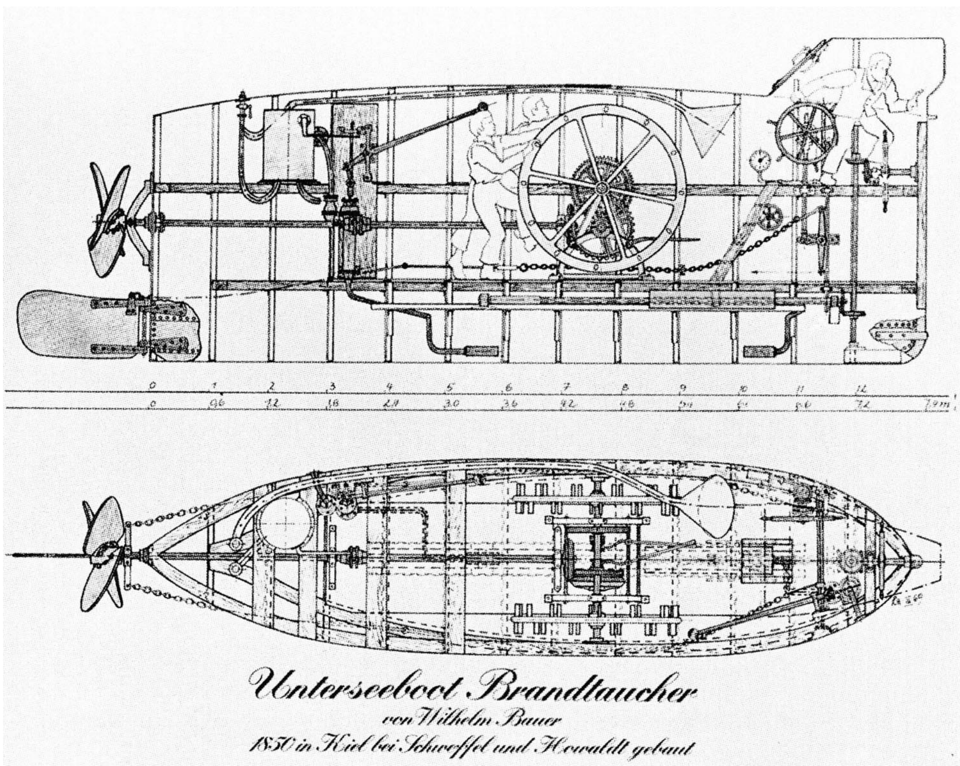

Figure 9. *Brandtaucher* drawings. Public Domain via Wikimedia Commons.

The submersible was 26 feet (8 m) long, had a beam of 6 feet (2 m), a submerged displacement of 30.5 tons, and was constructed in iron at the Machine Factory and Foundry of Schweffel & Howaldt in Kiel. Named *Brandtaucher* (*Incendiary Diver*), the vessel, like its predecessors, was human powered, uniquely with a treadwheel. Much like *Turtle*, surface draft was adjusted with metal weights to achieve slight positive buoyancy, and diving was accomplished by admitting water ballast in the bilge to achieve negative buoyancy. Lacking both diving planes and vertical propellers, *Brandtaucher's* depth control was managed by moving a weight along a bar, thus altering trim.[37]

Figure 10. *Brandtaucher.*

Courtesy of: Marcin Szala, Public Domain via Wikipedia Commons.

Brandtaucher sank during a test dive in Kiel harbor on 1 February 1851. In his description of the sinking Bauer noted that the boat was heavy aft, as a 68 kg piece of ballast had been left aboard. When water ballast was admitted *Brandtaucher* sank by the stern and struck the seafloor, springing a hull plate and dislocating the machinery. Once

[37] Compton-Hall, *Submarine Pioneers*, 60.

Brandtaucher settled on the bottom, Bauer observed that the pumps could not keep up with the flooding and convinced his terrified crew that the only chance of escape would be swimming to the surface once the internal pressure equalized with sea pressure. After this had occurred, they opened the hatch and made a buoyant ascent, the first such escape in the history of manned submersibles.[38] The lost boat was subsequently salvaged; it is displayed at the German Armed Forces Museum in Dresden, the earliest artifact of a powered manned submersible (Figure 10).

Bauer, like Fulton, embarked on a venture to sell his submersible to foreign governments demonstrating the boat's capabilities to several heads of state on the continent and in England. A demonstration model, an artifact of his sales endeavor, is in the collection of the *Deutsches Museum* (Figure 11).

[38] Hauff, *Die unterseeische Schifffahrt, erfunden und ausgeführt von Wilhelm Bauer*, 12-16. Hauff provides, what is apparently, Bauer's first-person account of the sinking of *Brandtaucher.*

Figure 11. Bauer's demonstration model. Courtesy of: *Deutsches Museum.*

In 1853 he was commissioned by Britain's Prince Albert to construct a vessel at the yard of shipbuilder John Scott Russell in Millwall on the banks of the Thames. When the enterprise proved disadvantageous for Bauer (the inventor perhaps felt that his plans were being stolen), he quit the project before the boat was finished and left for Russia. Russell completed construction but the sub was lost with all hands during its initial trials.[39]

Bauer would build another submersible in 1855-56 in Russia. The *Seeteufel (Sea Devil)* was much larger than *Brandtaucher*. Historians disagree on its exact length, reporting a maximum of 60 feet (16.3 m) and a minimum of 50 feet (15.2 m); however, beam is consistently reported at approximately 11.3 feet (3.5 m). The hull was of riveted

[39] Rössler, *The U-boat*, 12. Rösser provides a technical description of Bauer's submersibles.

iron plate over iron frames, and like *Brandtaucher* man-powered treadwheels geared to a shaft driving a screw propeller provided propulsion. Buoyancy was controlled with four cylinders (three large and one small) into which water could be drawn or expelled by a piston powered with a hand cranked screw. Fore and aft trim were regulated by a sliding weight as had been used in *Brandtaucher,* but *Seeteufel* also incorporated diving planes, which are visible on the demonstration model, this likely improved the vessels depth keeping abilities. An aft-mounted rudder and horizontal screw were installed, along with an aft-mounted stern thruster to provide improved lateral control.[40]

Seeteufel completed 134 dives, but how the vessel performed during those dives is not known. Keeping the vessel at the desired depth was surely challenging as speeds above three knots were only attainable for short bursts; the low flowrate of water over the control surfaces likely made submerged handling problematic.

Seeteufel reportedly participated in the coronation of Tsar Alexander II in September of 1856 (Figure 12). Members of a military band embarked in the sub playing the national anthem while the boat was on the surface. The band members then went below, and *Seeteufel* submerged, where upon the band played the tune God Save the Emperor. A sailor on a nearby sloop claimed to have clearly heard this music from the deep.[41]

[40] Hauff, *Die unterseeische Schifffahrt, erfunden und ausgeführt von Wilhelm Bauer*, 63.
[41] Ibid, 30., and Burgoyne, *Submarine Navigation* (vol. 1), 32.

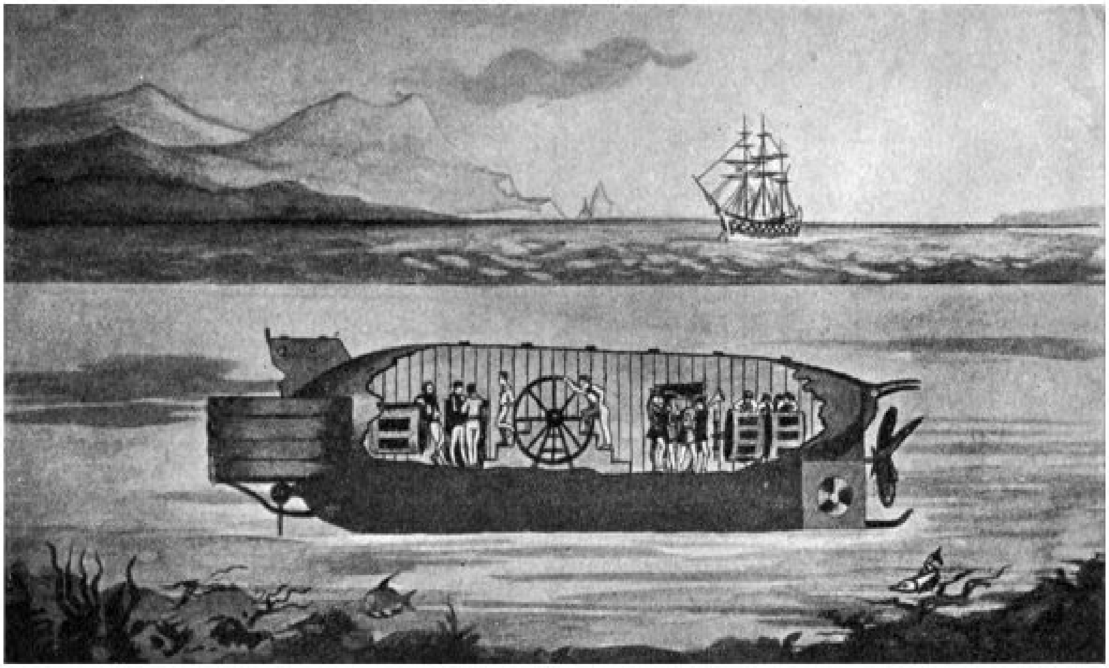

Figure 12. *Seeteufel* with band aboard. From: Burgoyne.

On 2 October 1856 *Seeteufel* fouled its propeller while attempting to attach a mine to a target ship. Bauer discharged ballast and the boat came up by its head. An impatient Russian naval officer opened the still-awash hatch flooding *Seeteufel*. The vessel sank, but Bauer and his crew escaped with their lives.[42]

Bauer left Russia in July 1858 traveling extensively to find clients for a growing portfolio of inventions including diving bells, salvage gear, and cable laying equipment. In his later years he experimented with kerosene engines for submarines; Bauer died in 1875 before the engine was operational.[43]

[42] Rössler, *The U-boat*, 13.
[43] Ibid, 13-14.

Narcis Monturiol – Ictíneo and Ictíneo II

Narcis Monturiol (1819-1885), a Spanish polymath and political radical, is virtually unknown today but he should be recognized as the inventor of the first true submarine and lauded as a visionary in submarine development. Unlike previous designers, his primary motivation was the scientific exploration and commercial exploitation of the sea, not warfare, although he clearly recognized the potential value of submersibles in a combat role.[44] Monturiol and his team, backed by a group of private investors, launched *Ictíneo* in Barcelona, Spain in June 1859 and *Ictíneo II* in 1864.

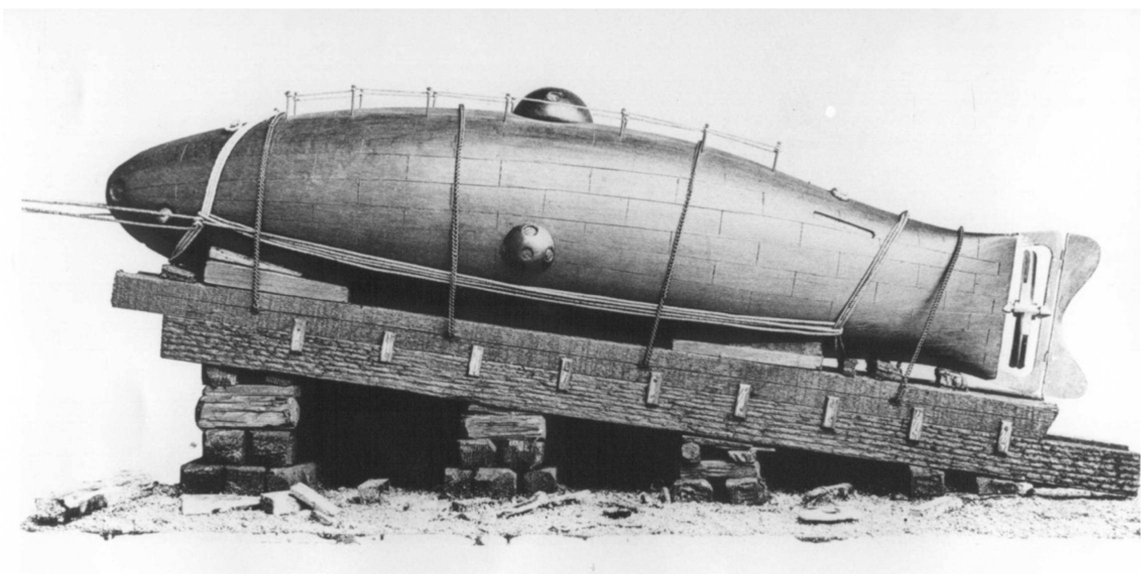

Figure 13. *Ictíneo.* J. Thomas & Company, Courtesy of: *Museu Marítim de Barcelona.*

[44] Monturiol, *Memoria Sobre la Navegación Submarina*, 1-4. In this text Monturiol provides his motives, some of the basic science behind his invention, and the results of testing conducted on the first *Ictíneo.*

Ictíneo was 23 feet (7 m) long and displaced 10 tons, designed for a crew of six and, like its predecessors, was human-powered and slow; nevertheless, it represented a large leap forward in submarine development (Figure 13). The most important of these developments was the inventor's use of a double hull. The inner hull, constructed of olive wood and clad in copper, was designed as the pressure vessel, while the outer hull, also of olive wood, was designed to be as hydrodynamically efficient as possible. Other innovative features incorporated in *Ictíneo* included ballast tanks located in the interstitial space between hulls and an atmosphere control system for removal of carbon dioxide and the enrichment of oxygen. *Ictíneo* operated successfully at depths up to 20 meters and achieved a submerged duration of four hours.[45] In January 1862, a freighter collided with *Ictíneo,* sinking it at its berth.

Monturiol's second vessel, launched in October 1864, followed the same design principles as the first. It was however much larger at 56 feet (17 m) in length and displacing 72 tons; it was designed for a crew of 20. *Ictíneo II* was also human powered but incorporated additional innovations. Auxiliary ballast tanks were added to improve fine buoyancy control; to submerge, the primary tanks were fully flooded to achieve near neutral buoyancy, then the auxiliary tanks would be slowly flooded to achieve slight negative buoyancy. Once at depth, to compensate for hull compression, the auxiliary tanks would be partially emptied by introducing compressed gas into the tanks.

[45] Stewart, *Monturiol's Dream*.

Atmosphere control was improved by the development of a method to measure levels of carbon dioxide and oxygen within the boat. Monturiol also developed an onboard oxygen generator using the reaction of manganese dioxide and potassium chlorate to replace bottled oxygen. The number and size of portholes were increased, and an underwater lamp fueled with hydrogen and oxygen was added to improve visibility at depth. Maneuvering propellers were fitted on the quarters to allow the vessel's heading to be altered when not making headway. However, even with all these innovations, Monturiol considered the human powered *Ictíneo II* too slow to meet his goals. He would install a steam engine in the coming years.

Monturiol understood that a carbon fueled boiler was not suited to the enclosed environment of a submerged submarine and experimented with several chemical mixtures to fire the boiler. He settled on a mixture of zinc, manganese dioxide, and potassium chlorate, the reaction of the mixture was controllable, created sufficient heat, and its byproduct was oxygen. Conventional fuel, coke, would fire the boiler on the surface.

A small steam engine was purchased and split into two, the larger for surface propulsion and the smaller for submerged. Following successful testing the engines and boiler were disassembled and installed in the boat. Surfaced and submerged testing was conducted satisfactorily apart for human comfort. The thick wooden hull proved a great insulator containing the boiler's waste heat which made all but short duration submerged operation impossible. Monturiol had no money to make the necessary engineering changes and in 1868 *Ictíneo II* was scrapped to satisfy debts.

Figure 14. Replica of *Ictíneo II*. Courtesy of: Ricardo Sosa, licensed under CC BY-NC 2.0.

Monturiol's concepts and inventions are available to us thank to the Naval Architect Joan Monjo I Pons (1818-1884) whose drawings provide rich detail of this historic craft.[46] *Ictíneo II* was the apex of development in human powered submersibles; many more would be built but none achieved a similar level of sophistication. A full-scale replica of *Ictíneo II* is on display at the *Museu Marítim de Barcelona* (Figure 14).

[46] Ibid 265-267.

The Confederate Consortium - H. L. Hunley

Notably missing from Monturiol's boats, and from most of the early designs, are diving planes positioned for effective depth control. Modern submarines utilize two sets of horizontally mounted hydroplanes, one pair located forward of center of buoyancy is most effective at low speed, and the other set located at the stern is most effective at high speeds. A series of otherwise primitive human powered vessels built during the American Civil War (1861-1865) provide examples of early submarines which maintained a slight positive buoyancy overcome by water flow over hydroplanes when diving.

The most significant of these vessels is the Confederate vessel *H. L. Hunley* (Figure 15). It made history as the first submarine to sink an enemy combatant when, on the night of 17 February 1864 under the command of Lt George Dixon CSA, it sank *USS Housatonic* off Charleston, South Carolina. *Hunley* also sank during the engagement with the loss of all eight souls aboard.

In 1995, following years of searching, *Hunley* was located and after much planning and preparation, a team led by Dr. Robert Neyland raised it in 2000. *Hunley* is undergoing conservation at the Warren Lasch Conservation Center in Charleston, South Carolina.

Hunley was the third and final vessel constructed by a consortium of Southerners: James R. McClintock, Baxter Watson, and Horace L. Hunley; McClintock and Watson were marine engineers and Hunley provided financial backing and political influence. Constructed in Mobile, Alabama in the spring of 1863, *Hunley* was launched and underwent testing that July.

Built of boiler iron and propelled by seven men turning a three bladed screw via a hand crank, the vessel, uniquely, was controlled in the vertical axis with large hydroplanes mounted forward of the center of buoyancy, the control rod for which is mounted slightly abaft the forward conning tower. The planes are remarkable in size and location. An analysis of the diving planes suggested that the length of the planes may have been excessive, exacerbating depth control challenges.[47]

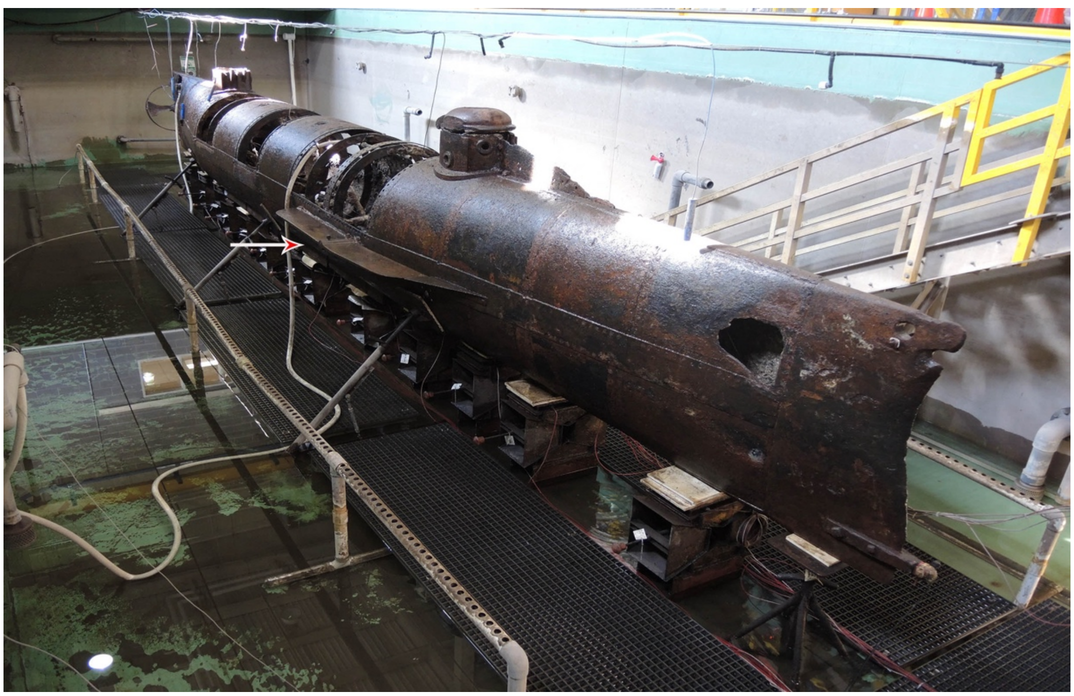

Figure 15. *H. L. Hunley.* Courtesy of: Friends of Hunley Inc.

[47] *Neyland and Brown, H. L. Hunley Recovery Operations*, 171-172. This volume extensively covers the raising and history of *H. L. Hunley,* her operations and final crew; additionally, analysis of construction, informed by study of the vessel, is presented.

Early Mechanically Powered Submersibles

In the second half of the 19th century submarine developers adapted various forms of mechanical power to propel their craft: external combustion steam engines (steam generation by fire or chemical means), electric motors, and internal combustion engines. A fundamental flaw of most early attempts was the use of a single system for both surfaced and submerged operations. Finding the appropriate combination of technologies required half a century of development.

Functioning steamboats were built in the late 18th century and commercial success followed early in the 19th century, maritime steam propulsion expanded and improved in the following decades; however, early steam engines were large, inefficient, and generated significant waste heat, making them unsuitable for use within a subs hull. It was these crude devices that were adapted for use in the first mechanically powered submersible. Piston and cylinder steam engines were fitted in many submersibles, albeit none very successfully. The steam turbine, first used in British K-Class submarines in 1916, would, following the development of nuclear power, become the most effective method of submarine propulsion.

The invention and continual improvement in the design of storage batteries, electric motors, and generators were foundational to the successful development of effective submerged propulsion. Internal combustion engines, temporally the last mechanical power generating method introduced, initially proved both unreliable and dangerous. However, as the technologies matured the dual approach of internal combustion engines for surfaced operation and electric power while submerged proved to be the ideal combination upon which successful submersibles were developed.

Pneumatic propulsion

In 1863 a new submarine designed by Captain Siméon Bourgois and the engineer Charles Brun was launched in Rochefort, France. *Le Plongeur* was the first submersible to be powered by mechanical means (a piston and cylinder engine) driven not by steam but by compressed air (Figure 16).

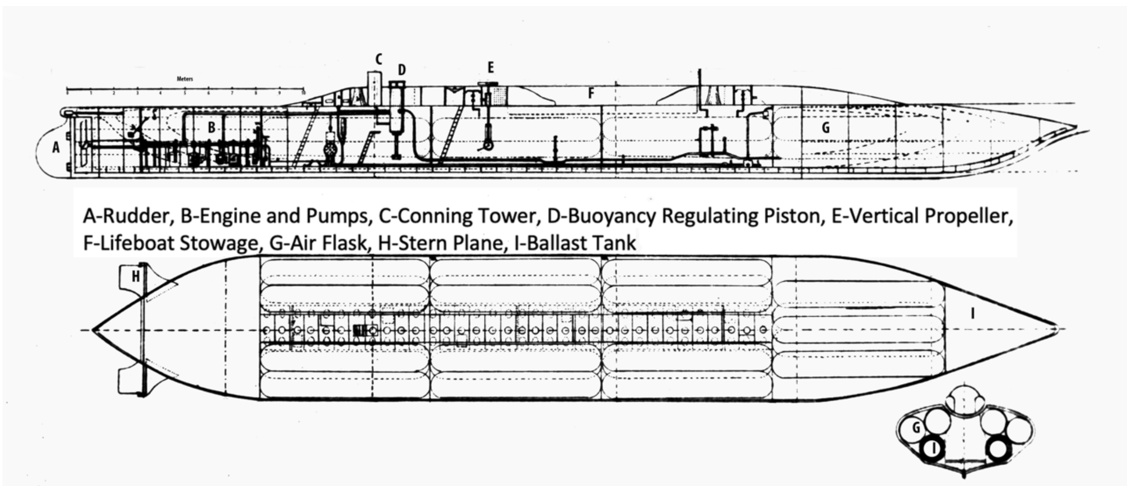

Figure 16. *Le Plongeur.* Author after NHHC.

The largest submersible launched to date, *Le Plongeur* displaced over 450 tons; its 140 ft (43 m) long, 20 ft (6 m) beam hull was constructed of riveted iron plates.[48] The hull was divided into watertight compartments by five transverse and two longitudinal bulkheads. The bow, stern, and wing compartments were used as ballast tanks, and 34

[48] Burgoyne, *Submarine Navigation*, (vol. 1), 49-52.; Sueter, *Evolution of the Submarine Boat* 70-72.; and Delpeuch, *La Navigation sous*-marine, 201-206. Burgoyne and Sueter provide the best discussion of *Le Plongeur* in English; Delpeuch provides additional detail, some mildly contradictory, in French.

tons of detachable ballast were installed to be jettisoned in an emergency. Compressed air was used for maintaining pressure in the vessel slightly above sea pressure, operating water pumps, blowing the ballast tanks, powering the buoyancy regulating piston, and providing propulsion. Compressed air, charged from a shore facility, was stored in 23 air flasks with a total capacity of 5191 cubic feet (147 m^3) at a pressure of 180 psi (12.4 bar). Propulsion was provided by an 80-horsepower compressed air engine. A submersible lifeboat large enough for the 12-man crew was fitted, which could be entered while submerged via a double hatch system.

Initial trials on the surface, while promising, showed a fundamental design flaw. *Le Plongeur* had a limited operating range of approximately five miles (8 km) at three to four knots, making it suitable for only limited duration harbor patrol.

Exercising caution, the first submerged trials were conducted in a dry-dock in Rochefort. Fortuitously, a tall standpipe was fitted over the hatch to facilitate crew egress in an emergency; on its first dive a portlight failed and the crew beat a hasty retreat up the standpipe as *Le Plongeur* filled with water. Once repairs were made, trials resumed and it safely submerged and surfaced in the dock.

Diving trials conducted outside the basin with *Le Plongeur* underway were a failure. The crew was unable to maintain depth or fore and aft trim, resulting in the vessel either bumping off the bottom of the harbor or unintentionally surfacing. The spindle-like hull form coupled with depth keeping systems which were wholly inadequate doomed the vessel to failure.

Stern planes were intended to drive the boat under the surface once neutral buoyancy had been achieved. While submerged, fine buoyancy control was meant to be accomplished through altering displacement with a piston and cylinder arrangement. Two buoyancy compensating pistons are noted in most textual descriptions; however, drawings and models of the vessel depict only a single such device. The piston, designed to operate pneumatically with manual backup, could be retracted into the cylinder, allowing water to enter, thereby increasing displacement. While in theory this could have worked, it is noted that the system operated too slowly to be effective, and a vertical propeller was incorporated, probably after the failures of initial submerged trials.

Further it does not appear that the designers considered free surface effect of the ballast tanks. Ballast water in these long cylindrical tanks surged forward or aft depending on the angle of fore and aft trim if the tanks were not completely full, rendering the vessel virtually uncontrollable.[49]

Over the following several years, design modifications would be attempted with little improvement. Plagued with air leaks, unable to recharge its own air flasks and unable to maintain depth and trim, the project was eventually scrapped. *Le Plongeur's* final service was as a water storage tank.

Despite suffering such an ignominious ending, *Le Plongeur* contributed greatly to the development of submersibles, adding both mechanical propulsion and the use of compressed air to operate machinery and force water from the main ballast tanks.

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[49] Lake, *Submarine in War and Peace*, 154.

Steam propulsion

The first steam powered submersible was developed by Narcis Monturiol as a modification to his human powered *Ictíneo II* (Figure 17). In his quest for mechanical power, he focused his attention on developing a steam propulsion system that utilized a mix of chemicals whose interaction safely generated heat while not contaminating the enclosed atmosphere of *Ictíneo II*. He found that a mixture of zinc, manganese dioxide, and potassium chlorate controllably produced heat with byproducts of oxygen and zinc oxide. [50]

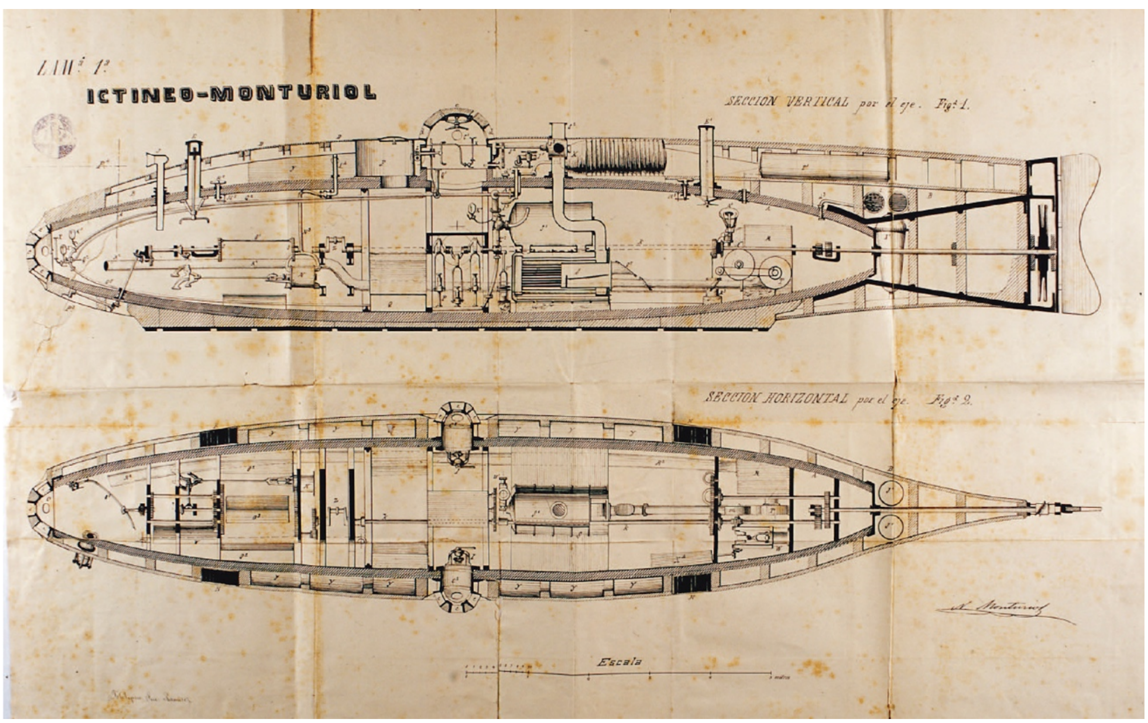

Figure 17. *Ictíneo II* fitted with steam engines. From: Stewart.

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[50] Stewart, *Monturiol's Dream*, 307.

In 1866 Monturiol purchased a six-horsepower steam engine and, using his chemical fuel, operated it successfully in his workshop. The engine was disassembled in order to fit its components through the hatch, then reassembled in *Ictíneo II.* He effectively split the engine into two smaller engines, one conventionally fueled for surface operation, the other chemically fueled for operating submerged.

While the engines functioned as designed, the waste heat generated by the boilers built up quickly in the closed environment, the thick olivewood hull acting as a superb insulator. Only short, submerged operations were possible as the crew could not stand the heat. The concept was proven and *Ictíneo II* become a submarine, but a barely functional one. Monturiol understood that a method of dissipating the waste heat required a complete redesign and an iron hull. Unfortunately, the inventor and his submarine company were penniless and awash in debt; *Ictíneo II,* their only asset, was seized and broken up, its components sold to pay debts.[51]

The desire for high-speed surface performance coupled with the technological maturity of steam propulsion resulted in continuing efforts, by numerous inventors, to adapt steam propulsion for use in submersibles, with varying levels of success. Other notable steam powered submersibles were the George Garrett designed Nordenfelt boats, of which three were constructed between 1885 and 1887, and the submarine *Peacemaker* built in 1885 by the American inventor Josiah Tuck (1824-1900). Both designs used steam propulsion while surfaced and submerged; *Peacemaker* had a chemically heated

[51] Ibid, 322.

boiler while the Nordenfelt boats used stored hot water under pressure which flashed to steam at low pressure. [52, 53]

Toward the end of the 19th century, as electric propulsion became more reliable and available, submersibles powered by steam on the surface and electric motors while submerged grew in favor. However, incidents in steam submersibles killed many submariners, frequently resulting from flooding through the numerous large hull penetrations necessary to support the propulsion system, demonstrating the incompatibility of submersibles and conventionally fired steam plants.[54]

The British K-Class submarines of the First World War were the last and, while plagued with problems, the most advanced of the steam powered boats developed until the launch of the nuclear-powered *USS Nautilus* in 1954. The last of its class, *K-26,* was sold for scrap in 1931.[55]

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[52] Swinfield, *Sea Devils*, 45-50.
[53] 'The Submarine Monitor *Peacemaker*', 354.
[54] Everitt, *K Boats*, 11-12.
[55] Akermann, *Encyclopedia of British Submarines 1901-1955*, 205.

Internal combustion engine propulsion

In 1873, John Philip Holland (1841-1914), an Irish schoolteacher with a penchant for engineering, emigrated to America. Settling initially in Boston, Holland drew his first set of plans for a submersible while recovering from a broken leg. His initial design was a crude, human-powered, one-man submersible. Following his recovery, the plans were filed away, and Holland took a position in New Jersey teaching school. He eventually sent his plans to the Navy Department in 1875, beginning what would become his life's work.

The Navy took little interest in his plans, but Holland's younger brother introduced him to members of *Clan-na Gael,* the precursor of the modern Irish Republican Army, who were interested in developing his submersible to strike back against the English.[56] This unlikely partnership financed Holland's early work and paved the way to his future success.

The first submersible Holland built for the Fenians incorporated a Brayton internal combustion engine to provide propulsion both on the surface and while submerged. The Brayton engine used a mixture of fuel and air, but unlike modern internal combustion engines in which the fuel mixture burns explosively, the Brayton engine burned the mixture in a more continuous manner, with the expansion of gas driving the piston.[57]

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[56] Morris, *John P. Holland, 1841-1914*, 24.
[57] Donkin, *A Textbook on Gas, Oil, and Air Engines*, 289-290.

Holland I was among the smallest submersibles ever built at 14.5 ft (4.4 m) in length, 3 ft (0.9 m) beam, and a height of 2.5 ft. (0.8 m) not including the raised turret.[58] It was moved to Paterson, New Jersey from its building yard in New York, likely for fitting of the engine. *Holland I* was launched 22 May 1878, whereupon it quickly sank. It was recovered, re-ballasted and re-launched; the second launching having better results. Holland was reportedly unable to get the Brayton engine to start and instead utilized steam from the escort launch's boiler to operate the engine.[59] Holland demonstrated his boat to the satisfaction of his backers as evidenced by their willingness to finance a second vessel. Following testing, Holland stripped his prototype of its valuable components and scuttled it. *Holland I* was later recovered and is now on display at New Jersey's Paterson Museum (Figure 18).

Figure 18. Holland Boat No. 1. Courtesy of: Tom Sulcer, licensed under CCO1.0.

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[58] Morris, *John P. Holland, 1841-1914*, 26.
[59] Ibid, 29.

Holland's next vessel was laid down in the yard of Delamater Iron Works in New York City and launched two years later in May 1881. This boat was significantly larger than *Holland I* at 31 ft (9.5 m) in length, 6 ft (1.8 m) in beam and displacing 19 tons. *Holland II*, dubbed *Fenian Ram* by a reporter, was a radical departure in design and construction from *Holland I.* The hull form was rounded, almost whale-like and the diving planes were located at the stern slightly forward of the screw (Figure 19). A breech-loaded pneumatic gun was fitted in the bow, and the muzzle closed with a hinged door. The boat was powered by a larger and more powerful two-cylinder Brayton engine developing approximately 15 horsepower.

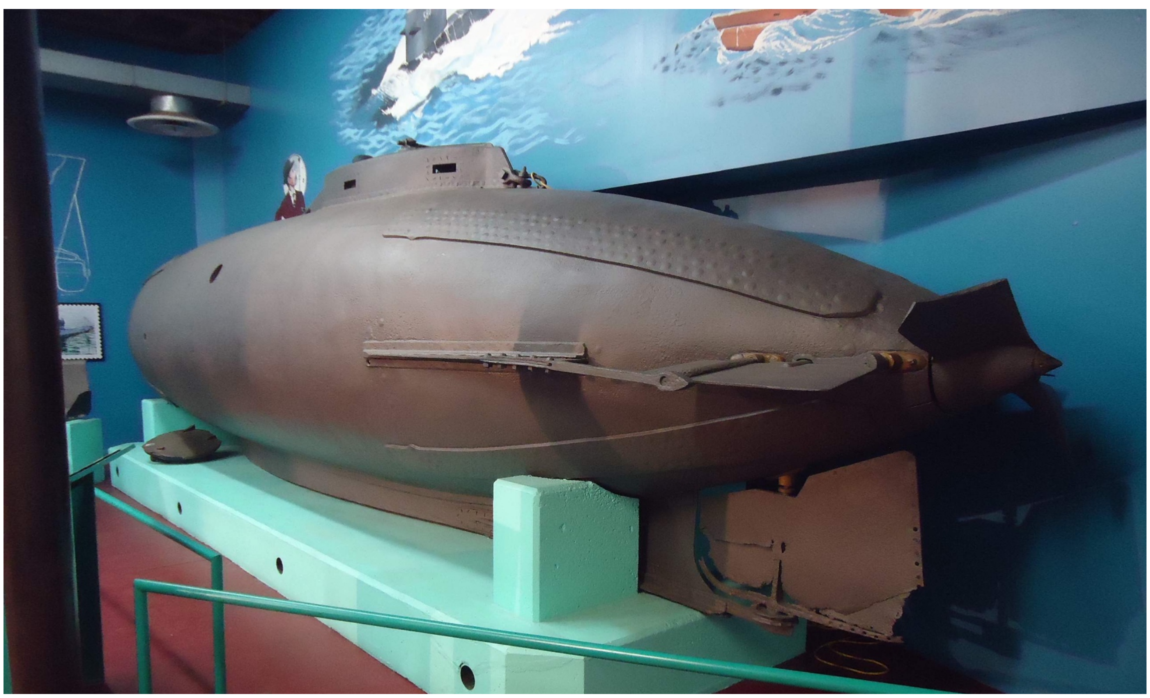

Figure 19. *Fenian Ram* (Holland Boat No. II). Courtesy of: Tom Sulcer, licensed under CCO1.0.

Fenian Ram was operated by a crew of three. The pilot steered the boat, operated the diving planes and controlled ballast. Holland's design maintained a fixed center of gravity and retained a slight positive buoyancy. Submerging the boat was accomplished by flooding the ballast tanks and using the diving planes to pitch the bow down, driving it down with the force of the screw. Holland's logic was that if propulsion were lost the boat would surface. The lack of instruments to navigate underwater meant that dives were necessarily of short duration as frequent observations of position were necessary.

The engineer operated the Brayton engine, the sole source of both surfaced and submerged propulsion. On the surface, combustion air could be drawn in via the open hatch; however, when submerged, compressed air provided the oxygen necessary to maintain combustion. This was accomplished by maintaining a pressure in the boat slightly greater than that of sea pressure, providing ample combustion air, breathing air for the crew, and allowing the engine to overcome exhaust back pressure.

The gunner operated the gun. A projectile was loaded into the breech of the gun, and the breech was closed; next the tube was flooded, and the muzzle was opened. The gunner would open the firing valve which allowed the contents of an air flask to force the projectile out of the tube. The gun was the only grossly unsuccessful aspect of the boat; its projectiles, lacking any guidance or directional stability, were woefully inaccurate.

Fenian Ram reportedly achieved surface speeds of 9 knots (17 kph), dived to 50 feet (15 m) and had a submerged duration of over an hour. It provided Holland with a testing platform for his ideas, while the Fenians provided the financial backing to bring them to fruition. The same concepts of hull form, positive buoyancy, and depth control are repeated in Holland's later designs.

The relationship with his backers eventually soured over the ongoing expenses of the project and in November 1883, the Fenians seized the *Ram* and a small prototype, *Holland III*. The prototype sank while under tow and has not been recovered. *Fenian Ram* was beached, spent over three decades in a shed, was displayed at the Clason Point Military Academy and was eventually donated to the city of Paterson, where it is also on display in the Paterson Museum.

The U. S. Navy was interested in Holland's work, and references to it, including an accurate description of *Fenian Ram,* appeared several times in the military-focused *United States Army and Navy Journal*.[60] While a direct nexus cannot be established between this publication and the first meeting between Holland and Lt. William Kimball (1848-1930), their friendship began in 1883. Kimball was keenly interested in undersea warfare and was an early promoter of submarines. He attempted have Holland hired by the Bureau of Ordnance as a draftsman but was unable to fund the position. Kimball would prove to be an ardent supporter of Holland's work when the Navy began seriously investigating submarine acquisition.[61]

Holland constructed another submarine in partnership with an U. S. Army officer, Edmund Zalinski (1849-1909), *Holland IV*. Holland and Zalinski formed the Nautilus Submarine Company and solicited private funding for the project. Their austere

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[60] 'A New Torpedo Boat', 1092.
[61] Morris, *John P. Holland, 1841-1914*, 50-51.

funding required significant design compromises including a wooden hull built on metal frames. The boat was the largest of Holland's designs at 50 ft (15.2 m) in length and 8 feet (2.4 m) in beam. The boat suffered significant damage on launching and never became fully operational; an abject failure, it was eventually sold for scrap.

Electric propulsion

Electric propulsion was crucial in the development of functional submarines. Experimentation with electric propulsion in submersibles dates to the 1860s. Both an electric motor and steam propulsion were unsuccessfully attempted in the second vessel built by the Confederate consortium of McClintock, Watson, and Hunley.[62]

The first submarine to operate with electric propulsion was developed in 1884 by Polish inventor Stefan Drzewiecki (Dzhevetskiy) (1844-1938) for the Russian Navy (Figure 20).

Figure 20. Drzewiecki submarine. Courtesy of: Nodotty, licensed under CC-BA-SA 4.0.

[62] Neyland and Brown, *H. L. Hunley Recovery Operations*, 15.

Drzewiecki built several submarines, beginning with a small single-place human-powered boat. He next developed a 4-place human-propelled submersible of which, Russia purchased 50 in 1879. In 1884, using a similar hull design, the inventor installed electric accumulators (batteries) and a small electric motor. His electric propulsion system gave the boat a 10-hour operational duration at 4 knots (7 kph).[63] Drzewiecki would go on to build several other submarines but is primarily known for his development of a torpedo launching system, mounted external to the submarine hull, and his pioneering work in aviation.

Battery and electric motor technologies were improving in the later years of the 19th century; inventors in England, France and Spain built electric powered submarines, each of which, while functional, suffered from the inability to recharge their batteries while underway. One of them, a Spanish boat named after its inventor Isaac Peral y Caballero (1851-1891), is worthy of further study for its technological advances.

An engineer and a naval officer, Peral developed his design while serving as a teacher at the naval school in Cádiz and was able to garner the support of his superiors and eventually that of the naval minister. The submersible *Peral* was laid down in October 1887 in the naval dockyard of La Carraca and launched in September of the following year. The boat's hydrodynamic hull form, interior torpedo tube, twin screw electric propulsion, automatic depth keeping system, and primitive periscope were significant advances in submarine development. Of these advances likely the most

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[63] Delgado, *Silent Killers*, 80.

significant was the invention of the internally reloadable torpedo tube, through which *Peral* successfully launched inert Whitehead torpedoes against a surface ship.

Peral was built of steel plate on frames; it was approximately 72 ft (22 m) in length, had a beam of 9.5 ft (2.9 m) and displaced 77 tons surfaced and 85 tons submerged. *Peral* was powered by two 30-horsepower electric motors driving independent propellers. *Peral* lacked hydroplanes, instead relying on five-horsepower electric motors driving two vertical-thrust propellers, the forward of which was located below the torpedo tube while the aft thruster was placed just forward of the rudder.

Peral's drawings show the machinery layout and torpedo storage but lack details regarding location of the storage battery, described as the largest of its day, nor can the location of ballast tanks be discerned (Figure 21).

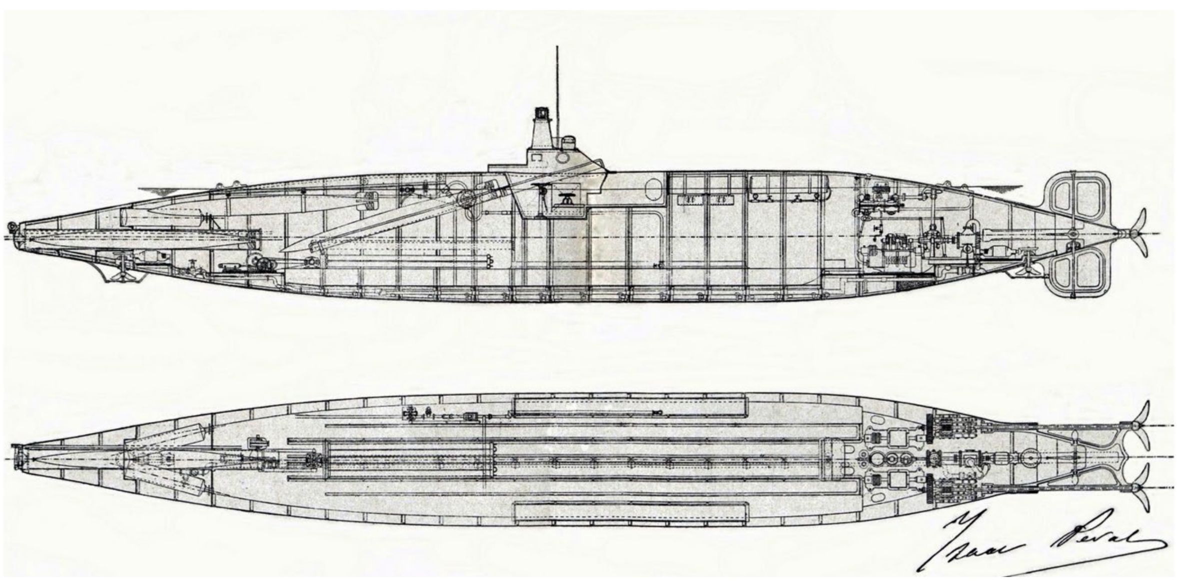

Figure 21. *Peral* plan and profile drawings. Peral, Courtesy of: Archivo Histórico Nacional.

Unique in *Peral* was an automatic depth keeping system. It is described by the Nobel prize winning author and engineer José Echegaray (1883-1916) as consisting of a barometer, with an adjustable contact that could be set to the desired depth. Submerging was accomplished by flooding the ballast tanks. When near-neutral buoyancy was established, the system was energized, and power would travel from the batteries via the closed contacts of the depth device to the motors operating the vertical-thrust propellers; their rotation causing the slightly buoyant *Peral* to submerge. Once the desired depth was reached a reduced current was applied to the motors, maintaining *Peral* at depth.[64]

How well the boat actually performed is a matter of question. Some sources report that it operated well, while others are far from flattering; the truth likely lies somewhere in between. Peral fell from favor in the Spanish Navy and his submarine languished in port; fortunately, it escaped the breaker's yard and is preserved in Spain's *Museo Naval in* Cartagena (figures 22 and 23).

[64] Echegaray, *Examen de Varios Submarinos Comparados con El Peral*, 6-9.

Figure 22. *Peral* from astern. Courtesy of: Dr. Alan P. Newman.

Figure 23. *Peral* from ahead. Courtesy of: Dr. Alan P. Newman.

Submarine Delivered Weapons

Unlike surface ships which could stand some distance off from their opponent to fire their cannons, early submarines lacked an effective standoff weapon. Initial submarine weapons were simple explosive charges that were either affixed to or forced into contact with the hull of the intended target; both methods required that the delivery vessel be very close to the enemy ship. These methods proved unsuccessful, as was the case with Bushnell's *Turtle* and Holland's *Fenian Ram*, or deadly to the submarine crew as was the case with *H. L. Hunley*. A few short years after *Hunle*y's attack on *USS Housatonic,* an English engineer developed the self-propelled torpedo that answered the need for a remotely-fired weapon. Robert Whitehead was employed as a marine engineer in what is modern day Croatia. Working from a design provided by Giovanni Luppis, a retired naval officer, he developed the automobile torpedo in 1866. Whitehead's weapons were powered by a compressed air engine turning a propellor, had a speed of approximately 6 knots (11 kph) and a range of approximately 200 yards (183m).

Initially employed on surface craft, the Whitehead torpedo was first used in combat to sink a ship during the Russo-Turkish war in 1878, when the Turkish steamer *Intibah* was attacked by Russian torpedo boats.[65]

The U.S. Navy was aware of these advances but declined to purchase the rights to build the Whitehead torpedo, instead independently pursuing torpedo development at the Torpedo Station in Newport, Rhode Island. The torpedo developed in the early

[65] Drashpil, 'Surface Torpedo Craft of the Imperial Russian Navy', 237.

1870's, the U.S. Navy Fish Torpedo, was roughly equivalent in performance to the Whitehead torpedo of the day but was never placed in service.

Lt. Cmdr. John Howell USN (1840-1918) developed a flywheel powered torpedo. Used solely in surface ships, the torpedo's flywheel was spun up using an external steam turbine prior to launch. In comparison against the Whitehead several benefits are noted: lacking an internal engine the Howell torpedo left no trail of exhaust bubbles, it was less expensive and simpler to build than the Whitehead, and it was more directionally stable due to the gyroscopic effect of the flywheel. Only 50 Howell torpedoes were built, ordered in 1889; the torpedoes remained in service until 1898 when improvements in the Whitehead design rendered them obsolete.

The E. W. Bliss Company of Brooklyn, NY negotiated a license to build Whitehead torpedoes and in 1892 the U. S. Navy placed an order with Bliss for 100 Whitehead torpedoes. Cold compressed air continued to be the power source for these weapons until 1901 when a kerosene fueled air heater was developed significantly improving range and speed. In 1904 Frank Leavitt, an engineer for Bliss, developed an alcohol fueled, turbine powered torpedo. This shift to turbine propulsion paved the way for the steam turbine torpedoes, introduced by Bliss-Leavitt in 1912, these weapons would remain in service through the Second World War. Bliss (later Bliss-Leavitt) would hold a virtual monopoly on U.S. torpedo manufacture until 1906 when the Navy opened its own torpedo factory in Newport, RI.[66]

[66] Jolie, *U.S. Navy Torpedo Development*.

Conclusions

Progress in the development of submersibles in the late 18th and throughout the 19th centuries followed technological and industrial advances in general. Most submarine inventors can best be considered as early adopters who skillfully adapted emerging technologies to fit their purpose. Some of them. Monturiol, Peral, and Holland in particular, stand above the crowd for their audacity and innovation.

Single mode propulsion, realized as a weakness as early as 1800, persisted for nearly a century. Through trial-and-error a system of internal combustion engines providing surface propulsion and electrical generation for battery charging coupled with electric motors for submerged operation would, in the closing years of the 19th century, become the primary method of submarine propulsion and persist until the advent of nuclear power.

The challenges of submerged stability, depth control, and navigation remained significant as submarining entered the new century. The principle of maintaining positive buoyancy and driving the boat down with motive force is fundamental, but the methods used to overcome that reserve buoyancy continued to be developed. Navigation was by simple observation as voyages had yet to take place beyond the harbor.

The submarine as a weapon of war was significantly advanced by Peral's integration of an internally reloadable torpedo tube capable of launching Whitehead torpedoes. The ability to launch a torpedo from a submerged boat and strike the intended target become a significant factor in determining the outcome of both World Wars.

CHAPTER II

THE UNITED STATES NAVY COMMISSIONS A SUBMARINE

False Starts – Civil War Years

The U.S. Navy began experimenting with submersibles early in the Civil War. The French inventor Brutus de Villeroi (ca. 1797-1875) designed, and the Philadelphia shipbuilders Neafie and Levy built, the Navy's first submersible, launched on 1 May 1862. Dubbed *Alligator,* the boat was approximately 47 ft (14.3 m) long and was human powered, utilizing oars which feathered on the forward stroke and opened on the catch (Figure 24). *Alligator* was to deliver explosive charges by a diver deployed through its lockout chamber, the sole innovation of this craft. *Alligator* sank on 2 April 1863 while being towed to Port Royal, South Carolina. It was never employed in combat.

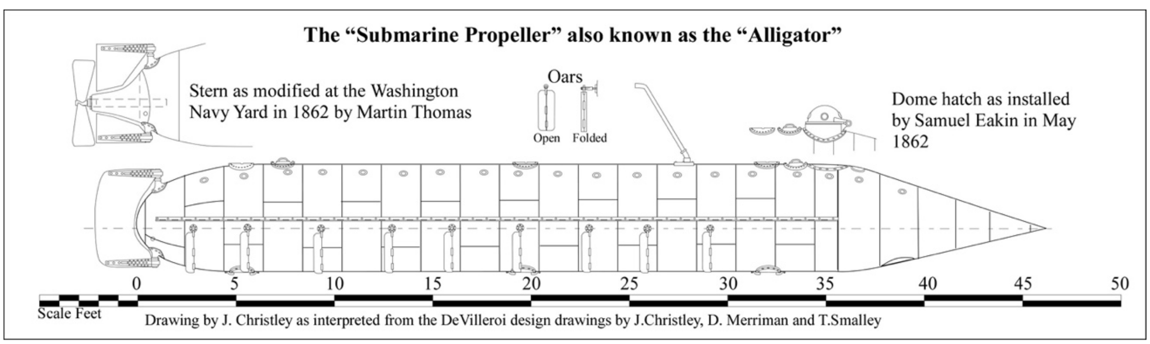

Figure 24. *Alligator.* Courtesy of: J. Christley.

The Navy showed continued interest in submarines over the course of the war, entertaining several designs and inspecting vessels built by inventors desiring to sell their inventions to the government. Among these vessels was *Intelligent Whale* (Figure 25), designed by Scovel Merriam. Laid down in late 1863 or early in 1864, evidence regarding the building yard is scanty at best. Like *Alligator* it was built for the purpose of clandestine insertion of divers to place explosive charges on enemy shipping or clear harbors of enemy mines. Initially, in July of 1864, the Navy found the vessel unacceptable; but after years of travails, the boat was eventually sold to the Navy in 1869. Following failed tests in 1872, the Navy lost interest in and abandoned the vessel.[67] Thankfully it was preserved and is currently on display at the Sea Grit Museum in New Jersey, the oldest U. S. Navy submarine relic.

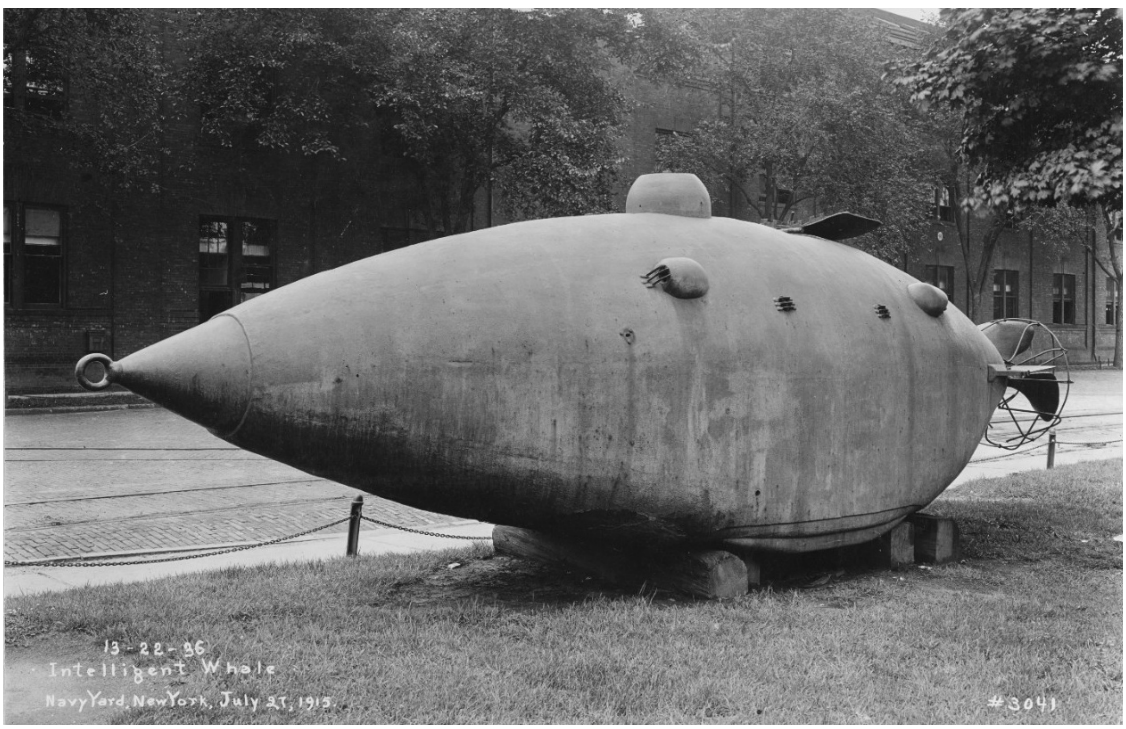

Figure 25. *Intelligent Whale.* Courtesy of: NHHC.

The Post-war Procurement Debacle

[67] Hitchcock, Master's thesis, 89-105.

In the years following the Civil War there was ongoing interest in the advancement of submarine technology within American political and military circles. *The Journal of the Army and Navy*, an unofficial newspaper, contains numerous articles detailing new subs. Formal interest is also evidenced by a lecture, prepared in 1875 by Lt. Francis Barber USN, published by the Navy Bureau of Ordnance detailing the history of submarine navigation and including many of the submarine designs that were forwarded to the Navy in the preceding years.[68] Interest, however, did not equate to action, likely due to a combination of resource availability and skepticism by Navy leadership as to the military value and practicality of submarine warfare.

The Civil War left the country mired in debt; the national debt in 1865 stood at some $2.7 billion.[69] The consequently austere Navy budget, averaging $18.3 million per year in the twenty years following the war, led to an aged, ill maintained fleet.[70] When money is tight research and development is typically a low priority, and as the scarce funding available was allocated elsewhere, submarine developers were forced to rely on private resources to further their designs.

Overseas, the proliferation of submarine and torpedo technology increased in the 1880s; during that decade the nations of Russia, France, Turkey, Greece, and Spain would each develop or purchase submarines. The Whitehead and Schwartzkopff torpedoes as well as vessels capable of launching them were also becoming common in

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[68] Barber, *Lecture on Submarine Boats*.
[69] Ippolito, *Why Budgets Matter*, 59.
[70] Department of the Navy, Financial Report, (1961), 14-15.

foreign navies. As early as 1880, the Navy considered torpedo boats vital to coastal and harbor defense; as such they were a significant part of fleet modernization.[71] However, no program for developing a submarine existed until 1887.

In a circular dated 26 November 1887, Secretary of the Navy (SECNAV), William Whitney announced a competition for the design of a submarine torpedo boat. Some of the critical requirements set forth included: speed of at least 15 knots (28 kph) surfaced and eight knots (15 kph) submerged, the ability to hover at depth, ability to submerge to at least 150 feet (45.7m), and the ability to effectively deliver torpedoes.[72] These design criteria were developed by Lt. William Kimball, a friend of John Holland, for the approval of the Chief of the Bureau of Ordnance (BUORD). Kimball notes that while he argued against the requirement that the boat be capable of hovering in the water column, BUORD was inflexible.[73]

Only two bidders participated, with John Holland presenting Holland's own design, and Maxim Nordenfelt Guns and Ammunition Company presenting the design of George Garrett. Most literature refers to submarines of Garrett's design as Nordenfelt boats; however, Thorsten Nordenfelt merely filled a financial and sales role to forward Garrett's design. Cramp Shipyard of Philadelphia, a reliable contractor for the Navy, was selected as the preferred building yard. The design requirements favored Nordenfelt/Garrett, as their previous vessel, built by Britain's Barrow Shipbuilding

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[71] Department of the Navy, Annual Reports of the Navy Department, (1880), 37-38.
[72] Department of the Navy, Annual Reports of the Navy Department, (1886-87), 273-276.
[73] Kimball, 'Supplementary Chapter', 320-321.

Company, demonstrated both the desired surface speed and the ability to hover; however, Holland's design won the day.[74] This proved a hollow victory for Holland as Cramp and the Navy failed to reach agreement on price and performance guarantees; hence no contract was forthcoming.

The competition was re-announced, with two bidders participating, Columbian Iron Works and Dry Dock Company presenting the Holland design and Mr. George Baker presenting his own design. Bids were opened on 15 February 1889 and Holland's design was chosen over Baker's. Again, the bids were rejected as the Navy Department did not accept any bids for the new submarine boat.[75] This inability to contract resulted from a reallocation of funding earmarked for the project by the incoming SECNAV.[76]

The quest for submarine acquisition stalled during President Benjamin Harrison's administration. Harrison's SECNAV, Gen. Benjamin Tracy (1830-1915), was intently focused on building a professional navy capable of both coastal defense and international power projection.[77] While Tracy's efforts left the nation with a much more powerful and professional naval service, this was undoubtedly a frustrating period for John Holland.

Another submarine competition was announced in May 1893 using the 1887 specifications. Holland borrowed the money necessary to participate in the bid process from a lawyer friend, E. B. Frost, and together they incorporated the John P. Holland

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[74] 'The Nordenfelt Submarine Torpedo Boat', 192.
[75] Department of the Navy, Annual Reports of the Navy Department, (1889), 446.
[76] Morris, *John P. Holland, 1841-1914*, 61.
[77] Cooling,'Making of a Navalist', 83-89.

Torpedo Boat Company, with Holland as manager and Frost as its secretary treasurer.[78]

Interest had grown since the earlier competition and five bids were received, among them a bid from the inventor Simon Lake (1886-1945). Lake notes in his autobiography that years later he learned, from a member of the board, that his design had been preferred over Holland's but he had been disqualified for failing to submit an actual construction bid.[79] That said, the board responsible for determining which bid best achieved the published requirements recommended Holland's proposal.[80] The Navy decided to conduct testing to determine crew survivability when a submerged boat was subjected to close aboard explosions, further stalling any contract award.[81]

Frustrated with the lack of progress with the U.S. Navy bid, the Holland Torpedo Boat Company began looking for foreign buyers. Following these overtures, on 13 March 1895, the Navy offered Holland's company a contract for $150,000 to construct a submarine that would be named *Plunger*.[82]

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[78] Morris, *John P. Holland, 1841-1914*, 67.
[79] Lake and Corey, *Submarine; the Autobiography of Simon Lake*, 41.
[80] Morris, *John P. Holland, 1841-1914*, 237-238.
[81] Department of the Navy, Annual Reports of the Navy Department, (1893), 29-30.
[82] Department of the Navy, Annual Reports of the Navy Department, (1895), XV.

Plunger

Plunger was the largest and most complicated boat Holland had attempted; built in the yard at Columbian Iron Works in Baltimore, MD, it was 85 feet (25.9 m) in length, 12 feet (3.7 m) in beam and displaced 168 tons. *Plunger* did not follow Holland's previous designs except in the most general of terms. Holland boats were single hull vessels, meaning that the pressure hull contained the entirety of the vessel's tanks, equipment, and personnel. The interiors of Holland's early boats were not divided into separate watertight compartments, exposing the entire crew to the same environmental hazards and the boat to catastrophic flooding. While *Plunger* was drawn by Holland it was essentially designed by committee (Figure 26).

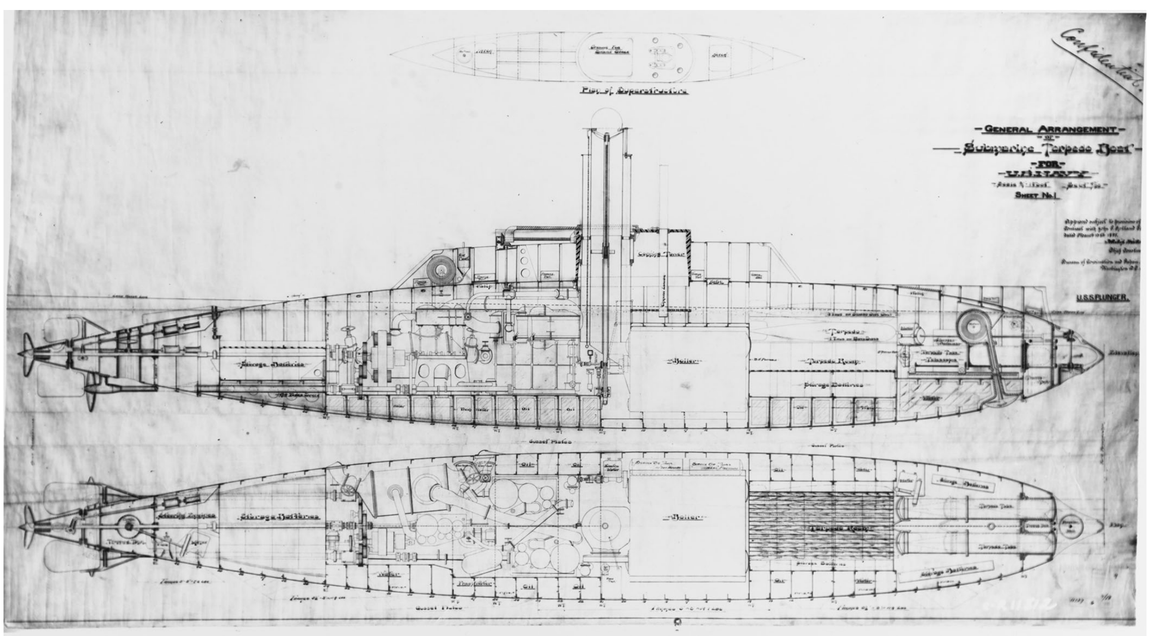

Figure 26. *Plunger* drawings. Courtesy of: NHHC.

In order to meet the Navy's requirement for a surface speed of 15 knots (28 kph), Holland designed the boat around a large steam powerplant, as the internal combustion engines of the day generated insufficient power. Steam was produced in an oil-fired boiler which filled a large part of the midships section of the boat. Steam from the boiler fed two triple-expansion steam engines attached to the outboard propeller shafts, as well as powering, via a small compound steam engine, the DC generator which charged the storage battery. The 60-cell lead acid battery provided motive force for the electric motors powering the centerline screw and the forward and aft vertical thrusters as well as for operating lighting and auxiliary equipment. The vertical thrusters were added to meet the Navy's requirement that the boat statically hover in the water column.

The triple screw configuration appears in the photo below (Figure 27). The outboard screws which provided surface propulsion were driven by steam engines, each generating roughly 810 horsepower at 400 revolutions per minute. The centerline screw, provided submerged propulsion and was powered by a 70-horsepower electric motor.[83]

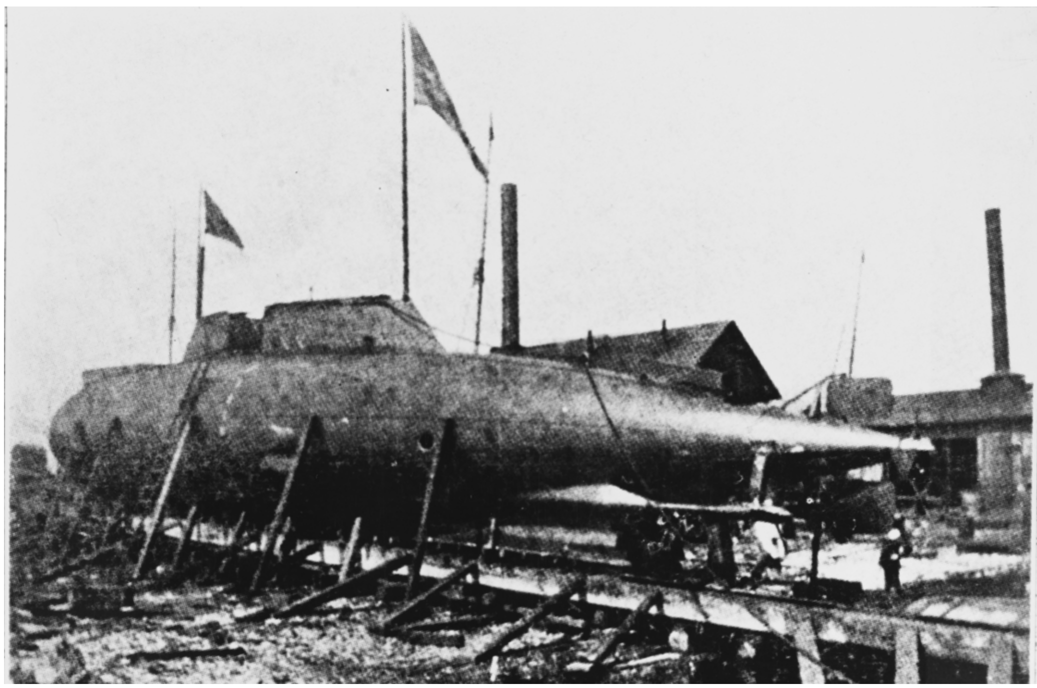

Figure 27. *Plunger* on the ways. Courtesy of: NHHC.

Plunger was doomed before the first bit of steel was cut. The government's requirements, some of them simply unobtainable with the technology of the day, coupled with intrusive oversight resulting in near-constant design changes, led to the boat's

[83] Morris, *John P. Holland, 1841-1914*, 75.

failure. Launched on 6 August 1897, *Plunger* was too hot for habitation when the boilers were lit and was unstable on the surface. It failed dock trials and, although ultimately purchased by the Navy, was never commissioned, becoming a training hulk for Navy divers.[84]

[84] Cable, *The Birth and Development of the American Submarine*, 102-104. Cable served as trials captain in *Holland VI*.

Holland VI

John Holland recognized that the *Plunger* project was not going to have a favorable outcome and, in the winter of 1896-1897, the Holland Torpedo Boat Company began speculatively building another submarine at the Crescent Shipyard in Elizabethport, New Jersey. This boat was to be constructed to Holland's design and wholly without government interference, with the goal of leveraging its success to gain future Navy contracts.

Holland VI was designed for a maximum operating depth of 75 feet (22.8 m), half of the Navy's design specification for *Plunger*.[85] It was smaller than *Plunger* at just under 54 feet (16 m) in length with a beam of slightly over 10 feet (3 m) and displacing only 75 tons submerged. Propulsion was provided by a single screw powered by a 50-horsepower Otto gasoline engine on the surface and a 50-horsepower electric motor, fed by a 60-cell lead acid battery, while submerged. Surface speeds of 6 knots (11 kph) were achieved on the gas engine while the electric motor produced 8 knots (15 kph). Submerged the boat could make 5.5 knots (10 kph) on the electric motor. It was initially designed to be armed with two dynamite guns of the Zalinski design, mounted forward and aft, and a single, bow mounted, 18-inch (46 cm) diameter torpedo tube for launching the short version of the Whitehead designed torpedo.[86]

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[85] Harris, *The Navy Times Book of Submarines*, 121-122.
[86] Cable, 'History of the Holland', 516.

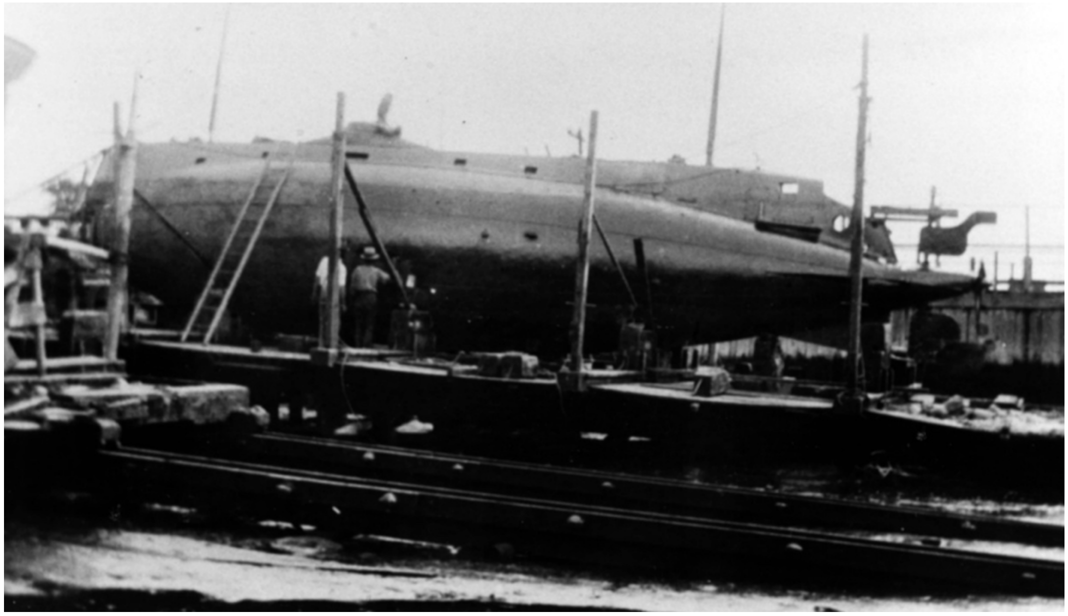

Figure 28. *Holland VI* circa 1898. Courtesy of: NHHC.

Holland VI was launched on 17 May 1897, three months before *Plunger*. The image above shows *Holland VI* in its original configuration; note that the rudders and diving planes are mounted forward of the propeller (Figure 28). On 13 October 1897 while undergoing alterations dockside, a sea valve was accidently left open allowing the boat to flood and sink; it was photographed on the dock being repaired following the incident.

After it was raised, attempts to repair the electric motor failed; removing and replacing the motor would have resulted in financial calamity for the company. The Electro-Dynamic Company, the manufacturer of the motor, was contacted for assistance and they dispatched a young engineer who was destined to become a submarine design pioneer. Frank Cable (1863-1945) repaired the electrical propulsion system and later became the captain of *Holland VI.*[87] The boat was ready for trials in late February 1898.

Following surface and dockside testing, sea trials were satisfactorily conducted, and while the Navy did not participate, results of these trials were reported to the Assistant Secretary of the Navy, Theodore Roosevelt (1858-1919). On 10 April 1898, Roosevelt made a recommendation to SECNAV that the Navy purchase the submarine. It would take just over two years for that recommendation to become reality.[88]

That two-year wait placed the Holland Torpedo Boat Company in dire financial straits. *Plunger* was a failure and building *Holland VI* required every bit of funding that Holland could amass. To make matters worse, during a formal Navy trial conducted in November of 1898, steering control of the boat was noted as erratic and blamed on an inexperienced crew. Captain Cable accepted the Navy's opinion publicly; however, he commented that "steering her was the most unsatisfactory task I had ever undertaken."[89] Cable prevailed on Holland to make several changes, both in design and procedures, that would significantly improve the operation of the boat.

Procedural changes included splitting the operation of the diving planes and rudder between two operators and increasing the fixed ballast to the point that the ballast tanks could be filled only to the level necessary to submerge. The design changes entailed moving the control surfaces aft of the propeller and modifying their operating

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[87] Ibid, 516.
[88] Morris, *John P. Holland, 1841-1914*, 87.
[89] Cable, 'History of the Holland', 519.

gear, removing the aft dynamite gun, and designing and constructing a compensating system to deal with the change in buoyancy resulting from the launch of a torpedo. The design changes were a time and resource consuming evolution that nearly bankrupted the Holland Torpedo Boat Company. The image below shows *Holland VI* awaiting launch following Cable's modifications and displaying a fresh coat of paint (Figure 29).

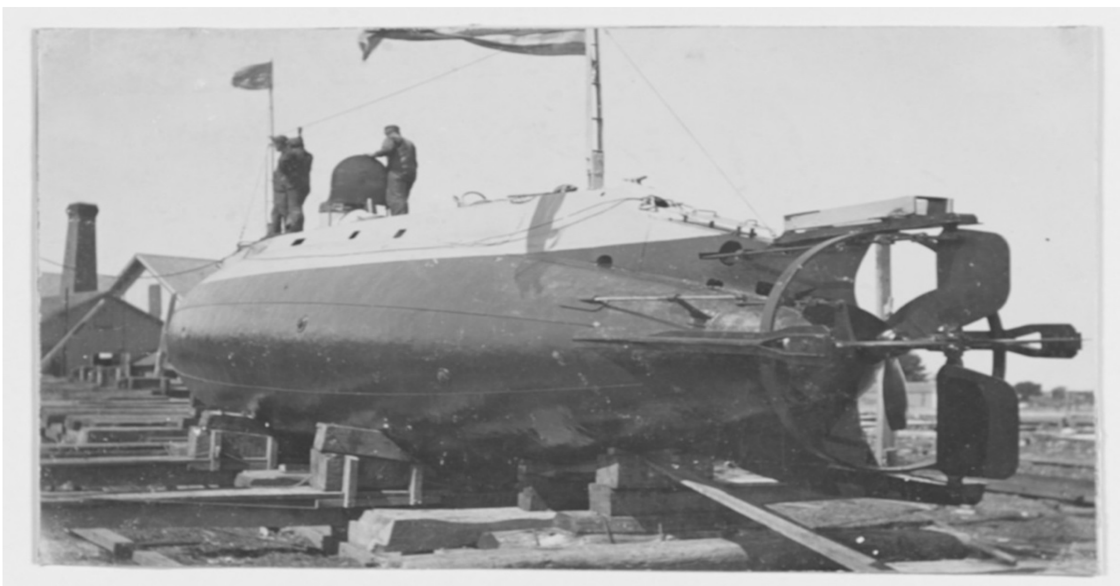

Figure 29. *Holland VI* circa 1899. Courtesy of: NHHC.

The Holland Torpedo Boat Company was saved from failure by a friendly takeover by Isaac Rice (1850-1915). A Philadelphia entrepreneur, Rice was involved in several businesses including the Electric Storage Battery Company, the manufacturer of *Holland VI's* batteries. To save Holland's company, Rice underwrote the above-mentioned modifications and formed a holding company, on 7 February 1899, of which the Holland Torpedo Boat Company and Rice's successful Electric Launch Company became wholly owned subsidiaries. By amalgamating companies specializing in batteries, electric propulsion, and submarine design and construction, Rice consolidated both logistics and opportunities for profit.

Rice brought political influence and manufacturing acumen to the submarine business, but most importantly he brought the concept of standardized production. This concept would facilitate the construction of classes of submarines, whereby improvements and design changes would be systematically incorporated in the follow-on class. Rice named the new company Electric Boat.[90] Holland's patents became the property of Electric Boat and Holland became Rice's employee, with a position guaranteed for five years.

Following successful trials, the Navy purchased *Holland VI*, its first functional submarine, on 11 April 1900 for the sum of $150,000. The boat, which had cost its builders $236,615, was renamed USS *Holland*.[91] Lt. H. H. Caldwell, who had been onboard to observe the boats trials, was selected as the boat's commanding officer. USS *Holland'*s crew would include an acting Gunner, and five enlisted volunteers. Frank Cable and his civilian crew trained the new Navy crew and in September certified them for independent operation of USS *Holland;* it was commissioned on 12 October 1900.[92]

John Holland's perseverance over nearly a quarter century of invention, both successful and otherwise, culminated in selling the navy his submarine; however,

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[90] Reyburn, *Electric Boat Corporation*, 7.
[91] Harris, *The Navy Times Book of Submarines*, 130.
[92] Cable,'History of the Holland', 525.

financing his endeavor ultimately cost him his most valuable possession, the patent rights for his submarines. He remained at Electric Boat for five years but was eventually pushed out, resigning in 1904. In the years following, Holland attempted to get back into the submarine business but was legally blocked from doing so by Electric Boat's political influence and control of patent rights. John Holland died on 12 August 1914, mere weeks prior to the dawn of modern submarine warfare in the First World War.[93]

[93] Morris, *John P. Holland, 1841-1914*, 129-134.

Conclusions

The sinking of USS *Housatonic* by the submarine *H.L. Hunley* during the Civil War, must have been written off as a "one off" event by the U. S. Navy, as it certainly did not inspire urgency to further develop submarines. Following the war, heavy national debt and an austere budget were among the many factors which contributed to the Navy's indifference to this new type of vessel. When money became available, coincident with John Holland's early projects, rebuilding the weak and outdated Navy took priority over research and development of submersibles.

Holland's initial designs were more novelties than vessels of direct military value. The Navy monitored Holland's developments and likely saw his efforts as entertaining, but not immediately applicable; mariners are notoriously slow to embrace new technology. Holland was lucky in his relationship with then Lt. William Kimball. Kimball would be known today as an "early adopter" and his advocacy and fortuitous introduction of Holland to Edmund Zalinski gave submarines a champion inside Navy circles and kept Holland involved in submarine development.

True breakthroughs came in Holland's implementation of hybrid propulsion and use of variable ballast tanks; these developments coupled with a reloadable torpedo tube and stowage capacity for multiple torpedoes gave the Navy an inexpensive tool for protecting home waters and meeting the nation's need to project maritime force internationally. The latter objective became more urgent following the acquisition of Guam, Puerto Rico, and the Philippines as concessions of the Spanish-American War, and the annexation of Hawaii during that conflict.

CHAPTER III

BUILDING THE SUBMARINE FORCE

The new century came with multiple contracts for the Holland Torpedo Boat Company, now known as Electric Boat. The speculative building of USS *Holland* paid off handsomely. The naval appropriations act of 7 June 1900 authorized contracts for five improved boats; through business and political machinations additional contracts for a sixth boat, funded by the 1899 appropriation, and a seventh boat, to take the place of the still undelivered *Plunger,* were awarded.

Navy leadership was not uniformly in accord with the congressional decision to purchase more submarine torpedo boats. Some within the Navy saw great promise; in the annual report of the Secretary of the Navy, Chief of the Bureau of Construction and Repair, Adm. Philip Hichborn, noted that the USS *Holland* had shown itself both functional and to possess "great offensive power." His report went further, addressing the fiscal and operational value of submarines for coastal and harbor defense, and suggesting the likely benefits of early adoption.[94] Adm. Charles O'Neil Chief of the Bureau of Ordnance (BUORD), kept his powder dry, noting that it was too early to judge the military utility of *Holland*. Naval Engineer-in-Chief Adm. George Melville opined that construction of submarines would likely result in a reduction in the funds available to construct capital ships; joining with BUORD, he argued that the testing had thus far been neither rigorous nor overly promising.[95]

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[94] Department of the Navy, Annual Reports of the Navy Department, (1900), 664.
[95] Cable, *The Birth and Development of the American Submarine*, 170-171.

John Holland is often credited with having said that senior naval officers did not like submarines as there was no deck on which they could strut; however, it was the Navy's most senior officer and head of the General Board of the Navy, Adm. George Dewey, who proved a powerful advocate. The General Board was formed in 1900 by order of the Secretary of the Navy, as a strategic planning organization chartered with ensuring the preparation of the fleet and naval defense of the coast.[96] Admiral Dewey testified that had the Spanish fleet in Manila Bay in 1898 included submarines he might have lost the battle.[97] Notwithstanding the objections of some in the Navy's leadership the United States would have a submarine force.

The Navy's naming standard for submarines changed over time. Initially the boats were named after a species of aquatic animal; in 1911 they were renamed with a letter designating their class and a number designating their place within that class. Thus, the inaugural *Adder* class became known as the A-boats, with the first boat of the class becoming USS *A-1*; the follow-on *Viper* class became B-boats, and so forth. For simplicity's sake herein, for vessels launched prior to November 1911, the vessel's original name shall be used; for vessels launched after November 1911 the naming schema adopted in 1911 will be employed.

The improved design provided to the Navy in 1899 by John Holland was envisioned as larger, deeper diving, version of USS *Holland* with some significant improvements (Figure 30).

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[96] Kuehn, *America's First General Staff*, 4.
[97] Cable, *The Birth and Development of the American Submarine*, 162.

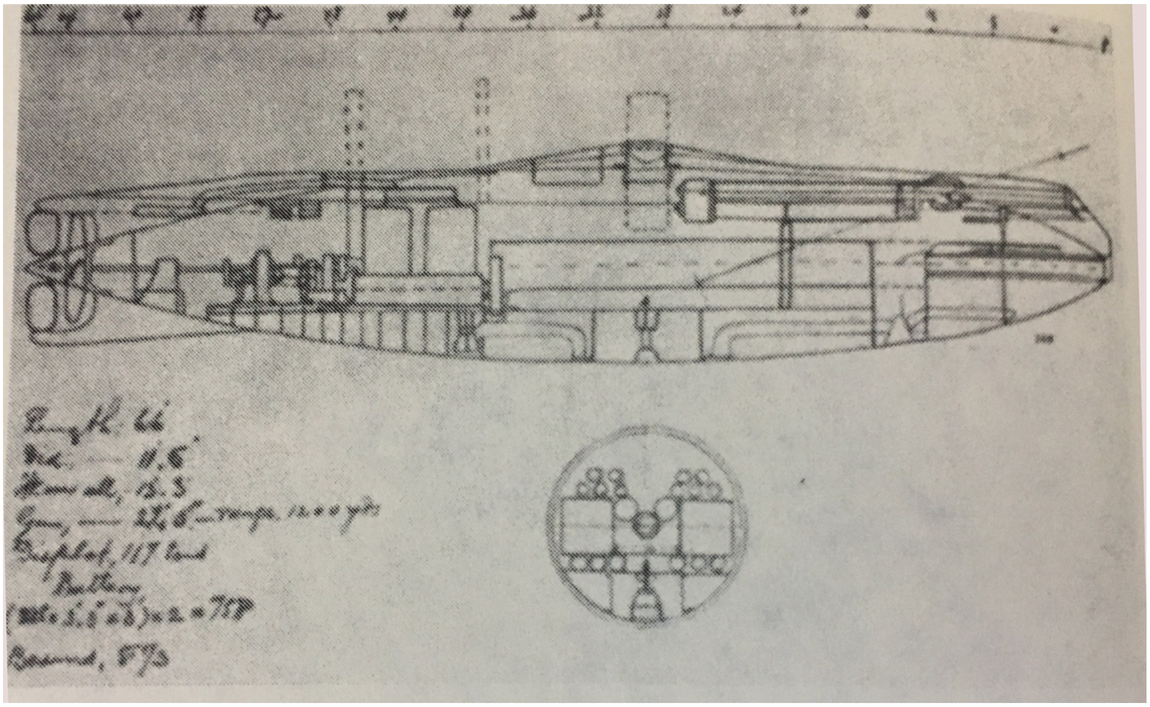

Figure 30. J. Holland's 1899 advanced *Holland* plan. From: Morris.

More powerful propulsion was necessary to reach the Navy's speed requirements with a larger vessel. A four-cylinder gasoline engine rated at 160 horsepower provided surface propulsion, and an electric motor rated at 70 horsepower powered the boat while submerged. The main ballast tank was relocated to improve trim, and a variable ballast (compensating tank) fitted amidships. The armament consisted of a single torpedo tube and a dynamite gun mounted in the bow, along with racks for storage of torpedoes and gun charges. Holland still owned the patent for the dynamite gun; retaining it in the design was likely a financially motivated decision. Holland had a long history of modifying his designs to incorporate incremental improvements, and predictably the 1899 plan was amended in many ways before construction began.

Fulton

Having gone from a speculative builder of a single submarine to a manufacturer of multiple iterations of a single design, practically overnight, and not wanting another *Plunger*-type failure, Electric Boat rapidly built a prototype *Fulton* as a proof of concept before completing the government contracted vessels (Figure 31).

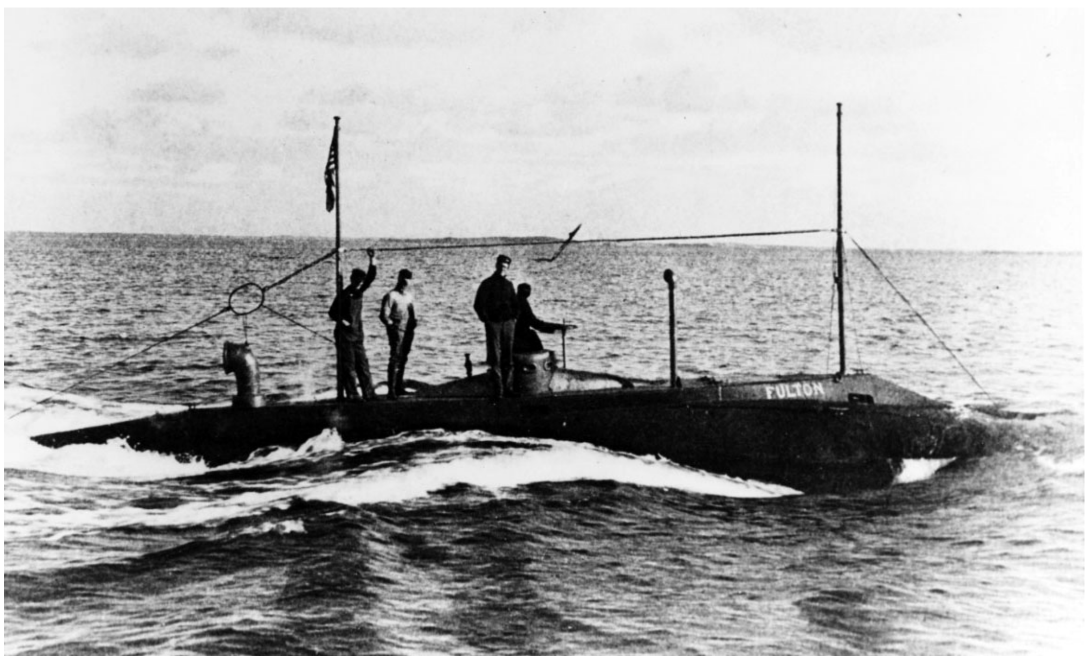

Figure 31. *Fulton* Courtesy of: NHHC.

While *Fulton* was a private vessel, it was built to Navy specifications under government oversight; Frank Cable lamented "… she was not our own child in certain essential features."[98] Cost control measures included the use of cast iron, instead of steel, both in

[98] Ibid, 174.

the fabrication of gears in the propulsion train and the Kingston valves which controlled the admission of seawater to the ballast tanks. After *Fulton*'s engineer was injured when a gear fractured, Cable refused to go to sea until the valves, failure of which could sink the boat, and the gears were replaced with steel components.

Fulton was constructed in the Crescent Shipyard and differed only slightly in dimensions from the 1899 plan; it was 63 feet (19.2 m) in length, had a beam of 11 feet (3.4 m) and displaced 120 tons submerged and had a maximum operating depth of 100 feet (30.5 m). Surface propulsion and electrical generation were provided by a 160-horsepower, four-cylinder, Otto gasoline engine; submerged propulsion was provided by a 70-horsepower electric motor. The engine drove the motor generator directly (this also acted as a generator to recharge the batteries) while the propulsion shaft, air compressor, and bilge pump were coupled via gearing. Holland's dynamite gun was not installed.[99]

Launched 12 June 1901,[100] *Fulton* lacked sufficient reserve buoyancy and could not make the required speed, necessitating major design modifications. Torpedo stowage was reduced from the planned five to three, some of the air flasks were removed, and the floodable volume of ballast tanks reduced. Speed was improved by replacing the propeller with an improved design.[101] While making the necessary changes by modifying the design in the prototype phase was costly, the lessons learned from *Fulton*

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[99] Ibid, 173-175. General description of *Fulton*
[100] Morris, *John P. Holland, 1841-1914*, 118.
[101] Cable, *The Birth and Development of the American Submarine*, 176-177.

allowed Electric Boat to bring the A-Class boats into compliance with government specifications.

Fulton was used extensively as a trials boat to test the limits of both crew and vessel. This was testing in every sense of the word. In November 1901 *Fulton* submerged at the dock with Cable, his civilian crew of three men, and two naval officers; the boat surfaced 15 hours later with the crew no worse for the experience. During this shake down period (like its predecessor *Holland VI*) *Fulton* sank at the pier due to the negligence of the yard crew, with the three men onboard narrowly escaping with their lives. Like *Holland VI,* it was raised and repaired. In April 1902, to demonstrate that submarines were capable of open sea navigation *Fulton* departed New York, with 14 crew on board. Encountering heavy weather while working its way south, *Fulton* and its escorts sought shelter in the lee of the Delaware breakwater. While laying at anchor here the battery exploded, injuring five men.[102]

During the Russo-Japanese War, Electric Boat, disregarding U.S. neutrality, secretly sold *Fulton* to Russia and smuggled it out of the country. The secretive sale of submarines by both Electric Boat and the Lake Torpedo Boat Company showed that the arms manufacturers were willing to ignore the law in order to sell submarines, a practice that would continue as the international appetite for this new type of warship increased.

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[102] Ibid, 180-191.

The *Plunger* (A) Class

The boats of this class, built to Electric Boat design EB7, were laid down in 1900 and 1901: *Adder*, *Moccasin*, *Porpoise*, *Shark*, and *Plunger* at the Crescent Shipyard in Elizabethport, NJ and *Grampus* and *Pike* at the Union Iron Works in San Francisco, CA.[103,104] Representing the Navy's first multi-vessel class of submarines, their hulls were, for all practical purposes, physical copies of *Fulton.* While standardized production was the goal, there were differences in the implementation of the design between building yards. The boats built in the Crescent Shipyard are recorded as slightly shorter (likely due to rounding up the fraction) at 63 feet 9-7/8 inches (19.453 m) versus 63 feet 10 inches (19.456 m), having a greater beam 11 feet 10-½ inches (3.62 m) versus 11 feet 9 inches (3.58 m), and displacing 122.55 tons, 2.55 tons more than the Union Iron Works boats.[105] It is possible that differences existed between boats built in the same yard. The Crescent Shipyard built *Adder* lacked sufficient buoyancy to operate in fresh water and required re-ballasting (Figure 32).[106] There is no record of the other boats of the class being re-ballasted; however, as *Adder* was the first of the class, it is also possible that the other boats were modified prior to launch because of the lesson learned from *Adder*.

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[103] The reuse of the name '*Plunger*' in the A-class unfortunately allows confusion with the never-commissioned *Plunger* from 1897, *Adder* (submarine #3) being launched first. As most naval documents refer to the *Plunger* class or A-Class, that standard will be followed herein.
[104] Department of the Navy, Annual Reports of the Navy Department, (1901), 12.
[105] Department of the Navy, Annual Reports of the Navy Department, (1902), 640.
[106] Cable, *The Birth and Development of the American Submarine*, 206.

Figure 32. USS *Adder* circa 1903. Courtesy of: NHHC.

As had been the practice since *Holland* the original design of the A-Class boats called for the control surfaces (rudder and diving planes) to be powered by pneumatic motors. The motors were abandoned as the Navy considered them a liability; their failure would leave vessels without the ability to operate the control surfaces. The replacements for the motors consisted of handwheels turning a shaft and linkage system; the relatively slow speed of the vessel and small size of control surfaces likely contributed to the success of this simple method.[107] The original plan also included a large seawater pump, powered by a separate engine; this was abandoned due to space considerations.[108] The final design of these boats might best be described as fluid; the

[107] Friedman, *U.S. Submarines Through 1945*, 30.
[108] Cable, *The Birth and Development of the American Submarine*, 176.

lessons learned from the *Fulton,* and the early class members as they entered post-launch testing, had an ongoing effect on the boats the government received.

As with Holland's previous designs no periscope was originally fitted on the A-Class boats; neither were they equipped with atmosphere control equipment, nor with adequate berthing, messing, and sanitation facilities (Figure 33). The conning tower on each vessel was only 2 feet (0.6 m) tall, affording little protection from winds and waves. These design factors clearly indicate a vessel best suited to submerged operations of short duration in support of harbor defense.

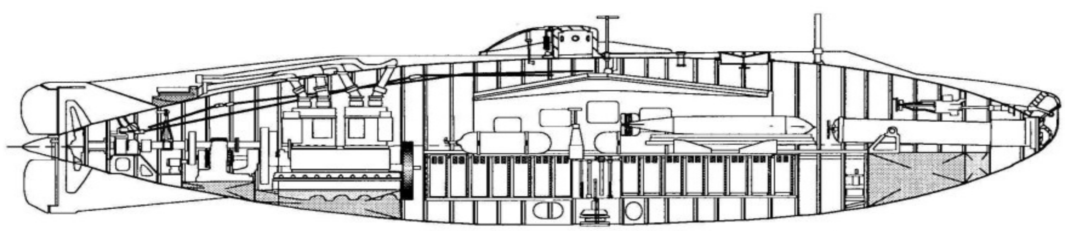

Figure 33. A-Class. J. Christley, From: Friedman.

In August of 1905 President Theodore Roosevelt embarked on a short cruise in USS *Plunger*, during which gained an understanding of the hardships and danger inherent in submarining. As a result of this experience he recommended that the men who volunteered for duty as submariners receive special pay. The Chief of the Bureau of Navigation noted, in SECNAV's 1906 Annual Report, that the number of volunteers far exceeded available submarine billets.[109] Submarine duty continues to be voluntary, and the Navy continues to incentivize those who serve on the boats.

In the years, following their acceptance by the Navy the A-Class boats were primarily used to train officers and men in the developing art of submarining. Through this exposure many potential improvements of the vessels' design were identified, resulting in significant alterations. Pivotal among these modifications were the installation of periscopes, increasing the size and height of the conning tower to afford greater heavy weather safety, improvements in the design of the battery cells, and the addition of variable ballast tanks to reduce the time necessary to submerge and better manage trim.[110] BUORD, in SECNAV's 1904 report, commented on the experimental nature of the boats, the hazards involved, and the courage of the crews; everyone involved in this new vessel type was clearly writing the book as they went along.[111]

Overseas sales of A-Class submarines contributed significantly to Electric Boat's financial stability while they struggled with delivery of the American boats and smaller follow-on orders. The first of five British built boats was launched on 2 October 1901.[112] Russia, following the purchase of *Fulton*, launched six boats in 1905 from the Nevskiy Shipbuilding and Machine Works in St. Petersburg;[113] five boats built in sections at the Fore River Shipyard in Quincy, MA were shipped to Japan where they were assembled in the Naval Shipyard at Yokosuka and launched in 1905, and finally, a 25th boat was

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[109] Department of the Navy, Annual Reports of the Navy Department, (1906), 421.
[110] Friedman, *U.S. Submarines Through 1945*, 34-35
[111] Department of the Navy, Annual Reports of the Navy Department, (1904), 655.
[112] Akermann, *Encyclopedia of British Submarines 1901-1955*, 117.
[113] Spassky, *Submarines of the Tsarist Navy*, 29.

built in the Netherlands in 1906.[114] Electric Boat's transfer of submarine technology provided a significant jumpstart for the submarine programs of the client nations, some of which become adversaries of America in the coming decades.

Adder, *Moccasin*, *Porpoise,* and *Shark* were the first American submarines deployed in distant stations. Transported as deck cargo to the Philippine Islands on USS *Caesar* in 1908 and 1909, they were assigned to the Asiatic Fleet where the four performed patrol duties. *Grampus* and *Pike* made the trip in 1915 aboard USS *Hector* (Figure 34).

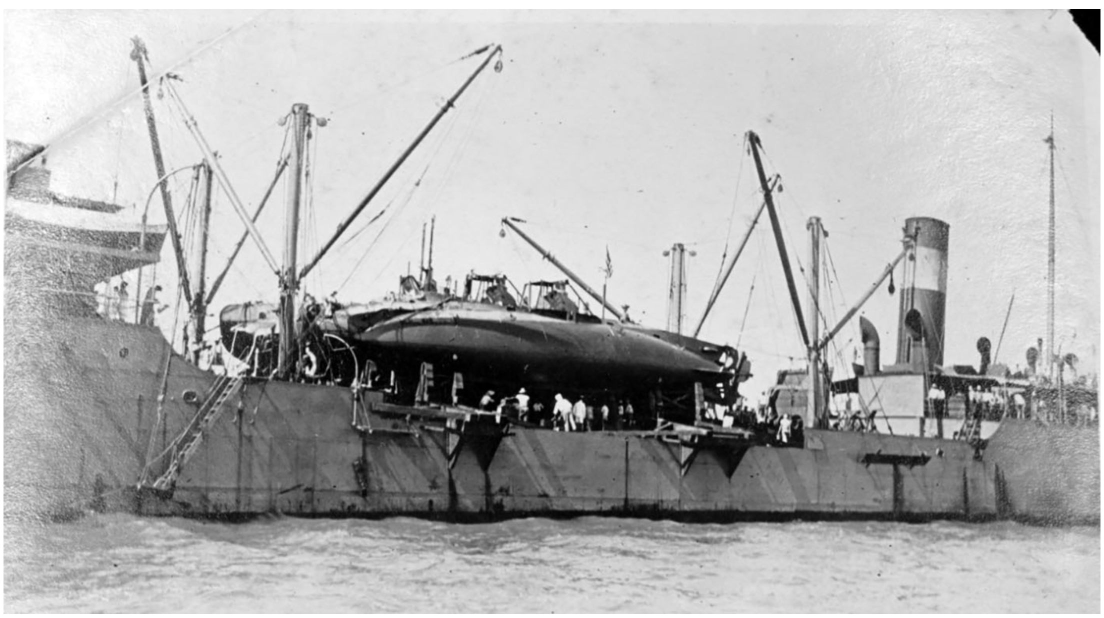

Figure 34. *Grampus* and *Pike* aboard *Hector.* Courtesy of: NHHC.

[114] Friedman, *U.S. Submarines Through 1945*, 36.

The A-Class boats in the Philippines served through the First World War, protecting American interests from a German fleet that never materialized. In the years following the war they were replaced by newer boats; their final duty, following their decommissioning was as targets, with all being sunk (Figure 35).

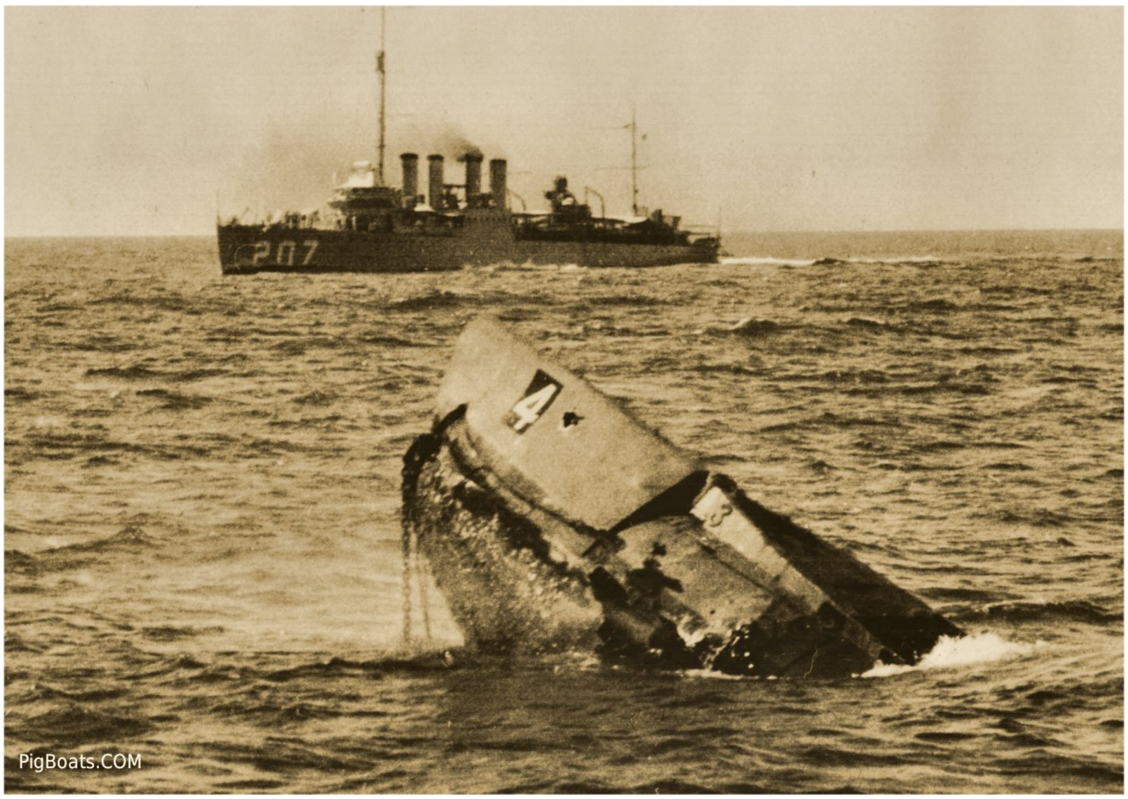

Figure 35. Ex USS *A-3* sinking as a result of gunfire. Courtesy of: PigBoats.com.

Construction of the A-Class submarines affected Electric Boat in many ways. Submarine construction and deliveries failed to meet contract schedules; as a result, no additional Navy contracts were let, and final payments were withheld. Rice and his team negotiated for foreign investment in the company, for foreign sales of submarines and for international licensing agreements to generate much needed cash flow. The British shipbuilder Vickers, Sons and Maxim invested heavily in the company. This relationship built the foundation of the Royal Navy Submarine Force, and likely kept Electric Boat financially viable during leaner times. Vickers maintained significant interest in the company until U.S. neutrality in the First World War forced them to sell off their holdings in 1914.[115]

One of the most lasting influences was the assignment of Lt. Lawrence Y. Spear (1870-1950) as a Naval Constructor for the A-Class boats being built in the Crescent Shipyard in 1901. Naval Constructors supervised the construction of vessels being built under Navy contracts and oversaw the performance of the contractor. Rice, impressed by Spear, hired him in 1902 and the young naval architect replaced John Holland in 1904. Spear's design philosophy and business acumen influenced submarine design and the operation of Electric Boat for the next four decades.

The genesis of American submarines leading to the delivery of the first H-Class boat in 1913 is presented in order, by class; it is important to understand that only about a decade separates the boats of the A-Class from those of the H-Class. Also noteworthy is the fact that several classes were built simultaneously, implementing improvements recommended by the ever-growing pool of experienced operators, developers, and builders. Oddly, in the pioneering of this new technology, the mariner's cautious attitude toward embracing change remains evident; development of the boats was, for the most part, an iterative process.

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[115] Ibid, 36.

Simon Lake Submarine Designs

Electric Boat enjoyed a monopoly in the United States submarine market but faced increased competition from the innovative submarines developed by the inventor Simon Lake. Lake's designs appeared more like a submersible surface warship when compared to those of Electric Boat: they had greater superstructure with higher freeboard and a larger conning tower, were propelled by twin screws, utilized forward, midships and stern diving planes to dive flat rather than at an angle, incorporated a diver lock in/out chamber, and the early designs even featured wheels for rolling over the sea bottom.

The Lake Torpedo Boat Company built *Protector* in 1902 and sought to have it reviewed by a Navy board the following year. A comparison test was eventually conducted between *Protector* and *Fulton*, during which the board selected *Fulton* as the preferred boat. Both submarines would be sold to Russia and their performance compared again, with the Russian naval board favoring *Protector*.

Lake competed successfully in the international market selling vessels and building licenses to Russia, Japan, Austria, and Germany, furthering the spread of submarine technology. Lake continued to be unable to secure a Navy contract, of which he was most desirous, and ordered the speculative construction of an improved submarine.[116] The Lake Torpedo Boat Company launched *Simon Lake X* at Newport News Shipbuilding and Drydock Company in Virginia on 27 October 1904.[117]

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[116] Lake and Corey, *Submarine; the Autobiography of Simon Lake*, 208.
[117] 'Launching of Submarine', *Washington Post*, 28 Oct. 1904.

Lake X was larger than the A-Class boats at 72 feet (22m) in length, 12 feet (3.6m) in beam, and had a greater displacement 153/187 tons surfaced/submerged. A twin-screw boat, it was propelled on the surface at up to 8 knots (15 kph) by two 120-horsepower gasoline engines and made 4 knots (7 kph) submerged using two 65-horsepower electric motors.[118] Lake scheduled a Navy trial, but *Lake X* was not ready on time and the Navy was unwilling to extend the deadline; frustrated, Lake sold it to Russia. Lake's biographer opines that Electric Boat saw the design as a serious threat to their business and developed their own twin screw submarine to counter it.[119]

Lake's father, J. C. Lake, ran the company while his son traveled the world selling submarines. In 1905, following the award of contracts for four submarines to Electric Boat, he appealed to President Roosevelt requesting that he intervene and cancel the contracts, but he did not.[120] Frustrated by the lack of contracts, the elder Lake convinced Congressman George L. Lilley of Connecticut to investigate alleged favoritism and corrupt practices on the part of Electric Boat and members of congress. A House Select Committee was formed to investigate the charges. Although the committee failed to substantiate the claims of corruption, the report notes that SECNAV was 'induced' to investigate the legality of splitting the 1908 submarine contract between competitors. Lawyers agreed that he could bifurcate the award, which he did.[121] *Seal* was laid down in Newport News Shipyard in 1909 becoming the lead boat of the G-Class.

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[118] Spassky et al., *Submarines of the Tsarist Navy*, 34.
[119] Poluhowich, *Argonaut*, 101.
[120] U.S. Congress, House of Representatives, Select Committee Under HR 288, (1908), 397.
[121] Ibid, 6.

The *Viper* (B) Class

In the years that followed delivery of USS *Holland* and the *Plunger* class submarines, new submarines would be developed as a result of demands from the Navy Board and input from the submariners tasked with operating the existing vessels. The boats of the B-Class were the last American submarines designed by John Holland, the mature outgrowth of his harbor defense boat (Figure 36). *Viper*, *Cuttlefish* and *Tarantula* were laid down in 1905 at the Fore River Shipbuilding Company in Quincy, MA.

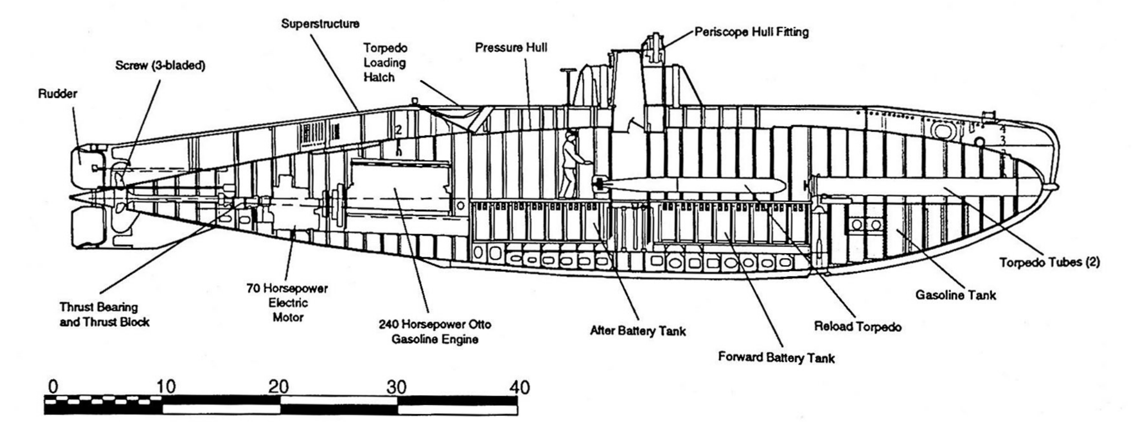

Figure 36. B-Class profile. J. Christley, From: Friedman.

The B-Class boats were a larger and improved version of the A-Class boats, equipped with more powerful propulsion systems, increased cruising radius, and more formidable armament. The new boats were designed with a range of 600 nautical miles (1111 km) and were operated with a ten-man crew. At 81 feet 5 inches (24.8 m) in length with a beam of 12 feet 6 inches (3.8 m) and displacing 173 tons submerged, they were significantly larger than their predecessors. Their 240-horsepower gasoline engine gave the boats a surface speed of 9 knots (17 kph) and the 70-horsepower electric motor propelled the boat at 8 knots (15 kph) while submerged. The propeller pitch could be changed (while stopped) to improve efficiency, with a finer pitch for the electric motor and a greater pitch for the lower RPM gasoline engine. An expanded conning tower was fitted for safer surface operations, a trend which would continue as submarine missions began taking them further to sea and away from the safety of the harbor.[122] The larger superstructure and conning tower improved the safety and comfort of surface watchkeeping. The temporary canvas bridge and awning seen in the photograph of *B-2* exemplify the adaptive nature of submariners (Figure 37).

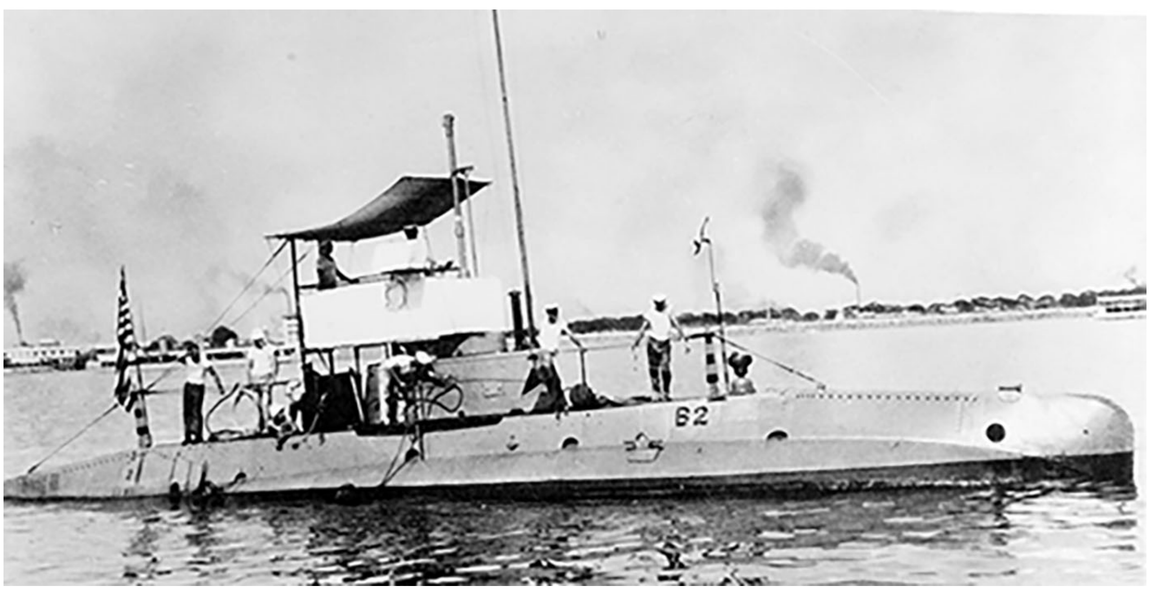

Figure 37. USS *B-2*. Courtesy of: NHHC.

[122] Silverstone, *The New Navy*, 57.

Perhaps the most important upgrade was the increase in armament from a single torpedo tube to two 18-inch (457mm) torpedo tubes (Figure 38); four torpedoes could be carried, two stowed in the tubes and two reload torpedoes in the torpedo room.

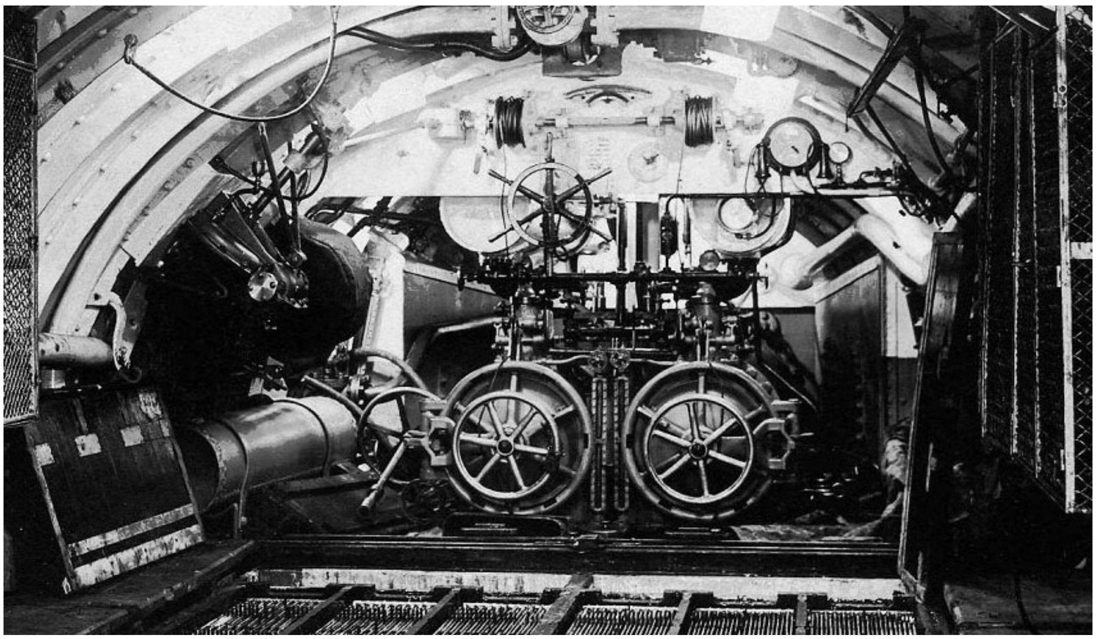

Figure 38. USS *Octopus* Torpedo Room. Courtesy of: Pigboats.com.

The muzzles of the tubes were covered with a rotating bow cap, which flooded both tubes when rotating it open, consequently wetting both torpedoes. If the torpedoes were not fired, they required cleaning and maintenance before re-use. The large spoked handwheel in the upper center of Figure 38 operated the bow cap, the large handwheels on each torpedo tube operated the breech door, and the two winches located above the bow cap operating gear were used for moving torpedoes in and out of the tubes. Figure

38 shows the deck plates are removed exposing the forward battery. The torpedo rooms of B and C-Class boats shared similar configurations.

The B-Class boats were commissioned in 1907, serving on the East Coast in the 1st and 2nd Submarine Flotillas. Each would go through a period of decommissioning before being shipped as deck cargo to the Philippines where, following re-commissioning, they joined the A-Class boats in the Asiatic Fleet. Following the First World War they would be decommissioned, stricken from the Navy list and sunk as gunnery targets.[123]

The austere living conditions aboard the early boats are vividly described by the Navy Surgeon General in the SECNAV's 1910 annual report. Therein the Surgeon General Adm. Charles Stokes provides his report of inspections of *Tarantula*, *Viper*, and *Plunger* conducted by Assistant Surgeon Micajah Boland, then serving as Medical Officer in the submarine tender USS *Castine*. Boland reported:

> "I have to report that an inspection of the submarines *Tarantula*, *Viper*, and *Plunger* on Sunday, October 24, 1909, shortly after they were moored alongside the *Castine*, showed their sanitary conditions to be far from satisfactory, notwithstanding the fact that they had only been at sea for about forty-five hours.
>
> One officer and a crew of 10 or 12 men had been living, that is sleeping, cooking, eating, and answering the calls of nature aboard each of these boats in addition to performing their duties navigating them.
>
> Being small, they pitch and roll considerably in a smooth sea, and about half the crew become seasick, largely due to the foul air in the boats; when the sea is moderately rough, practically the whole crew is seasick. Food has to be carried in crates and, when preparing for a cruise of several days, cramps very much the already overcrowded boat; even the cooked meats soon spoil, increasing the foulness of the air, and the use of the toilet, which is only screened off, adds to the unpleasant odor.

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[123] Naval Historical Center, *Dictionary of American Naval Fighting Ships*, 229.

> The small electric stoves with which the boats are supplied cannot furnish heat enough, hence they are cold and damp at certain seasons of the year and, in rough weather when water is shipped down the conning tower hatch, which must be kept open, they are wet and extremely uncomfortable.
>
> These conditions are a serious menace to the health of the members of the crew; there seems to be no remedy for them on prolonged cruises.
>
> I have the honor, therefore, to recommend that cruises be limited to not more than thirty-six hours, and that, when not underway, the crews of the submarines, except those absolutely necessary to be on the boats, live aboard the parent ship."[124]

One can only imagine the challenges faced by the crews of the submarines deployed to the Philippines. The boats had neither refrigeration nor air conditioning; the hot, humid equatorial climate quickly spoiled all but canned or cured foodstuffs and ripened the human and machinery odors, earning submarines the nickname Pig Boats.

As well as being devoid of most creature comforts submarining was also a risky and often fatal business. During the first ten years of the century a total of eight foreign submarines and their crews of 124 souls were lost in peacetime incidents.[125] American submariners fared much better; while injuries and incidents did occur in the early years, the first fatality, the result of a gasoline explosion in USS *Grampus*, did not occur until 19 September 1908. The newspaper report states that Chief Machinist Teddy May drowned after jumping overboard to escape the flames.[126] The next decade would not prove so lucky for U. S. Navy submariners.

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[124] Department of the Navy, Annual Reports of the Navy Department, (1910), 733.
[125] Bishop, *The Story of the Submarine*, 124.
[126] 'Burn to Death; Crew of submarine have thrilling experience at Mare Island', *Napa Daily Journal*, 20 Sept. 1908.

Along with being explosive gasoline fumes are intoxicating and the exhaust from gasoline engines is laden with poisonous carbon monoxide gas. Numerous non-fatal cases of carbon monoxide poisoning and gasoline vapor intoxication led submariners to keep mice in cages to warn them when the atmosphere became dangerous.

The *Octopus* (C) Class

In addition to the B-Class boats, a new type of submarine was laid down by Electric Boat in the Fore River Yard in August of 1905. This improved design (EB17) was the brainchild of naval architect L.Y. Spear and it would change the shape of submarines hulls for the next 45 years, abandoning Holland's cigar shaped form in favor of a circular midships tapering forward and flattening aft into an oval stern section facilitating twin screws. This configuration, patented by Spear, began Electric Boat's transition from an underwater vessel with limited surface capabilities toward a submarine optimized for submerged operation while possessing enhanced surfaced capability (Figure 39).[127]

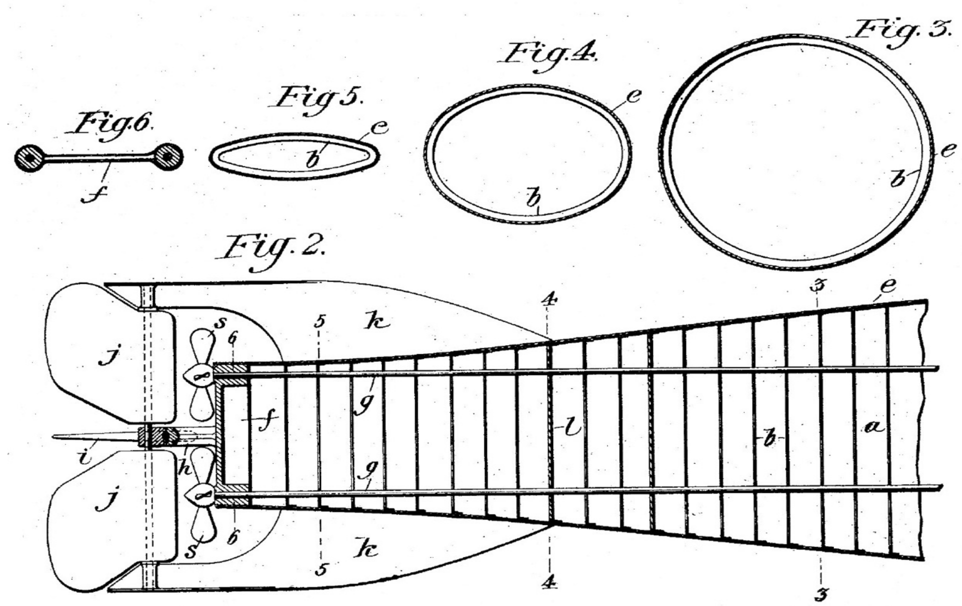

Figure 39. Twin-screw submarine design. From: U.S. Patent 878752.

[127] Spear, U.S. Patent 878752.

Octopus was, at its launching in 1906, the largest submarine yet built by Electric Boat (Figure 40). It measured 105 feet 4 inches (32 m) in length, 14 feet (4.2 m) in beam and displaced 238 tons surfaced and 275 tons submerged. *Octopus* was designed for a maximum safe depth of 200 feet (61 m) and had a range of 776 nautical miles (1437 km). Operated by a crew of 15 officers and men, it was armed with four torpedoes to be launched via two 18-inch (457mm) torpedo tubes arrayed in the same side-by-side configuration as the B-Class. Its twin screws were powered on the surface by two gasoline engines each rated at 250-horsepower giving it a design speed of 10.5 knots (19 kph); when submerged, two storage batteries of sixty cells each powered two electric motors each rated at 150-horsepower designed to achieve 9 knots (17 kph).[128]

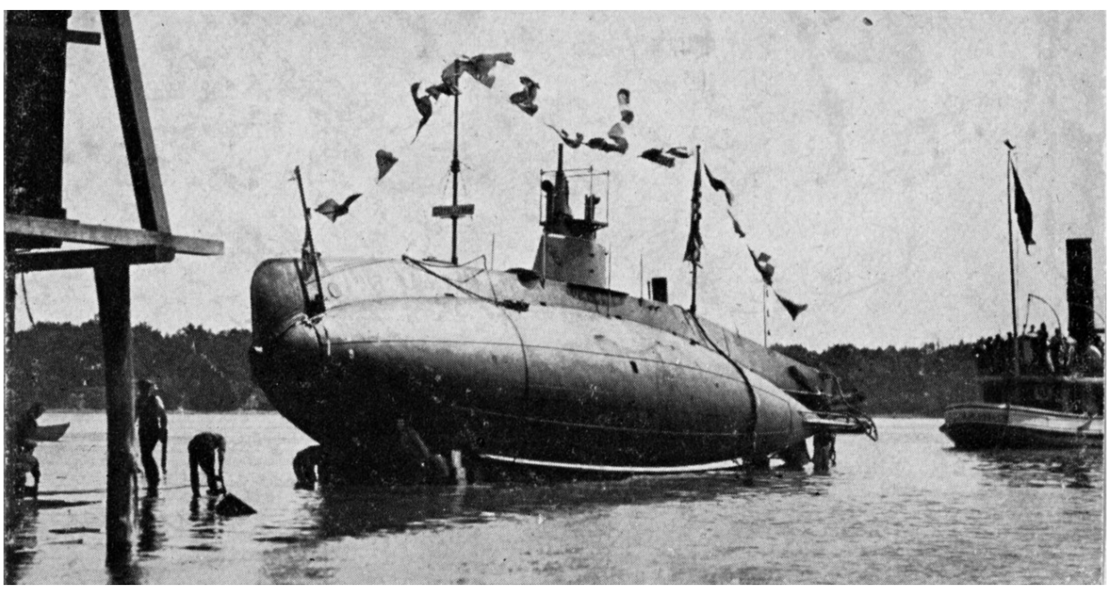

Figure 40. USS *Octopus* launching Courtesy of: NHHC.

[128] Silverstone, *The New Navy*, 57.

Octopus was fitted with an underwater communications system consisting of a pneumatically actuated bell and receiver. This system was developed originally as an aid to navigation, where lightships and shore stations were equipped with the signal bell and surface vessels were equipped with two receivers, one on either side of the ship, which facilitated rough resolution of the bearing to the signal bell. This technique was adapted to submarine use and allowed communications between similarly outfitted submarines and surface vessels. The installation in *Octopus* proved fortuitous: while on trials its tender signaled the boat to surface, narrowly averting a collision with the towing hawser being paid out by a tug crossing its track.[129]

The Naval Appropriations Act of 29 June 1906 authorized the expenditure of $1,000,000 by SECNAV for the purchase of surface or submarine torpedo boats and mandated comparative testing be conducted of the prototype vessels submitted for construction. The Act further required that the testing be completed not later than nine months from the date of the Act. The Navy convened a trials board in August of 1907 and developed a test plan; realizing that weather on the East Coast in the winter and spring was not conducive to submarine trials, an extension was requested of Congress, which was granted. The amended act gave the Navy an additional $3,000,000 and extended the deadline to 29 May 1907. Trials were scheduled for 30 April 1907.

Electric Boat Company submitted *Octopus,* Lake Torpedo Boat Company submitted *Lake XV* (later named *Defender*), and the Subsurface Torpedo Boat Company

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[129] Submarine Signal Company, *Submarine Signals*, 13.

submitted a quarter-size model for consideration. The trials board chose *Octopus* as the superior vessel and referred their recommendations to the Board of Construction.

The Board of Construction recommended the purchase of eight *Octopus* type submarines, four direct copies of *Octopus* and four larger, 134 foot (40.8 m) long, 340-ton versions. The actual purchase included five of the *Octopus* (C-Class boats), three of the larger *Narwhal* (D-Class) boats; and, as a result of political pressure, one submarine boat from Lake Torpedo Boat Company (provided that Lake could develop a boat that was equal to the best submarine owned by the Navy).[130] Lake's first Navy submarine, christened USS *Seal,* would not be launched until 1911, becoming the lead boat of the G-Class.

Octopus was commissioned in June of 1908 with *Stingray*, *Tarpon*, and *Bonita* being commissioned in November 1909 and *Snapper* joining the fleet in February 1910. The C-Class boats would serve as test craft for emerging submarine technologies and tactics and training platforms for the growing submarine force. [131]

The Panama Canal was not yet complete, but its security was already of national concern; in May of 1913 Submarine Division One, consisting of submarines *C-1* to *C-5* (renamed in 1911), was ordered to Guantanamo Bay, Cuba. The boats were towed to Cuba by USS *Mars* and USS *Castine,* where the submarines conducted training operations until December. On 7 December 1913, escorted by four surface ships, the boats got underway for Cristobal, Panama. Arriving on 12 December, a journey of 700

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[130] Department of the Navy, Annual Reports of the Navy Department, (1907), 12-15.
[131] Naval Historical Division, *Dictionary of American Naval Fighting Ships*, 230.

nautical miles (1296 km), they set the record for the longest transit by submarines under their own power.

The five boats guarded the eastern approaches of the Canal Zone. Supported by their tender, USS *Severn* (ex *Chesapeake*), later relieved by USS *Charleston,* the boats were kept moored inside the entrance to the unfinished French Canal. In port married officers were quartered ashore and the single officers and men lived aboard the tender. Life was good in the pre-war years with plenty of recreation time for the crews.[132]

The submarines were, understandably, not a maintenance priority for the Canal Authority, and they competed for the limited space available in the drydock at Cristobal. Lacking a proper dockyard, Submarine Division One officers found that major maintenance required innovation. In March of 1914, the boats were drydocked in the gigantic upper east chamber of the Gatun locks; the submarine crews, assisted by the Canal Mechanical Division, overhauled the boats; maintenance included pressure testing tanks and hulls, painting the boats hulls, and major work on C-4's stern planes.[133]

A joint submarine and aviation base would be constructed on the Caribbean side of the canal at Coco Solo during the First World War. The C-Class boats would serve out the war years in the Canal Zone, then taken out of service in August 1919 and sold for scrap in April 1920 at Coco Solo.

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[132] Barnes, *United States Submarines*, 62-67.
[133] 'Dry Docking Submarines', *Canal Record*.

The *Narwhal* (D) Class

Narwhal, *Grayling* and *Salmon* were laid down in the Fore River Yard on 16 April 1908; *Narwhal* and *Grayling* were commissioned on 23 November 1909, with *Salmon* commissioning on 8 September 1910. The boats were 134.8 feet (41 m) long, 14 feet (4.3 m) in beam, and displaced 288/337 tons surfaced/submerged. Two 300-horsepower gasoline engines provided power for surface propulsion and electrical generation. Power for submerged propulsion and other electrical loads was stored in two 60-cell storage batteries. Two 130-horsepower motor/generators provided submerged propulsion and recharged the batteries when the boat was surfaced. The propulsion systems were designed to give the boats a surfaced speed of 13 knots (24 kph) and a submerged speed of 9.5 knots (18 kph). Operated by a crew of 15, they were the first U.S. Navy submarine to be fitted with four torpedo tubes and subdivided internally with watertight bulkheads.[134]

Compartmentalization was introduced to improve collision and flooding survivability. Submarines on the surface are very hard to see from surface ships and submarines of the day were, for all practical purposes, blind during the period of transition from submerged to surface operations. The United States Navy had yet to suffer the loss of a submarine and its crew, but this was not so for England, Russia, and France.

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[134] Silverstone, *The New Navy*, 57.

Narwhal and *Grayling* were subdivided into a torpedo room, forward battery, control room, after battery, and an engine room (Figure 41); in *Salmon* the bulkheads separating the control room from the forward and after battery compartments were not installed, to facilitate installation of second periscope with an integral torpedo director.

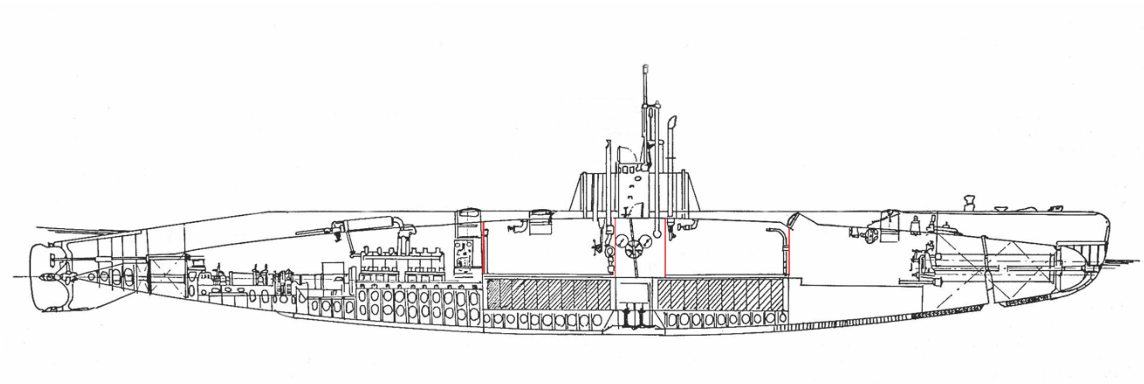

Figure 41. *Narwhal* watertight bulkheads in red. Author after Christley, From: Friedman.

Salmon benefited from its late delivery by receiving an improved electric propulsion system which included a newer motor generator, designed to take a much greater load, and higher capacity rheostats, the combination of which increased its maximum submerged speed from 11.3 to 12.4 knots (21 to 23 kph). When operated at top speed its batteries were rapidly depleted resulting in a significant reduction in submerged duration.[135]

Prior to its delivery to the Navy, *Salmon* made submarine history by transiting primarily under its own power on a round trip voyage from Quincy, MA to Hamilton,

[135] Friedman, *U.S. Submarines Through 1945*, 49.

Bermuda. Mission duration and the greater number of persons embarked necessitated some modifications be made for the voyage; additional fresh water was carried in the torpedo tubes, all but six of the fourteen bunks were removed, a large ice chest was installed in the torpedo room, and over 300 gallons (1136 l) of lube oil in five-gallon cans were stowed in the bilges. *Salmon* got underway on 5 July 1910 from Quincy with a mixed military and civilian crew of 21 onboard for Provincetown MA, where it met its escort tug *Underwriter*, assigned at the insistence of Electric Boat's insurance company. The next morning the two vessels took their departure at 0900 with *Salmon* in the lead.

Neither weather nor the engines were in its favor on the trip south. In the early hours of 7 July, the port main engine (No. 2 cylinder) head gasket failed, and the engine was shut down. The gasket was replaced but more issues, including water in the cylinders, a leaky gasket on No.5 cylinder, and a seasick crew, resulted in the maintenance being deferred until conditions improved.

The weather worsened and on the afternoon of 8 July, heavy seas carried away the canvas bridge screens, and the boat shipped water down the conning tower hatch. The bridge was abandoned, and the conning tower hatch secured until the seas abated. Weather improved the following day, and the engineers were able to repair the port engine. *Salmon* and *Underwriter* arrived in Hamilton the morning of 10 July, *Salmon* having traveled 760 nautical miles (1408 km) since departing Quincy.

On 13 July, after maintenance on both of the submarine's engines, which included removing, cleaning and renewing the gaskets on six of the twelve cylinder heads, *Salmon* and *Underwriter* got underway. The return trip was less eventful with both main engines working due to much “creative engineering” and, while some rough seas were encountered, watch was maintained on the bridge. *Salmon* intermittently took a tow line from *Underwriter* on the evening of 15 July and again the morning of 16 July in dense fog, to keep the vessels close while reducing the risk of collision. When the fog lifted, *Salmon* attempted to restart its main engines and discovered that all gasoline had been blown from the fuel tanks overboard. The boat proceeded to Provincetown on its electric motors, refueled, and the next morning departed for Quincy, arriving at 1100.[136]

The *Narwhal* Class boats were assigned to the Atlantic Torpedo Fleet operating out of Newport, RI. As with the rest of the infant Submarine Force the pre-war years were spent learning how to operate and fight this new platform. When America joined in the First World War in April 1917, the D-Class boats, renamed in 1911, were obsolete and spent the war years as training vessels. The class was sold for scrap in 1922 (Figure 42).

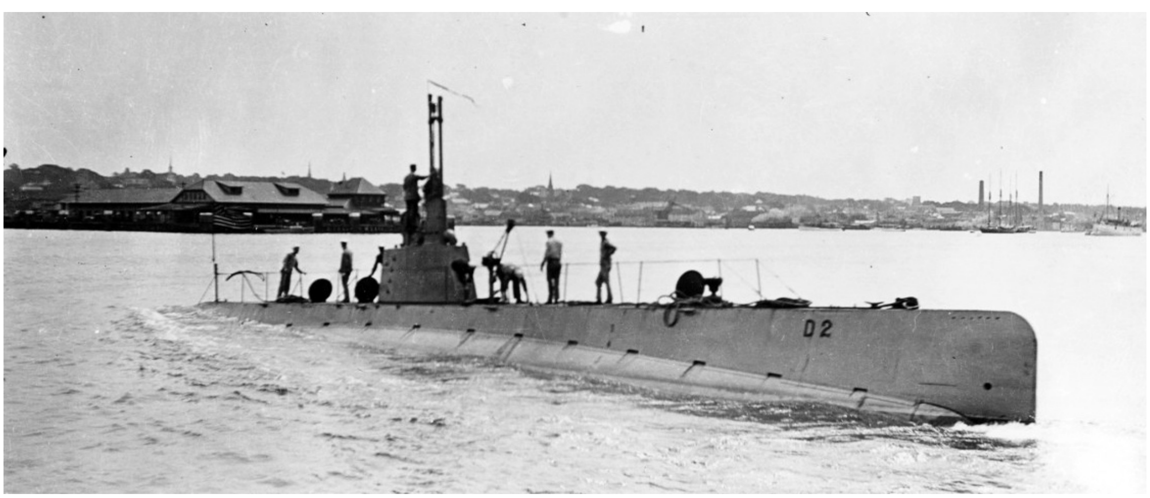

Figure 42. USS *D-2* ca. 1918. Courtesy of: NHHC.

[136] Weaver, ‘The Cruise of the Submarine Torpedo Boat Salmon’, 1089-1098.

The *Skipjack* (E) Class

USS *Skipjack* and its sistership *Sturgeon* were laid down in the Fore River Shipyard on 22 December 1909 and commissioned on 14 February 1912. While nearly identical in external dimension to the *Narwhal* Class these boats had a compliment of 20 men and incorporated four significant improvements: diesel engines, bow mounted diving planes, radio communications equipment, and lengthened torpedo tubes.

The new propulsion system incorporated twin four-cylinder diesel engines replacing the more dangerous, explosion-prone gasoline engines used in previous classes. The diesels were built by the yard to a British (Vickers) design, and each generated approximately 275 horsepower. The diesels were non-reversing and connected to the propeller shaft through a friction clutch; to back the submarine it was necessary to de-clutch the engine and engage the reversable electric motor. As well as improving safety, the diesels were far more economical and efficient than the gas engines, nearly doubling the surface cruising range to a theoretical 2090 nautical miles (3870km). Underwater propulsion was also upgraded, with more powerful, 150 horsepower electric motors installed giving the boat a surfaced/submerged speed of 13.5/11.5 knots (25/21 kph).[137]

Bow mounted diving planes (bow planes) were added to improve depth control. These planes were folded up flat against the hull when running on the surface and were

[137] Magdeburger,'Diesel Engines in Submarines', 580. and Friedman, *U.S. Submarines Through 1945*, App. D. Horsepower ratings differ between sources; these problematic engines were replaced as improved engines became available.

rigged out when preparing to dive. The stern planes' primary function remained controlling the up or down angle of the boat or the "bubble" in the parlance of submariners, while the bow planes were effective at fine depth control. Several foreign navies were already using bow planes on their submarines, and America's slow acceptance can likely be attributed to the design traditions of Electric Boat, the single supplier. In the image below the bow planes of *E-1* are visible in their rigged-out position and the boat appears to be surfacing as it is down by the stern (Figure 43).

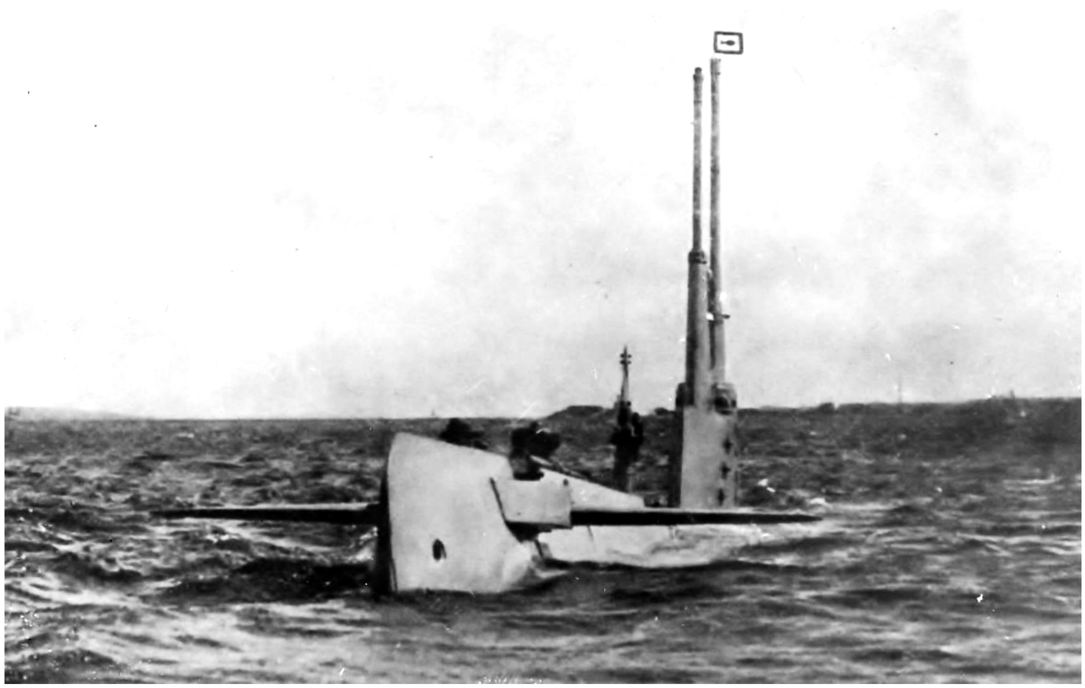

Figure 43. USS *E-1*. Courtesy of: Submarine Force Museum.

The four bow-mounted torpedo tubes were lengthened to facilitate the use of longer, more powerful models of the Bliss Levitt torpedo. Previous classes were configured to launch the Whitehead MK III torpedo manufactured by E.W. Bliss

Company. The MK III was 11.6 feet (3.55m) long and propelled by a compressed air engine giving it a range of 800 yards (732m) at 26.5 knots (49 kph); the warhead contained 118 lbs. (54kg) of wet guncotton.[138] Guncotton was a nitro-cellulose explosive which remained fairly stable in its wet form; it was replaced by Tri-Nitro Toluene (TNT) and later Torpex (TPX) in subsequent torpedo warheads.[139] The longer torpedo tubes of the E-Class boats would still accommodate the early torpedoes like the MK III while enabling the employment of the more advanced weapons in development. The Bliss-Leavitt Mark 7 torpedo, introduced in 1911, was the last and most advanced 18-inch (45.7cm) submarine torpedo purchased by the Navy; it could deliver its 326-pound (148kg) TNT/TPX warhead to a target at 35 knots (65 kph), with a maximum range of between 3500 and 6000 yards (2743-5486 m) depending on the model.

USS *E-1* was placed in commission under the command of Lt. Chester W. Nimitz (1885-1966). Nimitz, a native Texan, would rise to the rank of Fleet Admiral during the Second World War and be a lifelong proponent of the submarine service. *E-1* initially served on the east coast of the United States conducting training operations, and maintenance.

Following the outbreak of the First World War, neutrality patrols were added to USS *E-1*'s earlier primary mission of serving as a training platform at the submarine school in New London. After America entered the war in 1917, it along with six newer L-Class boats, were taken under tow by the submarine tenders *Bushnell, Fulton,* and a

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[138] Jolie, *U.S. Navy Torpedo Development*, 69.
[139] Alger,'High Explosives in Naval Warfare', 246-250.

submarine chaser, to sail from New London to Portugal's mid-Atlantic Azores Islands. *E-1* separated from the tow during a gale and attempted to make the Azores on its own power, but engine trouble caused it to abort to Bermuda for repairs. In January 1918 it arrived in the Azores where it conducted patrols to ensure German vessels could not operate from the islands. In September 1918 problems with the boat's batteries necessitated its return to the U.S. for maintenance; it was undergoing overhaul when the war ended. Obsolete, it was placed in reserve status, and along with *E-2* sold for scrap in 1922.

E-2 served primarily along the east coast, but also went as far afield as Guantanamo Bay, Cuba and the Gulf of Mexico. During an overhaul in the New York Navy Yard, the boat suffered a fatal battery explosion in January 1916, that killed four and injured seven men. It was decommissioned in March of that year and used as a test platform for the Edison storage battery. Recommissioned in the spring of 1918 it spent the war years initially as a training and development platform and later making war patrols out of Norfolk, VA. Following the war, *E-2* returned to training duties until its decommissioning and eventual scrapping.[140]

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[140] NHHC, *Dictionary of American Naval Fighting Ships*, @ https://www.history.navy.mil/research/histories/ship-histories/danfs.html

The *Carp* (F) Class

The ill-fated F Class boats were laid down in August 1909 in shipyards on the West Coast that were under contract to Electric Boat. *Carp* (*F-1*) and *Barracuda (F-2)* were built at the Union Iron Works in San Francisco, while *Pickerel* (*F-3*) and *Skate* (*F-4*) were constructed in the Moran Brothers Shipyard in Seattle. Building submarines on the West Coast was more costly,[141] and utilizing Moran Brothers, a yard that had yet to build its first submarine, imparted a level of risk; however, political pressure by regional members of congress, rising concern over Japanese imperialism, and the desire to protect the as-yet unfinished Panama Canal swayed the decision.[142]

The F-Class boats externally resembled a larger E-Class submarine; they were 142.6 feet (43.5m) in length, 15.4 feet (4.7m) in beam and displaced 330/400 tons surfaced/submerged. Like the E-Class, their diesel engines were of the Vickers design but were a more powerful six-cylinder version that developed 390 horsepower and provided a surface speed of 13.5 knots (25 kph) for a surface cruising range of 2500 nautical miles (4630km) at 11 knots. Electric motors rated at 160 horsepower provided a submerged speed of 11.5 knots (20 kph) for a submerged cruising range of 100 nautical miles (185 km). Manned by a complement of 22 officers and men, the boats of the F-Class were armed with four bow-mounted torpedo tubes firing through a rotating bow cap.[143] The image below is a photograph of the 1910 Naval Constructors drawing held in

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[141] Department of the Navy, Annual Reports of the Navy Department, (1909), 72.
[142] Lightfoot, *Beneath the Surface*, 15-17.
[143] Friedman, U.S. Submarines Through 1945, App D. Engine/motor horsepower from Figure 45.

record group 19 of the National Archives (Figure 44). It should be noted that the drawing does not depict bow planes. The F-Class were actually laid down before the E-Class and as both the E-Class and F-Class boats were built with bow planes, their absence in this plan, as well as the other views within the set, could indicate that bow planes were a late addition to the design.

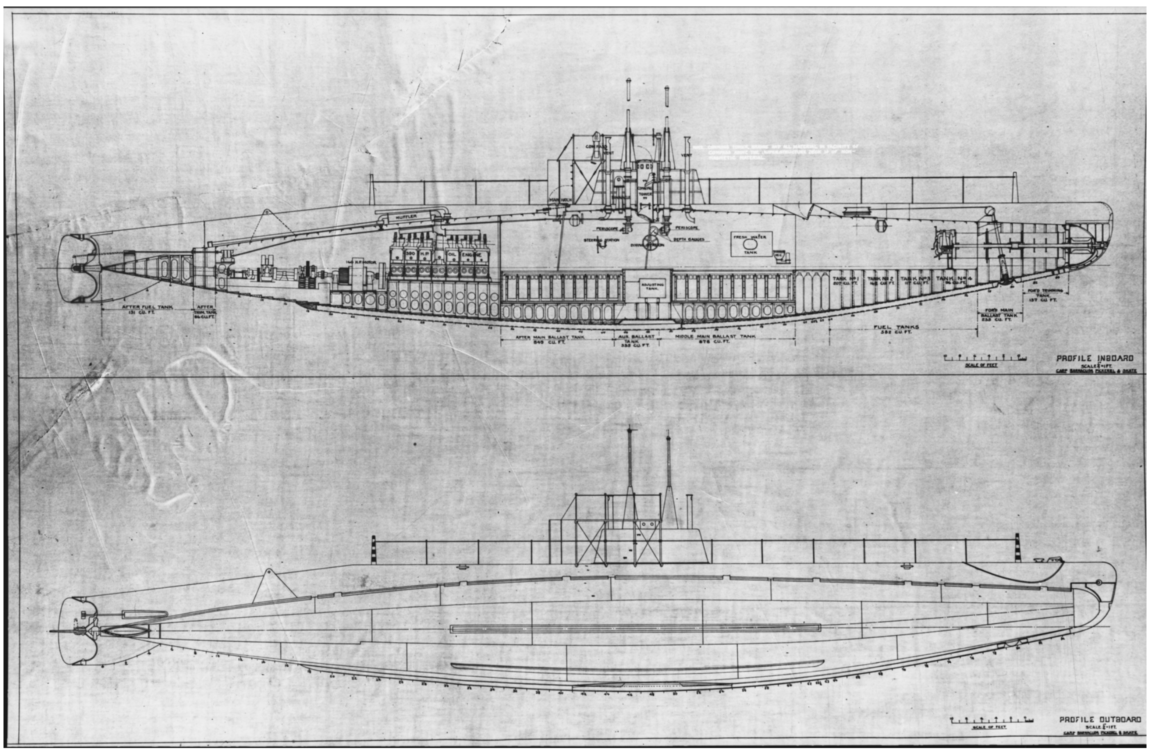

Figure 44. F-Class profile. Courtesy of: NHHC.

The Union Iron Works launched *Carp* in June 1911; it would be renamed F-1 in November, *F-2* was launched in mid-March 1912. The Moran yard launched *F-3* and *F-4* in January 1912. Following trials and commissioning, the four F-Class boats joined the

First Submarine Group, Pacific Torpedo Flotilla. They operated along the west coast, with their tender USS *Alert*, from the port of San Pedro, California.

Alert, an aged screw steamer laid down in 1873, had an amazing history spanning six decades. The final years were spent shepherding the navy's newest and most complex weapons system displaying a keen juxtaposition of new and old. As no submarine base yet existed in San Pedro, the boats anchored in the outer harbor during the week, going pier side on weekends to allow the crew shore leave.[144]

During the summer of 1914 the four boats were towed from San Francisco to Honolulu harbor on the island of Oahu, Hawaiian Territory by the cruisers USS *South Dakota* and USS *West Virginia*. The cruisers made two trips, first towing *F-1* and *F-3*. After coaling and some well-deserved shore leave for the crew, the cruisers sailed for the mainland, to return to Hawaii with F-2 and F-4 in late August.

The boats operated in island waters, showing the flag and protecting American neutrality. While their arrival initially made headlines in Hawaiian newspapers, it appears that the novelty of reporting their frequent sojourns to sea for training and diving practice quickly faded. This relative obscurity continued until 25 March 1915, when *F-4* tragically sank off the coast of Oahu with the loss of all hands.

On that morning *F-1*, *F-3*, and *F-4* had put to sea for diving practice. When F-4 failed to return, a search was organized involving several vessels. Air bubbles and an oil

[144] 'Deny Submarines will Abandon San Pedro', *San Pedro Pilot and Harbor Herald*, 26 Jul. 1913.

slick were sighted, and divers descended to investigate, but after reaching 215 feet they could not locate the wreck.

The stricken boat was located four days later, on 29 March, by dragging a length of anchor chain suspended on long wires connected between two towing vessels. It was repeatedly lifted from the seafloor and dragged into shallower water; efforts continued until the next day when the wires parted. Lacking sufficient salvage equipment and with no hope for survivors, the recovery was suspended until the necessary equipment could be constructed and divers brought in from the mainland.

F-4 was eventually salvaged and placed in a floating drydock on 30 August, where the crew's bodies were removed and an investigation into the cause of its sinking conducted. Evidence pointed to battery acid induced corrosion in the battery well, likely resulting from a plugged drain in the forward battery well. Concerned that the same problem could exist in other boats of the class, the decision was made to replace them with a flotilla of the newer K-Class boats.[145]

The remaining F-Class boats were towed back to Mare Island Naval Shipyard for overhaul. Following their repair, they were placed back in commission and conducted patrol and training operations on the west coast. *F-1* had always been what sailors call a hard luck boat, and the worst happened on 17 December 1917; operating off the California coast in dense fog, *F-3* struck *F-1* at high-speed, holing the latter boat's hull. It sank with the loss of 19 men. The last two F-Class boats were scrapped in 1922.

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[145] Searle and Curtis, *Undersea Valor*, 9-50.

The G Class

Unlike the standard designs used in each of the previous classes documented herein, the G-Class was a hodgepodge of four different submarines built in an attempt to diversify submarine suppliers and break the monopoly held by Electric Boat. *G-1*, *G-2* and *G-3* were designed by Simon Lake and built by the Lake Torpedo Boat Company. *G-4* was designed by the Italian naval architect Cesare Laurenti (1865-1921) and built by the American Laurenti Company in Cramp and Sons Shipyard in Philadelphia. While these boats were historically significant as the U. S. Navy's first non-Holland/Electric Boat submarines, they had no direct bearing on the genesis of the H-Class submarine.

G-1 was laid down in February 1909 as *Seal* at Newport News Shipbuilding and Drydock Company (Figure 45). It was 161 feet (49 m) in length, had a beam of 13 feet (4 m), displaced 400/516 tons surfaced/submerged, and was manned by one officer and 23 enlisted men.

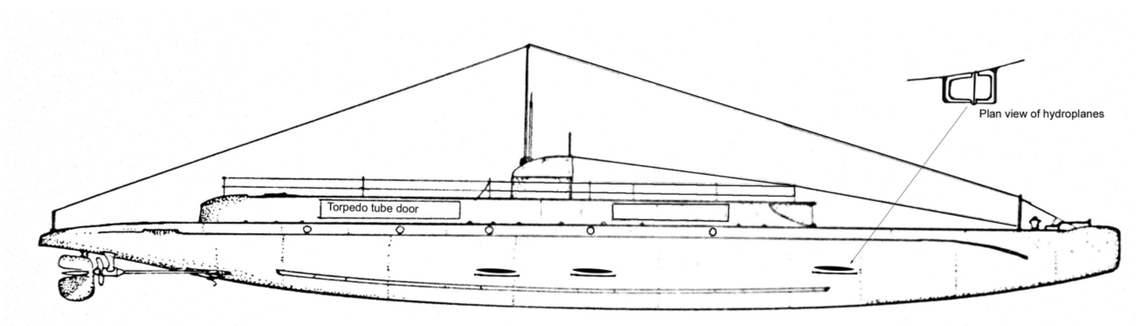

Figure 45. USS *G-1*. Author after Christley, From: Friedman.

Surface propulsion was provided by four 300-horsepower gasoline engines connected by clutches; this configuration provided a surface speed of 14.7 knots (27 kph) and a cruising range of 3500 nautical miles (6428km). Submerged, two 375-horsepower electric motors produced a maximum submerged speed of 10.7 knots (20 kph) with a submerged endurance of 24 nautical miles (44 km) at 8 knots (15 kph).[146]

G-1's design differed significantly from the Holland/Spear designs: the hull exhibited more pronounced rocker (upturned bow and stern); retractable wheels were fitted for crawling along the sea floor; a diver's airlock supported diving operations and emergency escape; three sets of diving planes mounted along the hull facilitated level instead of angular depth changes; two pairs of trainable 18-inch (457 mm) torpedo tubes, mounted in the superstructure, augmented two internal bow tubes which were fitted with independent outer doors. The periscopes, when lowered, retracted fully in the sail.

G-1 was truly unique; *G-2,* its less expensive sister ship, built at Lake Torpedo Boat Company's yard in Bridgeport, CT, lacked wheels, the diver's airlock, and superstructure mounted torpedo tubes; instead, its design incorporated four bow-mounted and two stern-mounted torpedo tubes. *G-3*, launched in December 1913, closely resembled *G-2* with the exception of the propulsion plant, in which the four gasoline engines were replaced with two 600-horsepower Sulzer diesel engines.

The Lake Torpedo Boat Company, unlike Electric Boat, was required to complete its boats and achieve government acceptance prior to being paid the contracted

[146] Friedman, *U.S. Submarines Through 1945*, App. D.

price.[147] None of the boats were completed on time and consequently Lake's one-way cash flow resulted in the closure of the Bridgeport plant before *G-2* and *G-3*'s final acceptance by the Navy. The Navy had them finished in the Brooklyn Navy Yard, under Lake's supervision. Commissioned in March of 1915, *G-3* was found to have significant stability problems requiring that sponsons be fitted to each side of the hull to remedy the problem (Figure 46).

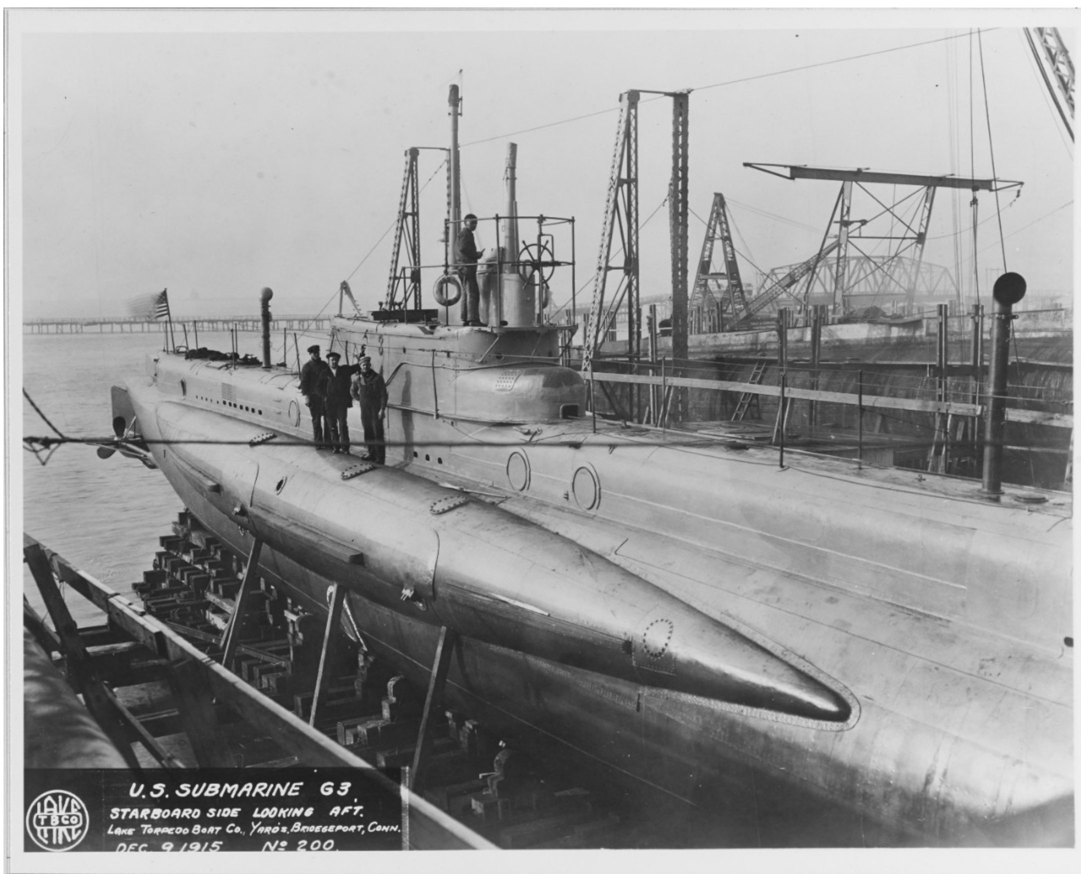

Figure 46. *G-3* on the ways showing sponson. Courtesy of: NHHC.

[147] 'Lake Boat Co. Turns Out Greatest Submarine Ever Built For "Uncle Sam"', *Bridgeport Evening Farmer*, 17 Oct. 1912.

The Lake designed boats were slow to dive, problematic to maintain, and required significant modifications and repairs over their short service lives. Following the First World War, the boats were declared surplus and decommissioned. G-1 was used as a depth charge target in 1921. *G-2*, slated for a similar fate, sank at an offshore mooring during an inspection team visit in July 1919, tragically drowning three men. *G-3* met its fate in a wrecker's yard after being sold for scrap in 1922.

G-4 was laid down in Cramp Brothers Yard in July 1910, launched in August 1912, and not commissioned until January 1914 (Figure 47). Built to a Laurenti design it was 157.5 feet in length, 17.5 feet in beam and displaced 360/457 tons surfaced/submerged.

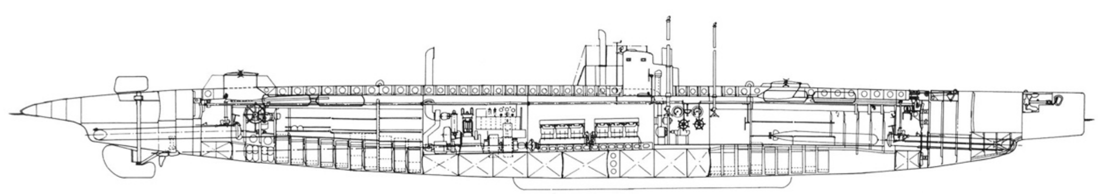

Figure 47. *G-4*. From: Friedman.

Surface propulsion was provided by four 250 horsepower gasoline engines, two per shaft giving the boat a maximum surface speed of 14 knots (26 kph). Unlike the engines of *G-1* and *G-2*, which were clutched together, *G-4*'s were joined mechanically. Submerged propulsion was by four electric motors, two per shaft, giving a maximum submerged speed of 9.5 knots (18 kph).[148] *G-4* mounted four torpedo tubes, two forward and two aft, canted down by the muzzle (outboard opening of tube), this likely done to keep the torpedo from striking the overhanging structure during launch. Other unique features included a drop keel, controllable pitch propellors, and a rudder mounted well aft of the screws with a topside section projecting from the deck.

Like the Lake boats *G-4* was so late in commissioning as to be obsolete on joining the fleet. The new boat was a one-off design which required the development of at specialized operation and maintenance procedures be developed; it was also plagued by equipment failures that required significant maintenance time. *G-4*'s short operational life was filled with local operations, training, and it served as an experimental platform for both sound and magnetic detection systems; it was decommissioned in September 1919 and sold for scrap in 1921.

[148] Friedman, *U.S. Submarines Through 1945*, 65-66 and App. D.

Conclusions

The United States Navy's first decade of active submarine development was filled with experimentation. John Holland's successful combination of electric propulsion for submerged operation and internal combustion engines for surface propulsion and battery charging was the lynch pin for future development. Once submarines became operational the growing pool of submariners provided design input contributing to the rapid progression of Electric Boat's designs. This design progression, illustrated in Table 1 below, led to larger, faster, more powerfully armed submarines with greater operating ranges

Year Laid Down	Lead Boat Class	Length Ft-in/m	Beam Ft-in/m	Displacement Surf/Sub (tons)	Speed Surf/Sub (kts)	Range Surf (nm/kts)	Range Sub (nm/kts)	Torpedo Tubes/ Torpedoes	Complement Officers/Men
1896	*Holland*	53-10/ 16.4	10-3/ 3.1	64/74	6/5.5	200/6	30/5.5	1/3 and 1 pneumatic dynamite gun	1/6
1900	*Adder* A-Class	63-10/ 19.5	11-11/ 3.6	107.6/ 122.6	8.5/ 7.2	250/8	25/7 [149]	1/3	1/6
1905	*Viper* B-Class	82-5/ 24.8	12-6/ 3.8	145/ 170	9.2/ 8.2	600/NL	NL	2/4	1/9
1905	*Octopus* C-Class	105-4/ 32	13-11/ 4.2	238/ 275	11/ 9	776/8	24/8	2/4	1/14
1908	*Narwhal* D-Class	134-10/ 41	13-11/ 4.3	288/ 377	13/ 9.5	1179/9.6	24/8	4/4	1/14
1909	*Skipjack* E-Class	135-3/ 41.2	14-7/ 4.4	287/ 342	13/ 11	2090/10.2	27/9	4/8 [150]	1/19
1909	*Carp* F-Class	142-7/ 43.5	15-5/ 4.7	330/ 400	14/ 11.3	2500/11	25.5/8.5	4/8	1/21

Table 1. Electric Boat submarine design progression. Primary Source: Friedman.

[149] Akermann, *Encyclopedia of British Submarines 1901-1955*, 117. Estimate based on contract data for British Holland Class submarines which were similar in size and propulsion systems.
[150] Friedman, *U.S. Submarines Through 1945*, App. D. conflicts with United States Navy, *Submarines: Military Characteristics, Tactical Use, and Methods of Defense Against Them*. which shows torpedo capacity of four for the E and F Class submarines.

Most historians refer to the submarines in the A through G classes as harbor defense boats; however, considering the data presented in Table 1, a natural break appears in the transition to E-Class submarines with their far greater range. The transition from harbor defense to coastal defense in historical writings is coupled to the fiscal year 1910 procurement of the H-Class submarines, the specifications for which were influenced by an April of 1909 presentation to the Navy's General Board by L. Y. Spear of the Electric Boat Company.

Spear opined on the tradeoffs inherent in different submarine designs. His recommendations supported the concept of a mid-size, medium range, coastal defense vessel. The Board recommended the 1910 submarine building program consist of four vessels of a modified F class design to be constructed on the West Coast. Major improvements specified for the new submarines included: reversing diesels, providing storage for four torpedo reloads, increasing the size of the conning tower to facilitate installation of a walk-around periscope, and requiring surfaced/submerged speed capabilities of 14 knots (26 kph) and 9.5 knots (18 kph) respectively.[151]

Congress authorized contracts for four vessels; SECNAV awarded one contract to the Lake Submarine Company (G-3), and the remaining were let to Electric Boat for the construction of three H-Class boats to be built on the West Coast.

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[151] Friedman, *U.S. Submarines Through 1945*, 76-78.

CHAPTER IV

H-CLASS SUBMARINES

Time and Chance

Were it not for time and chance, H-Class submarines might well have been merely another short-lived contribution to the rapid evolution of this new naval technology. At the time these submarines were laid down political turmoil and a complex web of alliances between nations in Europe were becoming akin to dry tinder on a forest floor. Chance sparks set patches alight and the resulting fires resulted in a greater calamity. The First World War began less than a year after the commissioning of the first H-Class boats and several of the belligerents found themselves lacking in capable submarines.

H-Class boats were the right design for the conflict; they had the endurance to cross the Atlantic, were well-armed, and proved to be relatively inexpensive and quick to build. The boats were of a size and design compatible with shipment by railroad and by sea, in a semi-assembled condition, allowing them to be sold in a build-it-kit form. H-Class submarines built for the Brittan account for nearly half of the class (20 of the 45 total H-class submarines built, see Appendix A), and encompass the entirety (23 submarines) of the follow-on H-21 Class.

Also in confluence in this era was the rapid development of mechanical military technology and its indiscriminate foreign sale; arms merchants peddled their wares with little regard to the geopolitical impact. Plans and technology for the construction of warships had previously been closely-guarded national secrets. This was not the case with submarine technology in the early 20th century. Submarine inventors and their merchant backers actively marketed their vessels, plans, and building licenses to foreign countries, rapidly transferring this new technology.

Design

American H-Class submarines were built to design EB-26 and the export versions to EB-602, with the foreign builds further identified by a letter. The major difference between design 26 and design 602 was the number of watertight bulkheads. Design 26 had a watertight bulkhead separating the forward battery compartment from the torpedo room, a bulkhead that was not included in Design 602. The rationale behind this change in design has not been discovered; however, removing the bulkhead reduced weight in the forward section of the submarine, improving overall reserve buoyancy. This coupled with the ability to shift the stowage of spare torpedoes slightly further aft, likely improved bow buoyancy, reducing the tendency of the boat to plunge.

As with previous Electric Boat designs EB-26/602 incorporated iterative improvements on the previous designs, while retaining much of the basic structure. H-Class boats were essentially larger, better armed F-Class submarines with improved diesels and a larger conning tower.

The original boats were 150.3 feet (45.8m) in length, 15.8 feet (4.8m) in beam, and displaced 358 tons surfaced and 434 tons submerged. H-Class submarines were operated by a crew of 25 men, typically two officers and 23 enlisted men, and armed with four bow-mounted 18-inch (45.7 cm) torpedo tubes; the boats could carry up to eight torpedoes. Four torpedoes were stowed in the torpedo tubes with four reloads stowed on racks in the torpedo room.

Power for surface propulsion and battery charging was provided by two 475-horsepower diesel engines. The diesels were two-stroke direct reversing engines; direct reversing allowed the engines to run in either clockwise or counterclockwise rotation, powering the boat either ahead or astern. Backing the boat in previous classes necessitated de-clutching the main engines from the shaft and clutching in the electric motors. The new diesels were designed by *Maschinenfabrik Augsburg-Nürnberg AG* (M.A.N.) of Germany and built under license by New London Ship and Engine Company (NELSECO), a recently formed subsidiary of Electric Boat.[152] The diesels provided a design speed of 14 knots (26 kph) and an operational range of 2500 nautical miles (4630km).

Two sixty-cell Exide batteries stored energy for submerged propulsion and supplied the myriad electrical loads necessary for vessel operation. The twin 160-horsepower electric motors provided a submerged speed of 10.5 knots (19 kph) and an operational range of 25.5 nautical miles (47 km) at 8 knots (15 kph).

The size of the conning tower and sail (superstructure surrounding the conning tower) were increased to facilitate installation of two periscopes, one situated in the conning tower itself and the second, which the operator could rotate while walking around it, located in the control room below the conning tower. The larger control room was enclosed by watertight bulkheads, as had been the case with *D-1* and *D-2*.

Figures 48, 49 and 50 provide the reader with visual frame of reference for the descriptions of the vessel.

[152] Cummins, *Diesels for the First Stealth Weapon*, 218-221. These engines were of varying dependability, due to poor metallurgy by NELSECO, and were replaced as improved engines became available.

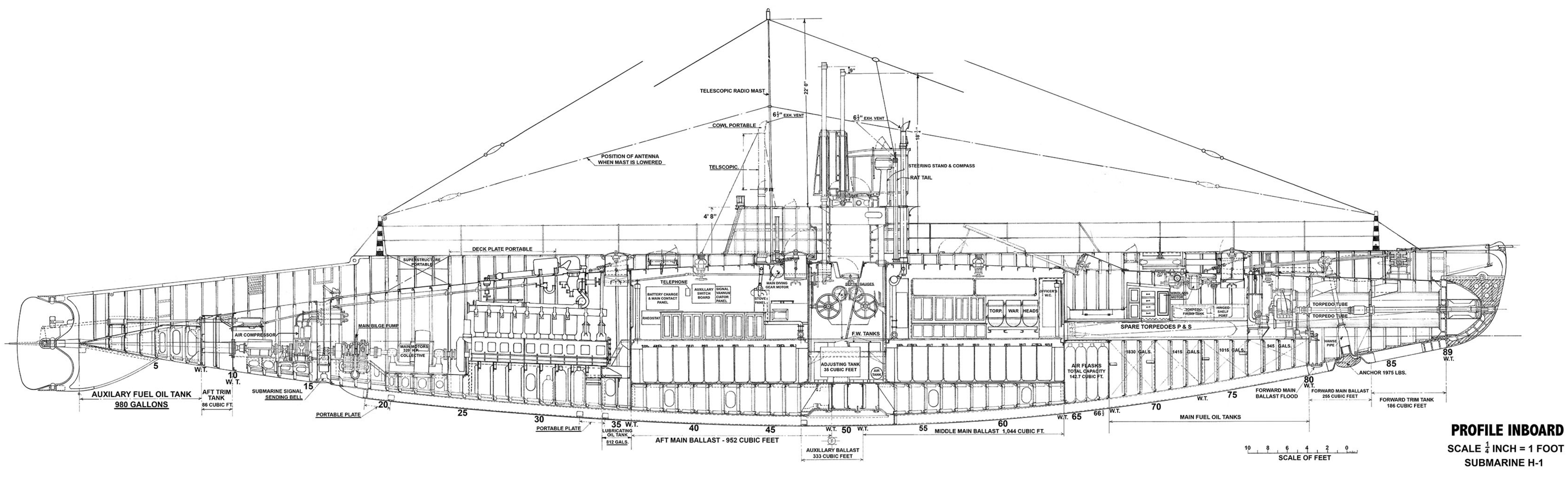

Figure 48. USS *H-1* inboard profile 1918. Design EB-26.

A. Dobbs after U.S.N., Courtesy of: NARA.

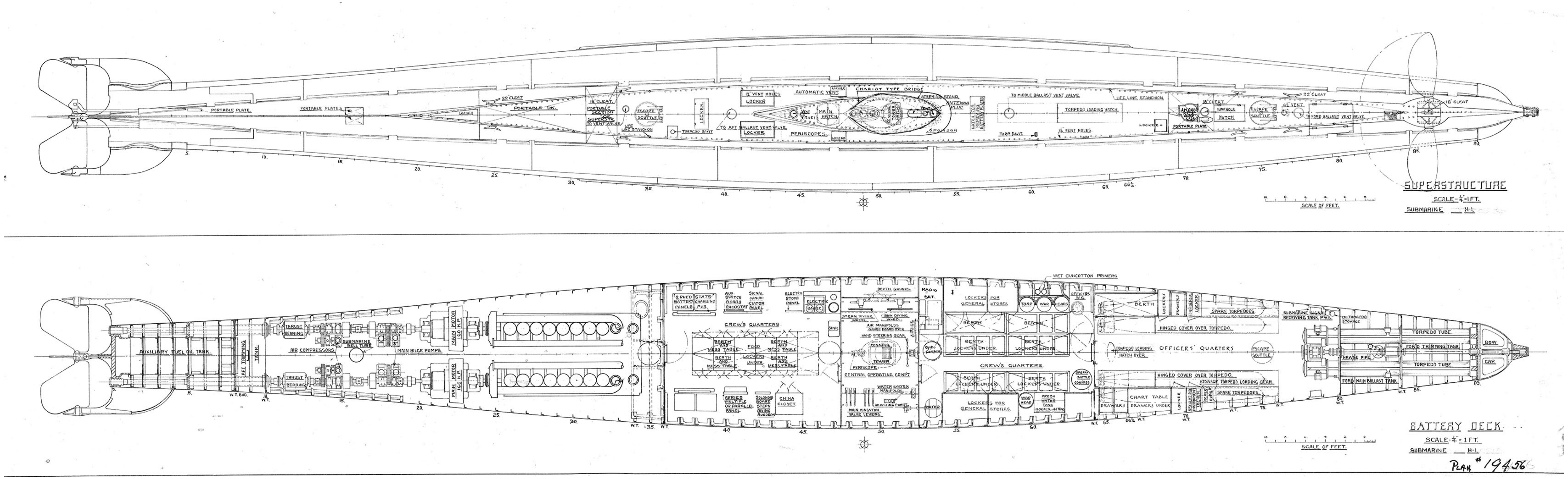

Figure 49. USS *H-1* superstructure and battery deck, Design EB-26. U.S.N., Courtesy of: NARA.

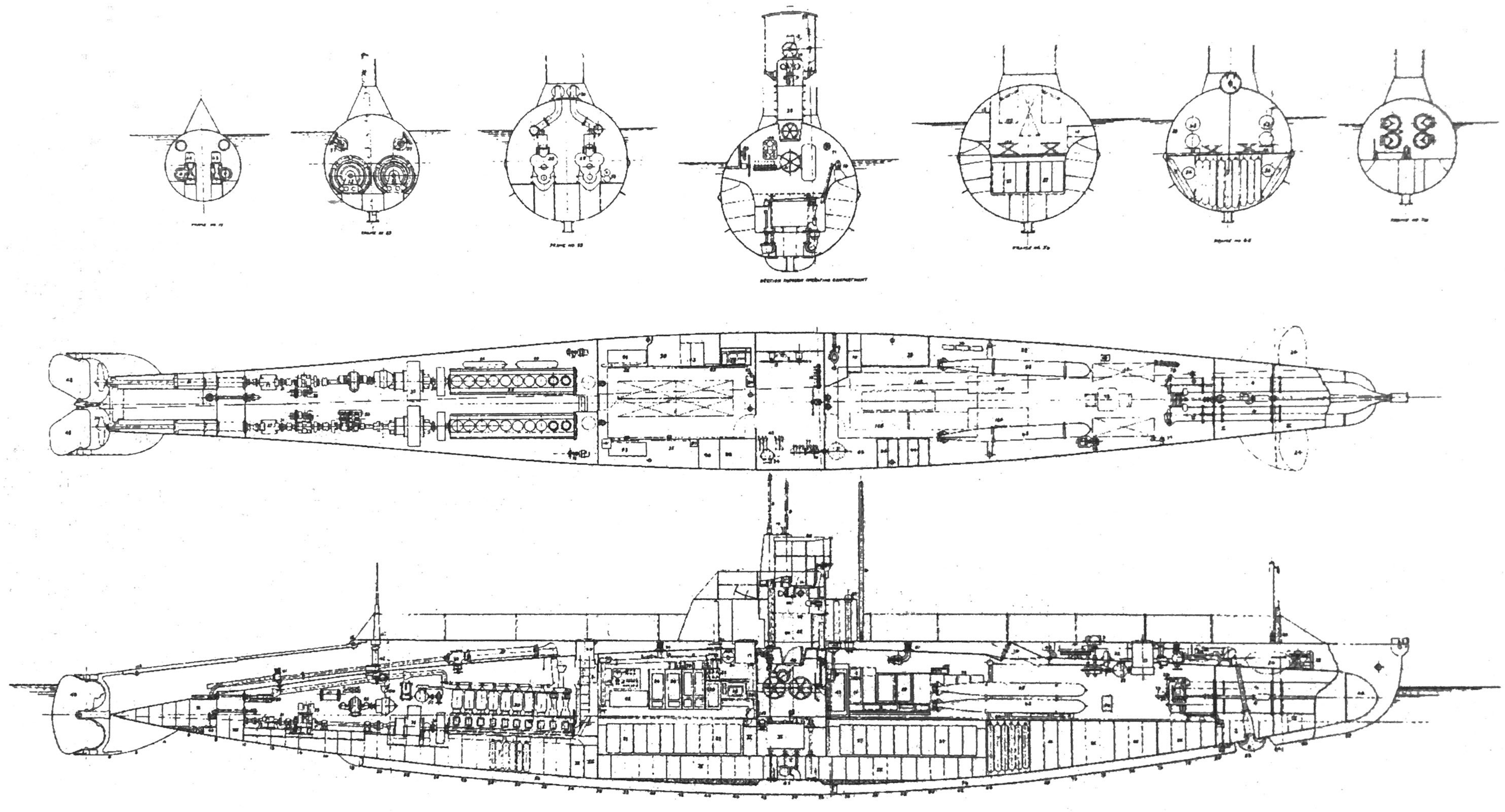

Figure 50. Design EB-602 longitudinal sections.

Courtesy of: Whatcom Museum of History and Art.

Hull Construction

Photographs of the building of the first boats, USS *Seawolf* (*H-1*) and USS *Nautilus* (*H-2*) in the Union Iron Works at San Francisco and USS *Garfish* (*H-3*) in the Moran Brothers shipyard at Seattle were not found in the author's research. Fortunately, images depicting construction of other H-Class boats and similar submarines of this period, coupled with the archaeological investigation of the wreck of USS *H-1*, provide the basis for understanding the construction process.

Among the better-documented vessels are the five H-Class submarines ordered by Russia in the summer of 1915. These boats were built in a remote shipyard in Burrard Inlet, Barnet (present-day Burnaby), British Columbia, Canada by the British Pacific Engineering and Construction Company. The Canadian company was created by James Venn Patterson, of Seattle Construction and Drydock Company Ltd, the restructured Moran Brothers operation.[153]

Figure 51. Barnet building ways. Courtesy of: City of Burnaby Archives.

[153] Lamb,'Building Submarines for Russia in Burrard Inlet'. Lamb provides a detailed description of the political and business maneuverings incident to building submarines for Russia in British Columbia.

The hulls of H-Class boats were constructed by riveting steel plate on structural frames, a process resembling the wooden plank on frame construction method utilized in shipbuilding for centuries. Construction began with the erection of building ways; these wooden structures provided the foundation upon which the vessel was built (Figure 51). The timber supported above the building ways appears to be a skeleton mold of the bottom of the hull.

The dimensions for the mold were taken off the plans by a loftsman and laid out in timber; once constructed the mold could then be erected, plumbed, and leveled to establish the appropriate height and positioning of the keel blocks. Pre-assembled keel sections were then placed on the blocks. The image below shows the same process with the keel of USS *O-2* being laid at Puget Sound Naval Shipyard in 1917 (Figure 52).

Figure 52. *O-2* keel laying. Courtesy of: Pigboats.com.

H-Class submarines lacked a traditional solid keel running from stem to stern. Instead, they were constructed with a heavy keel plate which provided longitudinal rigidity and a duct keel which contributed additional longitudinal stiffening but did not run the full length of the hull (Figure 53). The keel plate, shown here in green, was approximately 1.5 inches (3.8 cm) thick and 6.8 feet (2.1 m) wide at the midships frame, the width tapering fore and aft as the hull diameter decreased. The components annotated '20LBS FLNG' and '20LB PORTABLE' make up the stiffening structure of the duct keel which spanned from frame 19 aft to its abutment with the stem at frame 89 (Figure 48). The hollow structure duct keel, patented by L.Y. Spear in 1906, provided communication between the ballast tanks, ballast pump, and the sea.[154] The fairing labeled '20LB PLATE PERFORATED WITH ½" D. HOLES' was located under the valves which controlled flooding and draining of the main ballast tanks at frames 47-53; the perforated plate provided free communication with the sea while protecting the critical valves. The watertight section of the duct keel could also be flooded to improve stability.

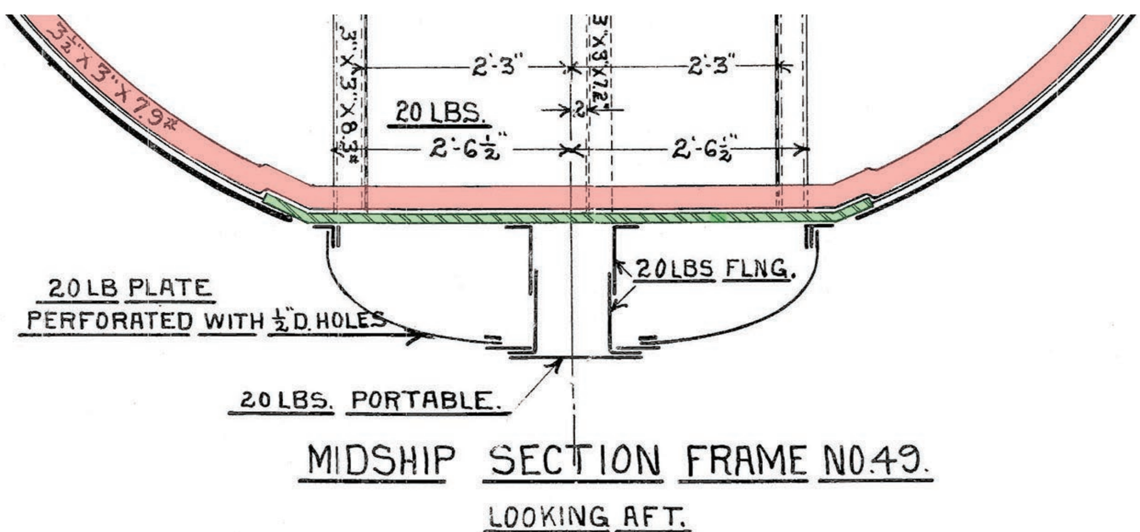

Figure 53. *H-1* keel plate and duct keel. Author after U.S.N.

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[154] Spear,'Duct Keel'.

The above drawing has several annotations indicating weight; this, in reference to rolled plate, refers to the weight of the steel measured in pounds per square foot of plate. The American standard for steel is based on a weight of 489.6 pounds (222 k) per cubic foot (.03 m^3); therefore, 20-pound plate is approximately .5 inches (1.3 cm) thick.[155] Structural steel, such as the lower framing section shown in red, is identified as '3 ½" x 3" x 7.9#', indicating its physical dimensions and weight in pounds per lineal foot. The steel which makes up the flanges in the duct keel, annotated "20-LBS FLNG.", is shown without physical dimension indicated, and measurements taken off the drawing indicate that the legs of the flanges are of different dimensions, presenting the possibility that, contrary to standard practice, the labeling may indicate the material, 20-pound plate, from which the flanges were formed instead of the weight of a foot of the flange.

Once the keel structure was in place, the boat was framed and plated. Frames were fabricated and installed in sections, with the distance between the frames being approximately 18 inches (457 mm). This close frame spacing and thick hull plating gave the boats a 200 foot (61 m) maximum operating depth. Lower frames, seen in the foreground of the image below, were set on the keel plate and riveted in place (Figure 54).

[155] American Society for Testing Materials, *ASTM Year-Book 1913*, 73.

Figure 54. Framing in progress. Courtesy of: City of Burnaby Archives.

Hull plating is shown attached to the section aft of frame 46. This manner of construction fitting plates to frames early in the assembly sequence both stiffened the assembled frame sections and provide additional structure upon which to secure the upper frames. Hull plates were identified by letter, with the A strakes adjacent the keel plate, and the B and C strakes continuing up the sides of the hull, finishing with the D strake at the top of the hull.

Installation of the upper frame sections and the C and D strakes of hull plating likely proceeded in an interrupted fashion to facilitate installation of major equipment (Figure 55). This image shows two types of upper frames; those in the foreground form an uninterrupted arch supporting the D strake, while the partial frames, located above the foundations for the diesel engines, are drilled for rivets to facilitate installation of an upper section to close the arch, presumably following the installation of major engine room equipment.

Figure 55. *H-6* Engine Room. Courtesy of: U.S. Navy.

The overlapping horizontal join of hull plates and the sequencing of hull plate installation can be deduced by observing which plate overlaps which (Figure 56). The B strake, overlapped by both the A and C strakes, was the first to be installed and was likely followed by the A strake to enclose the bottom. The C strake could not be installed until the D strake was in place as it overlaps both the B and D strakes. Both the C and A strakes would have required a filler strip, called packing, be installed between the frame and plate as neither the frames nor the plates appear to have been joggled.[156]

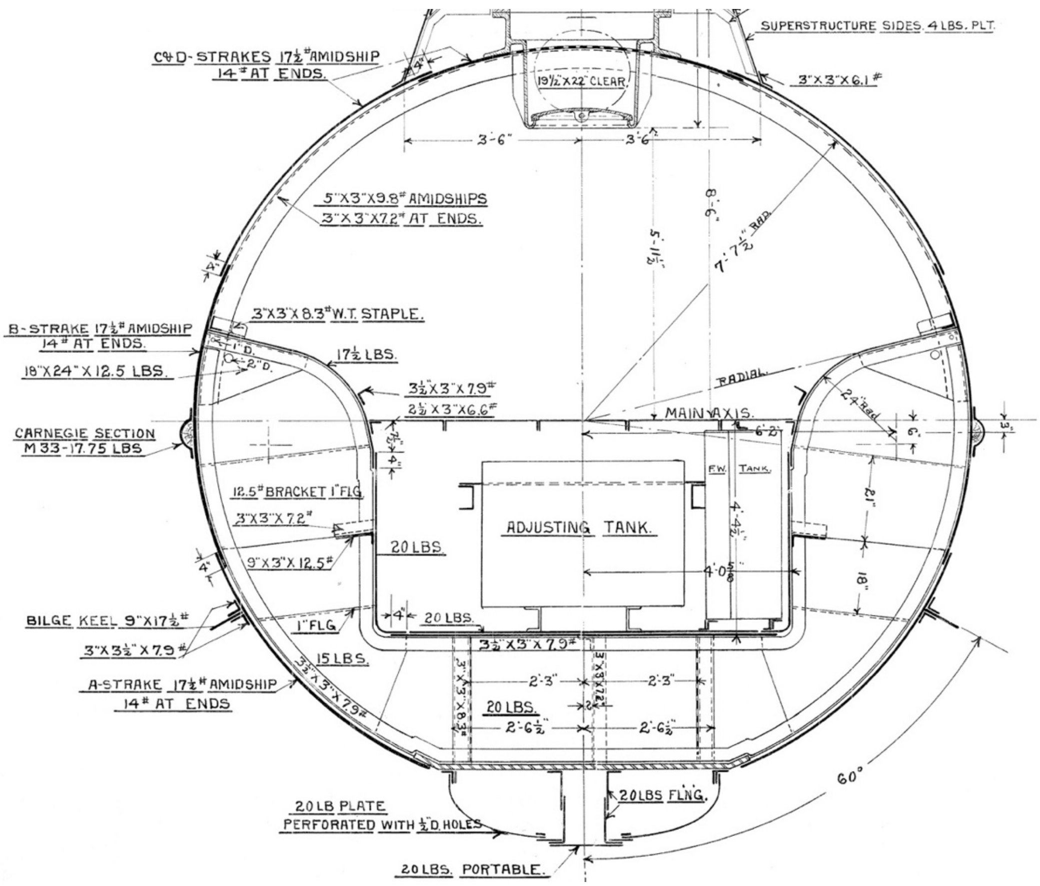

Figure 56. *H-1* midships section. U.S.N., Courtesy of: NARA.

[156] Walton and King, *Present-Day Shipbuilding*, 164.

Rivets were used to mechanically join the plates. A red-hot rivet was inserted through holes in the plates to be joined, the rivet was then compressed until it both filled the holes and had a mushroom-like shape on the point. Unfortunately, the details of riveting process are not known. Hand riveting was time consuming and was not appropriate for large rivets or pressure tight applications. Hydraulic riveting presses, in use in large shipyards at the time, were too large to be effective in the cramped interior of the submarine hull. Pneumatic riveting hammers, in common use in shipyards, better fit in the confines of the submarines, making them the most plausible option.[157]

The types of joints used to join the hull plates were the double riveted butt lap (detail A below), joining horizontal edges of adjacent hull strakes, and the double riveted butt strap (detail B), joining vertical edges of sections of hull strake (Figure 57).[158] The strap was affixed on the internal surface of the hull strakes. Both riveting patterns are visible in Figure 55, the double riveted butt strap (image lower right) appears to use a zig-zag pattern, improving the strength of the join.

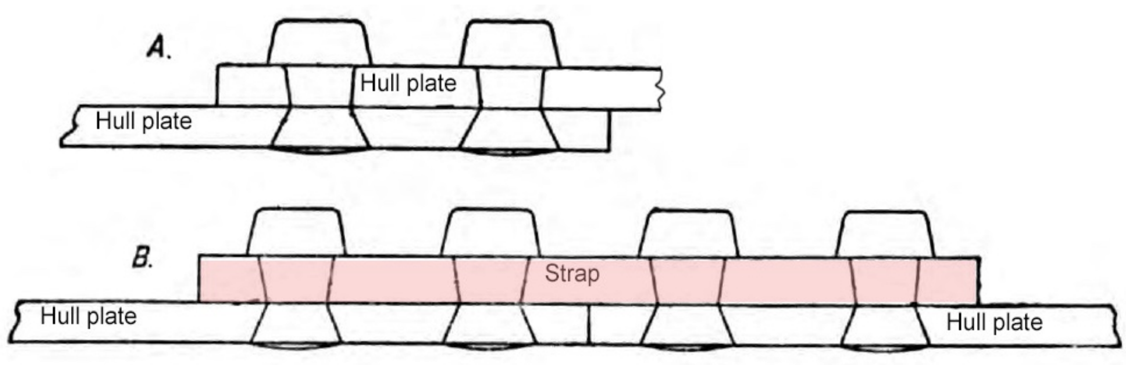

Figure 57. Butt lap and butt strap connections. Author after Walton.

[157] Lightfoot, *Beneath the Surface*, 54-55.
[158] Walton and King, *Present-Day Shipbuilding*, 177.

Riveting alone would not always produce a watertight seam; this was typically accomplished by caulking or fullering, these finishing methods are illustrated below (Figure 58). In the context of finishing methods used in the assembly of H-Class submarines, caulking refers to the practice of striking the edge of the steel, first with an angular faced splitting tool which nicked the edge of the plate, followed by striking the same surface with a flat faced edge calk tool or butt calking tool, the resulting distortion creating a watertight seam.[159] Fullering, a similar practice, used an iron of comparable width to that of the plate, developing a smoother edge.[160]

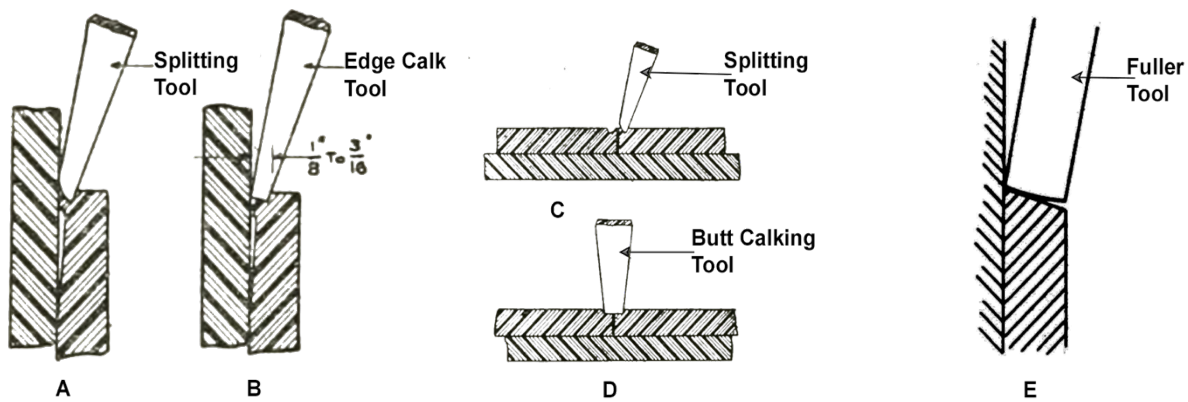

Figure 58. Caulking and fullering. Details A-D From: Hovgaard; Detail E From: Hiller.

Testing the watertight integrity of modern submarines is accomplished by pressurizing the individual compartments and observing that the pressure remains constant for the prescribed period, a process known as a drop test. Notes provided on the inboard profile drawings for submarines *H-4* through *H-9* indicate that the hull was tested to 30 psi (2.1 kg/cm^2) and, while

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[159] Hovgaard, *Structural Design of Warships*, 182.
[160] Hiller, *Steam Boiler Construction*, 126.

historical documents have not provided insight into the testing method employed during construction, it was likely consistent with the drop test prescribed in the Manual of Bureau of Construction and Repair.[161]

Forward and aft watertight bulkheads at frame 10 and frame 80 closed the ends of the habitable section of the pressure hull but framing and plating continued fore and aft, incorporating the tanks and castings which finished the bow and stern. The bow was composed of a bow casting at frame 89, a rotating bow cap through which the torpedoes fired, and stem pieces (Figure 59).

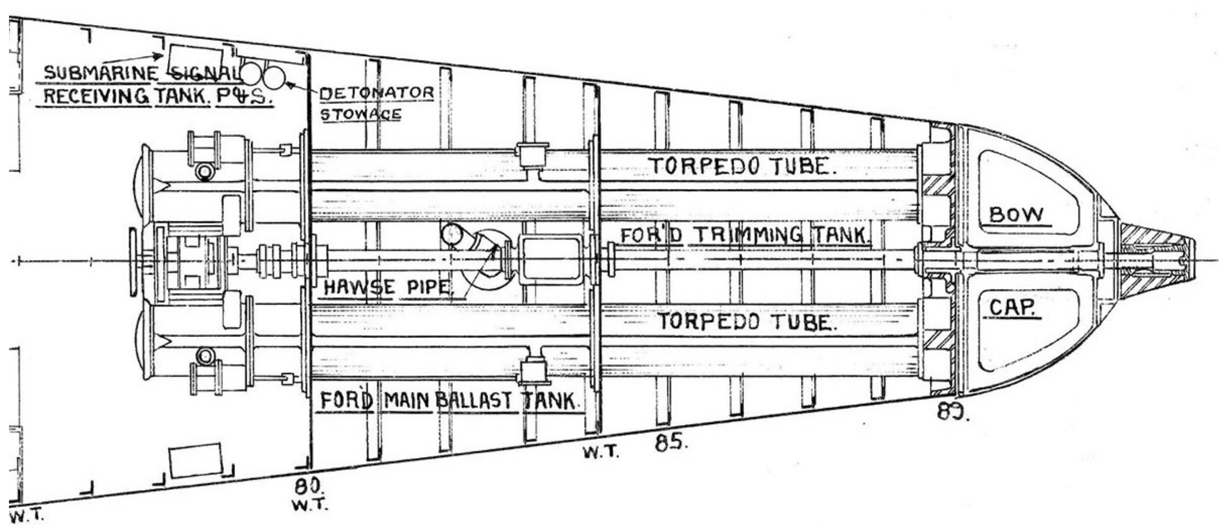

Figure 59. Plan view of *H-1* bow section. U.S. Navy, Courtesy of: NARA.

[161] U. S. Navy, *Manual of Bureau of Construction and Repair*, 109.

The bow caps have been removed from the H-Class boats in the image below, leaving the stem pieces and bow casting visible (Figure 60). The bow casting supports the forward ends (muzzles) of the four torpedo tubes and the operating shaft for the bow cap which runs through the center penetration visible on *H-3*, the submarine to the right.

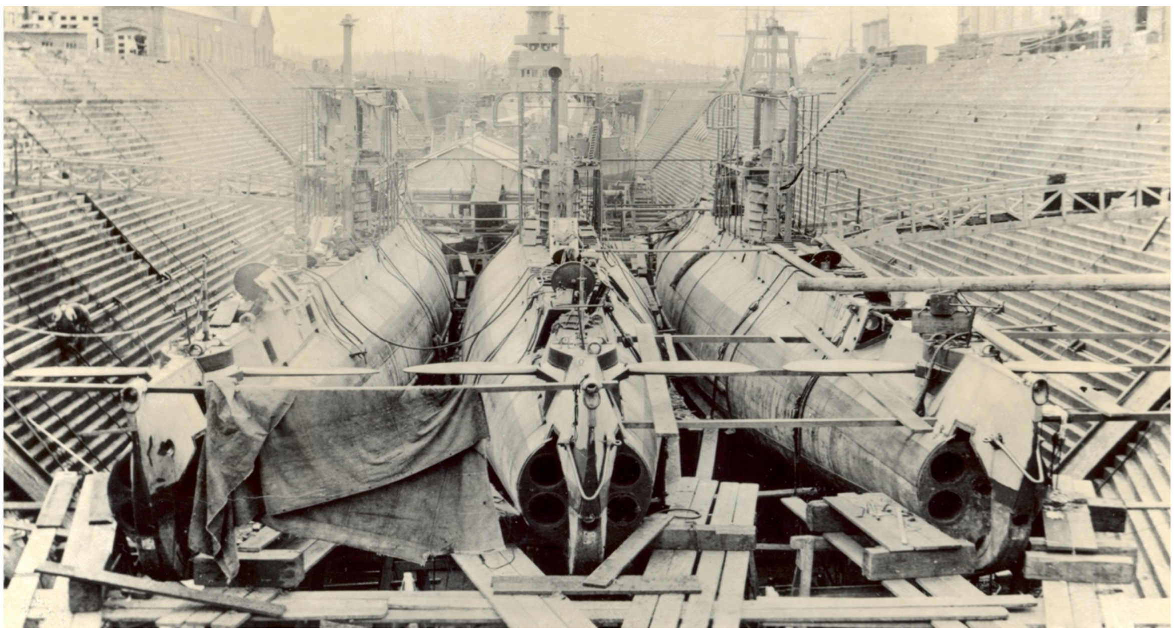

Figure 60. H-Class drydocked in Puget Sound Naval Shipyard. Courtesy of: NARA.

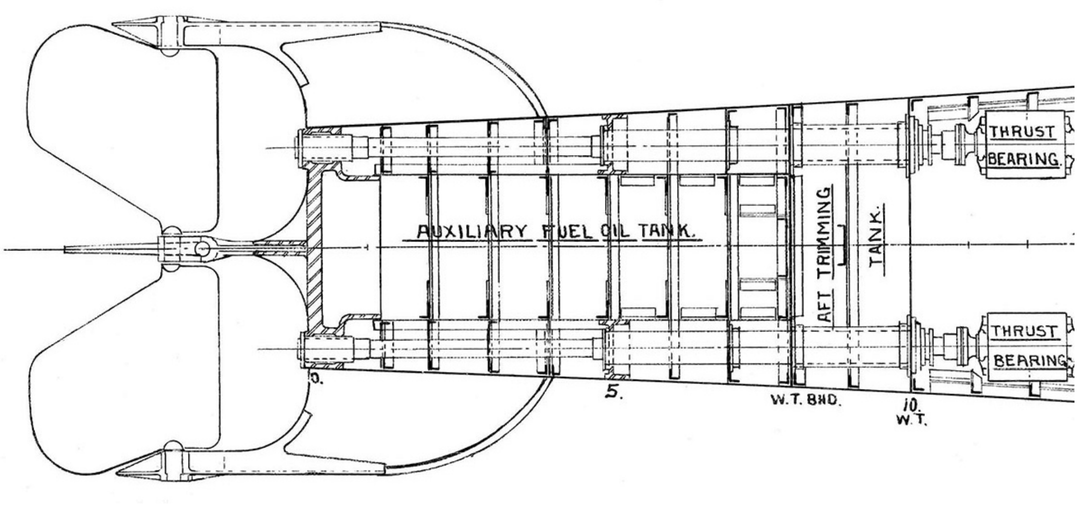

Figure 61. Plan view of *H-1* stern section. U.S.N., Courtesy of: NARA.

The figure above shows the stern castings which supported the stern tubes (frame 5) and cutlass bearings (frame 0), through which the propulsion shafts passed, and provided strong mounting surfaces for the rudder and stern planes (Figure 61). The vertical section of casting shown below provides an indication of the size of the rudder and its position relative to the ship's screws which mounted on the propulsion shafts nearly flush to the stern tube through which the shafts pass (Figure 62).

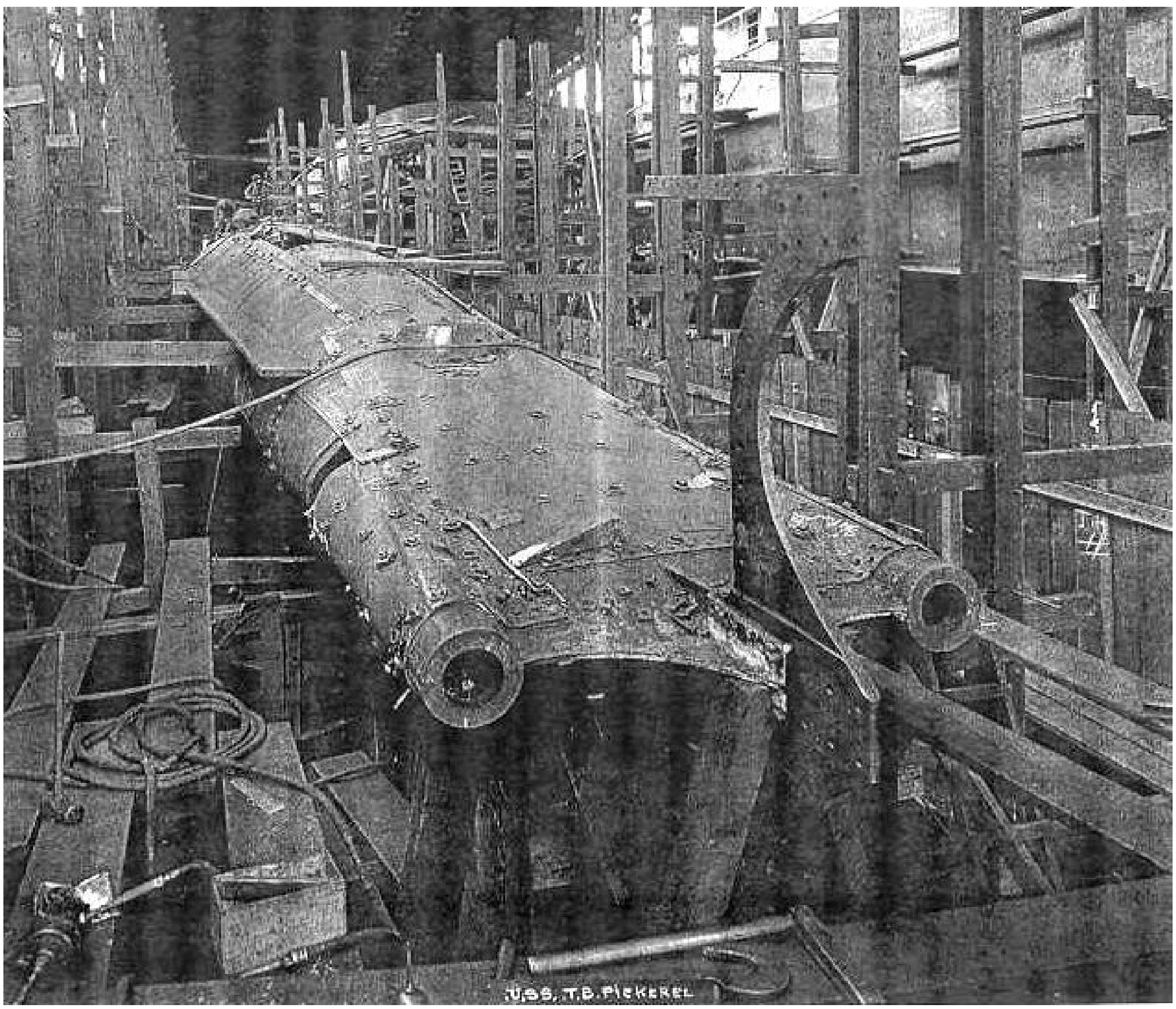

Figure 62. Stern view of *Pickerel* in Union Iron Works. Courtesy of: PigBoats.com.

The conning tower, an isolated pressure tight space, was made of non-ferrous metal (brass) 1 inch (2.5 cm) thick; the choice of material improved the performance of the magnetic compass. Ship's drawings show it cast in three segments: a lower section which provided a flanged interface to the hull and contained the control room access hatch, a middle section, and a top section which contained glass deadlights and the upper hatch (Figure 63).

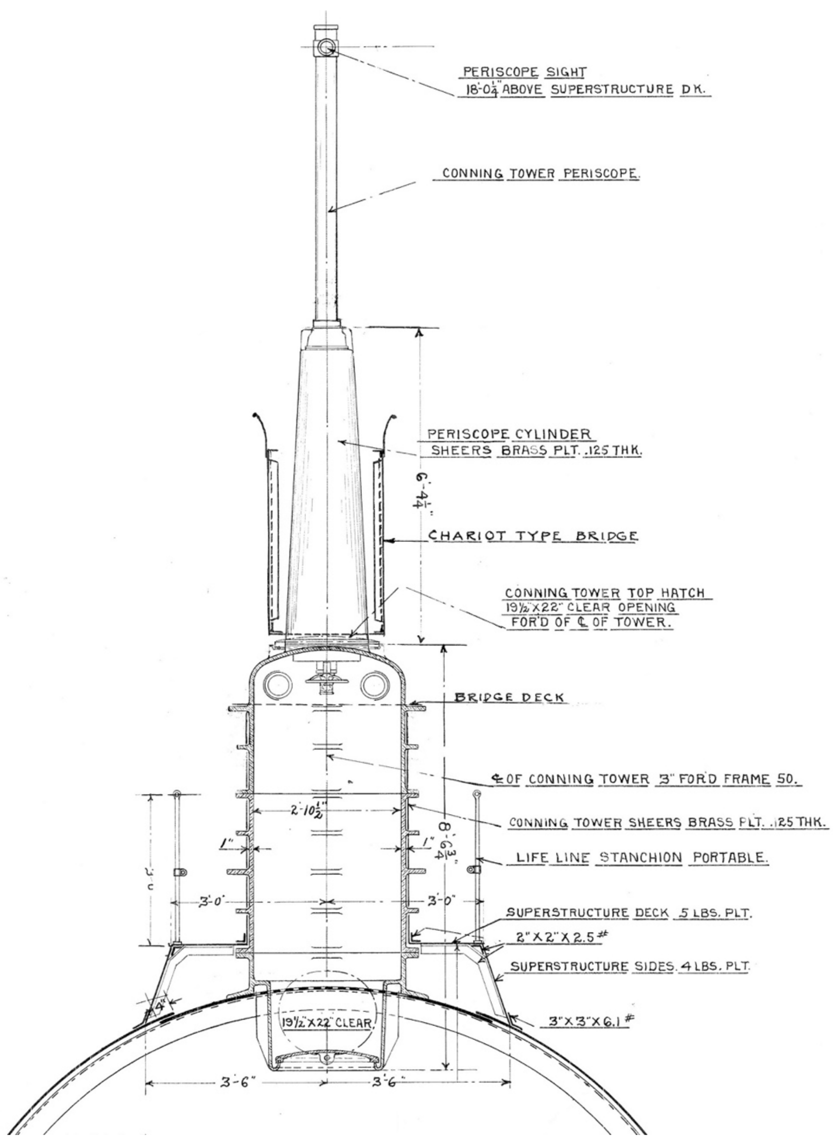

Figure 63. *H-1* conning tower detail. U.S. Navy Courtesy of: NARA.

H-Class Ship's Systems

Submarines consist of multiple complex systems amalgamated to enable the covert deployment of weapons of war in an inherently hostile underwater environment. Understanding those systems, and how they functioned, is critical to comprehending how H-Class submarines operated. The systems examined here include propulsion and auxiliary, ballast and trim, ship control, navigation, weapons, and communications.

Propulsion and Auxiliary System

The propulsion and auxiliary system was comprised of four subsystems: main engines, direct current motor generators, storage batteries, and auxiliary shaft line components (figure 64).

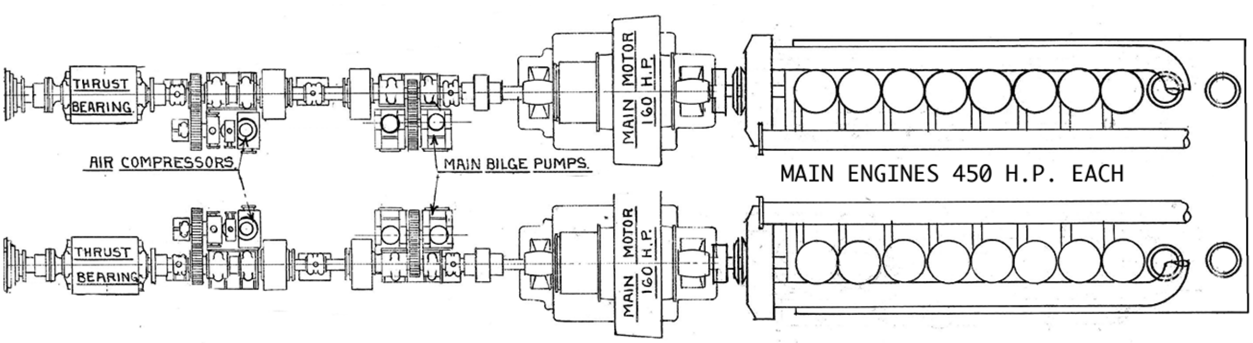

Figure 64. *H-1* propulsion system, batteries not shown. U.S. Navy, Courtesy of: NARA.

The main engines provided propulsion by exerting motive force to turn the shafts; shaft rotation operated the clutched-in shaft line auxiliary equipment, and turned the screws, with thrust transferred to the hull through the thrust bearings. The main engines also rotated the motor generators which, when operated in generator mode, charged the batteries. A low charge rate could be maintained while using the engines for propulsion; however, greater charge rates required dedicating one engine to the charge while the other provided propulsion.[162]

The diesel engines, described on page 115, required only air, fuel, lubricating oil, cooling water, and a discharge path for their exhaust to operate. The main engines' air intake took suction directly on the engine room, and the vacuum from the running engines drew fresh air through the open conning tower hatches. When sea conditions required closing the hatches, air was drawn through the ventilator pipe fitted in the sail, highlighted in green (Figure 65).

Diesel fuel for the main engines, totaling 6250 gallons (23,659 l), was stored in five tanks located within the pressure hull. The four forward Main Fuel Oil Tanks' total capacity was 5270 gallons (19,949 l) and the aft Auxiliary Fuel Oil Tank capacity was 980 gallons (37,10 l); in the figure below, fuel tanks are highlighted in yellow.

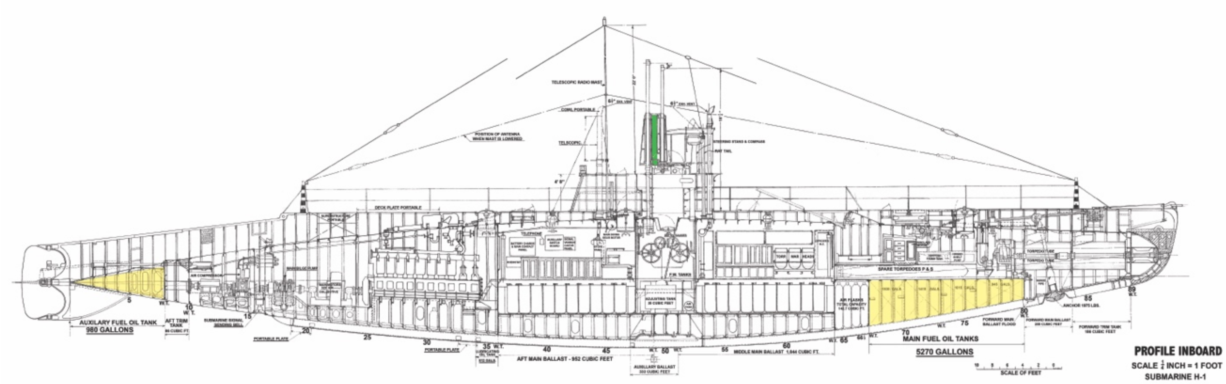

Figure 65. *H-1* ventilators and fuel oil tanks. Author after U.S. Navy.

[162] Bullard, *Naval Electricians' Text Book*, 447.

A submarine must have as little change in the weight of the boat as possible to support maintenance of near neutral buoyancy, commonly referred to as diving trim. This necessity requires compensation for lost weight due to burned fuel. Sea water, although a heavier liquid than diesel fuel, was introduced into the fuel tanks, to compensate for slack in the tanks resulting from fuel usage. Fuel was drawn from the top of the tank. The diesel fuel floated on the heavier seawater beneath it and was transferred to a clean fuel oil tank to settle, any remaining water would be stripped from the bottom of the tank ensuring that no water remained in the diesel oil supplied to the engines.

The engines were started using compressed air to get the engine rotating and compress the injected fuel to initiate combustion. Engines were clutched directly to the shaft without the benefit of a transmission. Backing the boat required stopping the engines and restarting them with rotation in the opposite direction; this change in rotation was also accomplished with compressed air, pneumatically shifting several engine components. The pneumatic starting and reversing system, while simple to operate, often leaked and was considered unreliable.

This lack of dependability resulted in submariners reverting to backing with the electric motors and not the diesel engines.[163] This practice may have contributed to the loss of USS *H-1* when it grounded while operating on the surface on its starboard main engine.[164] Immediately upon the vessel's grounding, the captain ordered "Emergency Astern", and when the electrician engaged the motors, instead reversing the diesel engine, the circuit breakers overloaded, and all propulsion was lost.[165]

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[163] Magdeburger, 'Diesel Engines in Submarines', 588.
[164] NARA D.C., H-1 Sinking Investigation. Testimony of GMC W.L. Albrecht USN, 26.
[165] NARA D.C., Board of Inquest into the Death of Harvey William Giles. Testimony of MM1 H.C. Bradley USN

The waste products of H-Class diesel engine operation were heat and toxic exhaust gasses. Engine cooling was provided by the direct use of seawater. An engine driven pump drew seawater through isolation valves and associated piping and pumped it through the engine's cooling water jacket, removing latent heat. The heated water was pumped back to sea via the discharge valve. The exhaust was directed overboard via exhaust piping, through the outboard exhaust valve and through a muffler mounted in the superstructure, to the atmosphere; this exhaust system was located above the main engines.

The historical record demonstrates that the NELSECO engines initially installed in the H-Class boats were problematic to maintain; chief among the identified causal factors were lack of trained personnel and manufacturing flaws. Diesel technology was still in its infancy in submarines and a steep learning curve existed for the men who operated and maintained these engines. Manufacturing flaws were common with castings produced at the NELSECO foundry, with the initial rejection rate for cylinder castings exceeding 90 percent.[166] Inadequate seals on interface points appears to have been causal in many engine casualties. Intrusion of saltwater from the cooling system into both cylinders and the lube oil, and high-pressure air from the scavenging air system leaking into the crankcase all wreaked havoc on the engines. The engine room was cramped with a narrow walkway between the engines and even less room outboard, this limited access to the engines and exacerbated maintenance difficulties. However, boats with experienced and innovative engineers were able to keep the engines operating through both adaptive modification and preventative maintenance.[167]

[166] Shane, 'Nurnberg Two-Cycle 450-B.H.P. Heavy-Oil Engines', 448.
[167] Sherman, 'Diesel Submarine Engines'.

In 1913 marine electrical technology was more mature than diesels technology and navy electricians were experienced in operating and maintaining electric plants; consequently, the electric equipment was less problematic than the diesel propulsion system. The motor generators, like the diesel engines, required the support of sub-systems to function, these being the storage batteries and control.

Batteries were the foundation of the electrical propulsion system and provided energy to operate lights, pumps and motors. Without batteries, machinery powered submerged propulsion was impractical; however, lead acid batteries added unique hazards to submarine operation. Sulfuric acid, used as electrolyte, is caustic and will consume metal; also, when mixed with seawater, it forms deadly chlorine gas. Batteries give off hydrogen gas when charging, which is explosive at concentrations above four percent. Hydrogen sulfide gas, hydrogen, and heat are produced as batteries discharge. Battery exhaust fans ventilated the wells to keep hydrogen levels from building up while the batteries were being charged. The fans exhausted through vent pipes above the bridge. Failure to manage these hazards resulted in the sinking loss of submarines and deaths of submariners. Hull weakening, due to acid induced corrosion, caused the loss of *F-4* and is considered the likely cause of loss of two other boats.[168]

[168] Friedman, *U.S. Submarines Through 1945*, 265. USS *O-9* lost in 1941 and USS *S-28* in 1944 each with the loss of all aboard.

In an effort to manage these risks the batteries were installed in tightly sealed tanks, called battery wells, under the decks in the forward and aft battery compartments (Figure 66).

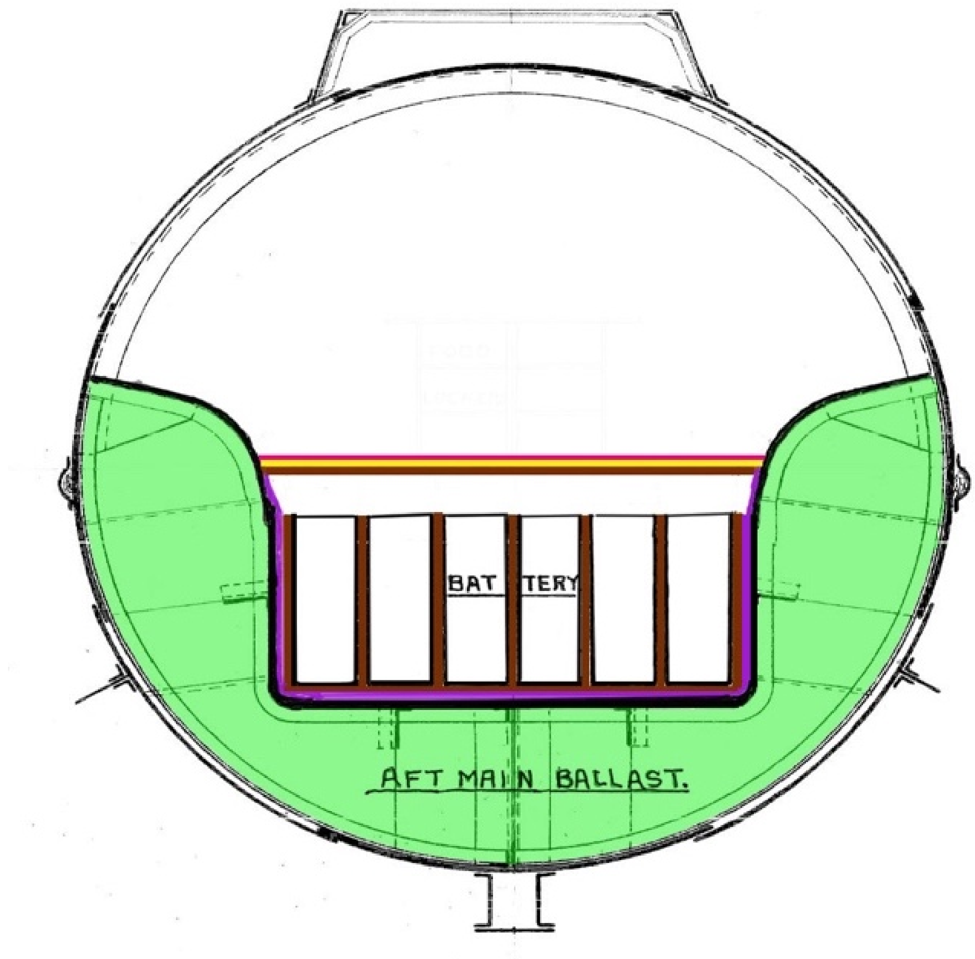

Figure 66. H-1 aft battery well. Author after U.S. Navy.

The outer boundary of each well, which also comprised the inner wall of the main ballast tank, was of steel plate coated with bituminous composition (coal tar). Lining the steel, as shown in Figure 66, was a layer of lead (purple); wood (brown) was used to separate the cells from each other, the tank walls and deck, and provide a structural deck above the well. This wooden deck was covered in sheets of rubber (yellow) and a layer of shellacked canvas (magenta).[169] This construction worked under normal circumstances but failed to prevent seawater intrusion in cases of flooding, resulting in fires due to catastrophic battery failure and the release of chlorine gas.

The forward and aft batteries were each composed of sixty lead acid cells (Figure 67). The cells are best described as large rectangular jars made of hard rubber. Each cell contained positive plates, made from lead peroxide, and negative plates of purified lead.

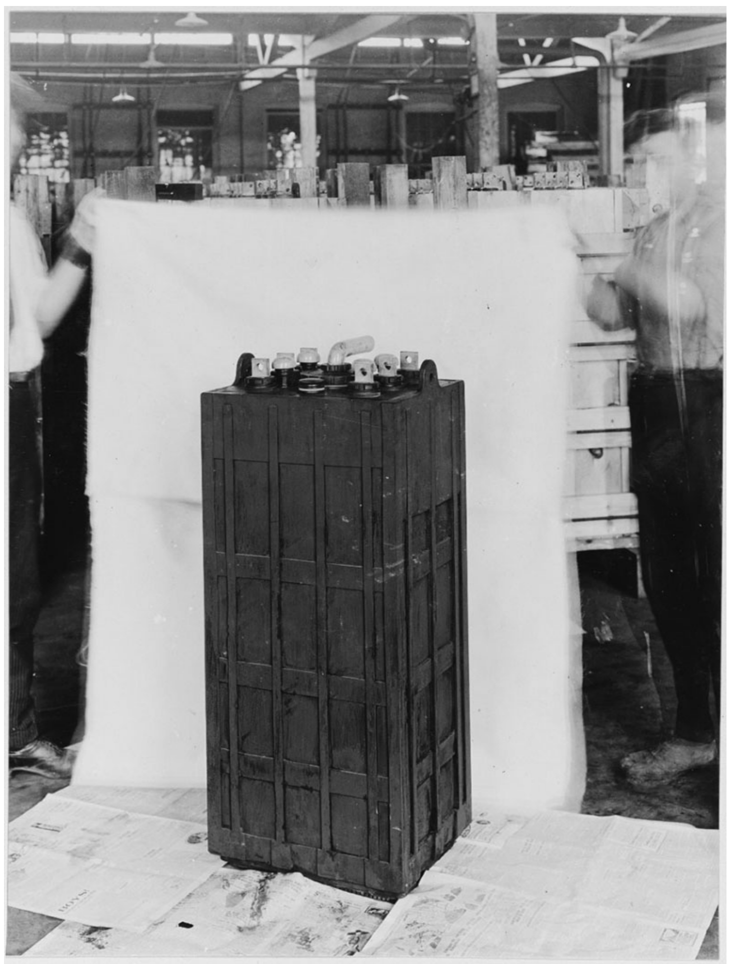

Figure 67. *H-1* battery cell. Courtesy of: NHHC.

[169] Pate, *The Naval Artificer's Manual*, 706.

Cells were assembled in sandwich fashion, with a positive plate, a separating insulator made of perforated rubber, a negative plate, another rubber insulator, a positive plate, and so on. Plates of similar polarity were connected to each other via a bus bar and the corresponding terminal. The plates were suspended by their buss bars in an electrolyte solution, normally sulfuric acid and distilled water.

Charging the cells resulted in a difference in electrical potential between the plates, thereby effectively storing the electricity until the battery was connected to an electrical circuit into which it could discharge. The cells in each battery were wired together in series, and each provided about two volts, giving each battery an average of 120 volts. Energy flowed through the battery emergency disconnect switches via heavy gauge wires to the main and auxiliary switchboards, located in the aft battery compartment. The main switchboard provided control for the motor-generators and the auxiliary switchboard serviced all other electrical loads on the boat.

H-1's underwater endurance was inversely proportional to the speed at which it operated. Design specifications required the batteries to support 9.5 knots (18 kph) for one hour and 8.5 knots (16 kph) for three hours.[170] The boat's underwater endurance was controlled by both equipment and human factors; primarily battery life and quality of atmosphere. Research has not provided a specific time or distance for the class; however, in 1915 HMS *H-1* transited the Strait of Marmora submerged, covering approximately 70 nautical miles (130 km) in just over 12 hours with a relatively new battery.[171] As battery life is inversely proportional to speed, an endurance of 20+ hours at 3 knots (6 kph) is probable.

[170] Friedman, *U.S. Submarines Through 1945*, 78.
[171] Moth, 'Wartime Memoirs of Coxn Oscar Moth'.

When a boat prepared to submerge, the diesel engines were de-clutched from the shaft and shut down. Propulsion was shifted to the motors by engaging the tail clutch at the aft end of the motor. The electrician at the main switchboard configured the batteries either in series or parallel, selected direction of rotation either ahead or astern, and controlled motor speed by operating a rheostat which controlled voltage. Energy from the batteries caused the motor to rotate, turning the shaft, which operated clutched-in shaft line auxiliaries and turned the screws.

Each motor was rated at 160 shaft horsepower (continuous operation) and 320 shaft horsepower for one hour. The motors differed from electric motors used in surface ship applications, in that they could function on a much wider range of voltage. In submarines, voltage varied as a function of the charge state of the batteries, position of the speed control rheostat, and selection of the series/parallel switch. This switch controlled the battery voltage available at the motor by connecting the batteries in parallel for the low power option, or in series for the high-power option. Series operation rapidly depleted the batteries. [172]

Two separate shaft line auxiliaries, bilge pumps (also referred to as main power pumps) and air compressors, were also driven by either the engines or motors and while not directly affecting propulsion they were both critical to the operation of the submarine. The main power pumps were used to move water from tank to tank within the boat and to discharge water from the boat, either bilge to sea or tanks to sea. The air compressors provided compressed air at 2500 psi (17,237 kPa), which was stored in the five air banks and reduced to various pressures for a myriad of tasks: blowing water from ballast tanks and trim tanks or fuel from fuel tanks to sea, blowing water and fuel between tanks, charging torpedo air flasks, firing torpedo tubes, starting the main engines, and providing air for breathing.

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[172] Bullard, *Naval Electricians' Text Book*, 447-460. Provides detailed description of submarine electrical system

Ballast and Trim System

Control of buoyancy and trim is fundamental to submarine operation. The ballast system was used to control the boat's gross buoyancy to facilitate diving and surfacing (Figure 68). The ballast system consisted of three main ballast tanks: forward, middle, and aft, (blue) and a single auxiliary ballast tank (tan). Each ballast tank was fitted with a Kingston valve (magenta), and a vent valve (yellow); ballast tanks were flooded by opening these valves, with water entering via the Kingston valves and air being forced out the vents. The main ballast tanks, when flooded, left very little reserve buoyancy, and that small reserve could be overcome by flooding the auxiliary ballast tank. When the ballast tanks were filled and the submarine submerged, the valves would be shut. The ballast tanks were connected to the high-pressure air flasks (gray) via ballast tank blow valves located in the control room. When the vessel was ready to surface, the tanks would be pressurized with air via the blow valves, and the Kingston valves opened, allowing water to be blown from the ballast tanks, or pumped with the main power pumps, restoring positive buoyancy. An automatic blow system, designed to blow the ballast tanks if a pre-determined depth was exceeded, was installed but does not appear to have been completely effective as the normally-shut Kingston valves needed to be manually opened for it to function.[173]

Diving and surfacing required the boat to be in diving trim. Maintaining a diving trim required comparing the submarine's current buoyancy condition against a reference trim. Reference trims documented the quantity and location of all variable weights on the boat as well as water temperature and salinity when the boat was submerged at near neutral buoyancy. Diving trim was calculated against this standard and appropriate compensation made by adjusting the amount of water in the trim tanks, as shown in green (Figure 68).

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[173] Searle and Curtis, *Undersea Valor*, 47. F-4 was lost with forward ballast tank Kingston valve shut.

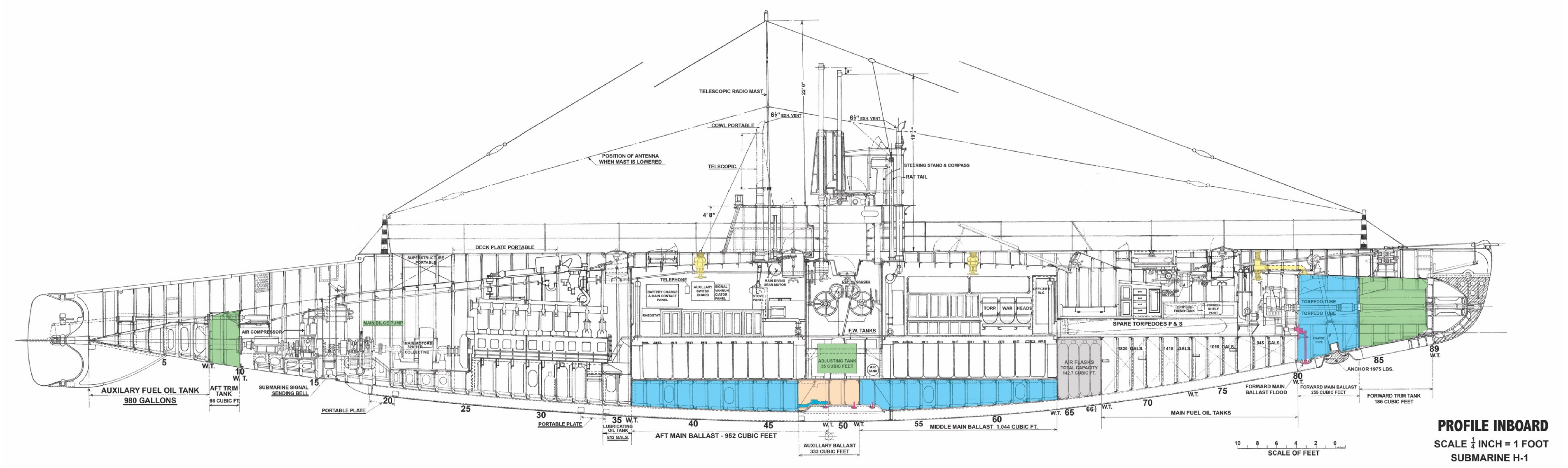

Figure 68. *H-1* ballast and trim. Author after U.S. Navy.

The tanks of the trim system located at the ends of the ship allowed fore and aft trim to be maintained, while the adjusting tank facilitated compensation for changes affecting overall trim such as changes in water temperature and salinity. Water in the trim and ballast tanks could be blown to sea, pumped with the main power pumps or with the hand pump via the duct keel. The duct keel could be flooded to add additional ballast at the very bottom of the boat, improving stability and reducing rolling on the surface. To trim the boat, water was transferred between tanks either by pumping it with the adjusting pump, or by blowing. A well-maintained diving trim allowed skilled operators to control depth to within one foot under good conditions.

Depth control used a combination of ship's trim, speed and the forces exerted by the diving rudders, hereinafter bow planes (red) and stern planes (green); as with surface ships, a vertical rudder (magenta) controlled heading (Figure 69). Steering could be controlled from a helm station on the bridge in fair weather, or from the control room when weather was foul, or the boat was submerged.

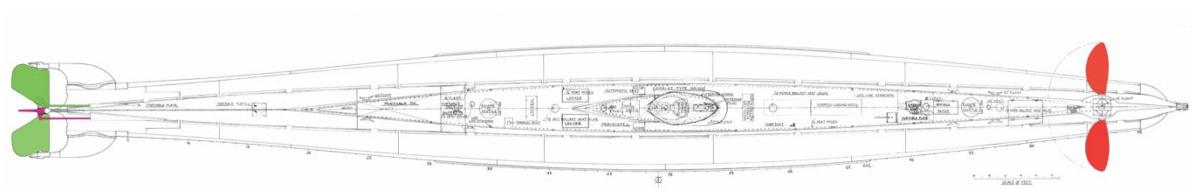

Figure 69. *H-1* control surfaces. Author after U.S. Navy.

The submarine's crew controlled the boat's depth using handwheels. Each wheel operated a motor which turned the shaft linked to the control surface; if electrical power or the motor failed, the control surfaces could be operated manually as well (Figure 70). On its left, the image shows the diving station of *H-5*, located on the port side of the control room; the hand wheels control the bow and stern planes. Between the wheels are coarse and fine clinometers measuring the inclination of the boat, referred to as the bubble in submarine vernacular, and deep and shallow water depth gages. The right image shows the helm of *H-3*. A drive chain can be seen going from the wheel to the rudder shaft in the overhead, and the steering motor lies aft of the visible shaft. The mirror mounted on the bulkhead, just above the wheel, allowed the helmsman to view the compass.

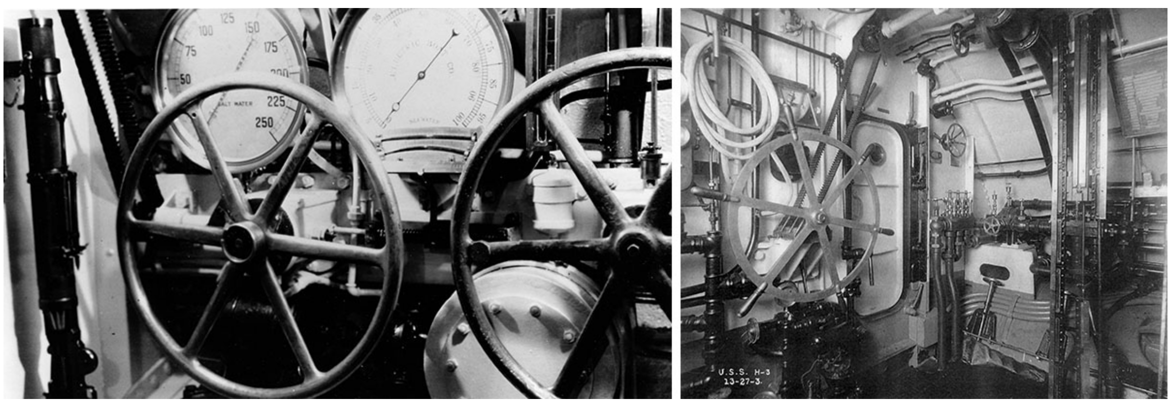

Figure 70. H-Class diving and steering stations. Courtesy of: NHHC.

Aft of the door (which lead to the forward battery compartment) are control valves for the trim system and sight glasses for measuring tank levels. When the vessel was submerged a minimum of five men, one on each control wheel, an operator for the trim and ballast systems, and an officer of the watch, worked in this small space.

Submerging the boat required the coordinated operation of these systems. When the captain was ready to submerge, he directed the men to secure the bridge. The early H-Class boats were equipped with a large pole awning and canvas bridge skirts to protect the men on watch and reduce the possibility of taking water down the open hatch (Figure 71).

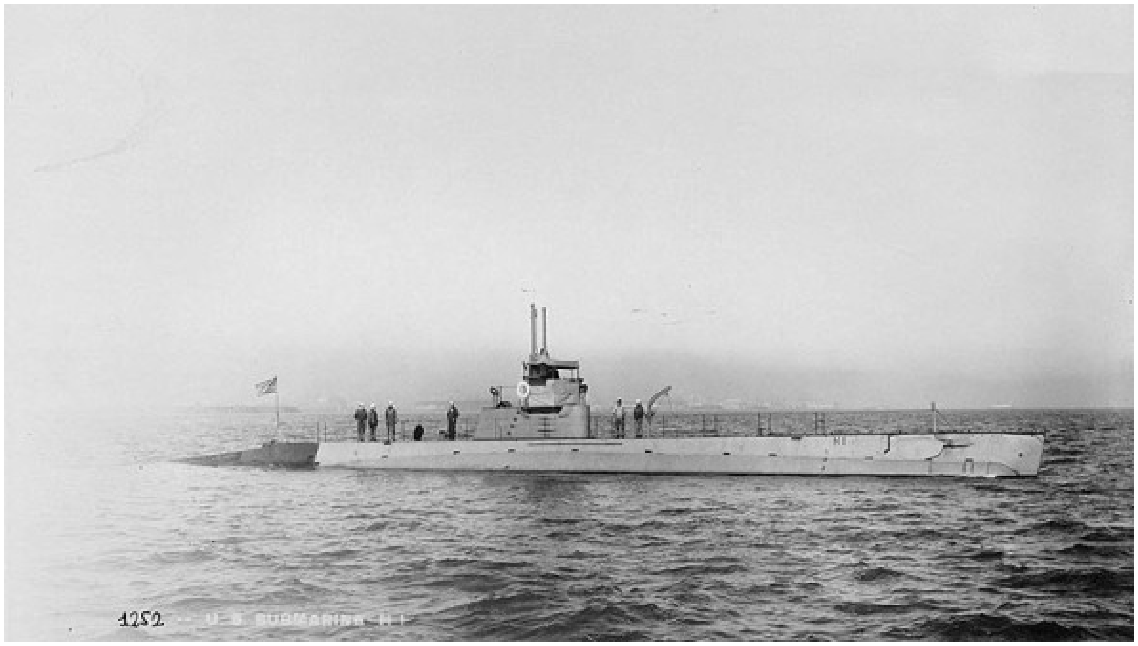

Figure 71. *H-1* canvas bridge. Courtesy of: NHHC.

Disassembling the canvas bridge and stowing it was a lengthy and onerous job, relegating its use to operations where a quick dive would not be necessary. In preparation for diving the battery ventilator pipes and radio mast (if rigged) were also removed and stowed. In the engine room, diesel engines would be shut down, their cooling and ventilation systems isolated from sea pressure by shutting hull valves, and propulsion shifted to the electric motors. During this process a helmsman took over steering in the control room and the topside wheel would be removed and stowed. The Officer of the Deck (OOD), typically the captain, ordered all hands below, made a final check of the topsides and then went below to the control room, shutting and securing the upper and lower conning tower hatches. The men took their stations and the bow planes were rigged out.

Once all was in order, final adjustments were made to diving trim and the OOD would order the ballast tank vent valves and Kingston valves opened and, providing diving trim was correct, the boat would begin to submerge, retaining only slight positive buoyancy. Final adjustments to trim were made and once he was satisfied, that all was satisfactory the OOD ordered an ahead bell on the motors and desired diving depth; planesmen would set the bow planes on dive and the stern planes on rise to give the boat a slight down angle and it would be driven down by forward motion. Ballast tank vents were shut after the boat submerged, restoring the ability to blow water from the tanks should the need arise.[174] The practice of the day also included shutting the Kingston valves thereby isolating the ballast tanks; in an emergency, Kingstons would need to be opened before blowing the ballast tanks, adding time and complexity. Kingston valves were discontinued early in the Second World War to facilitate faster diving and simpler emergency surfacing.[175]

Diving and surfacing are risky operations that required each man to know his job. While submarines are known for their informal atmosphere and close-knit crews, evolutions on the boats were nonetheless formal and exacting. The method of communication used illustrates this formality. Orders were acknowledged by repeating them back verbatim, the order was carried out and reported and that report was acknowledged. If the OOD desired to open and then shut the forward main ballast tank vent he would order the torpedo room (TR) watch to do so, with the exchange as follows:

> OOD "Torpedo room cycle forward main ballast tank vent"
> TR "Cycle forward main ballast tank vent aye" TR opens and shuts vent.
> TR "Officer of the Deck forward main ballast tank vent cycled. Vent is shut"
> OOD "Very Well Torpedo room."

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[174] Hinkamp, 'Submarines and Torpedoes',440-445.
[175] Friedman, *U.S. Submarines Through 194*5, 210.

Riskier than diving, the transition from submerged to surfaced operation required the boat go from a safe depth, well below the keel of any passing surface ship, to periscope depth. The H-Class boats had no way of detecting nearby vessels and made this transition blindly. Once safely at periscope depth the OOD looked around through the periscope and once he determined it safe, ordered the crew to surface the ship. Surfacing the submarine was accomplished by driving it close to the surface using a combination of speed and control surfaces. Once near the surface the Kingston valves were opened and high-pressure air admitted to the ballast tanks forced the water out, or tanks could be pumped with the main power pumps, restoring positive buoyancy. Bow planes were rigged in, the conning tower hatch opened, the diesels started, and the watch shifted up to the bridge.

Navigation

Navigating a submarine on the surface was only slightly different than navigating a surface ship of similar size. Submarines have a disproportional portion of their hull underwater and consequently tend to be harder to control at slow speeds, neither stopping nor turning handily. Fixing position while surfaced was either by terrestrial navigation, taking bearings on known objects on the shore and plotting them on a chart; or celestial navigation, measuring the altitude of celestial bodies and computing lines of position through the process of sight reduction. Fixes could also be established, albeit with less accuracy, by discerning the bearing to stationary submarine bells. The location and unique characteristics of the bells were published in the List of Lights. Another tool for discerning a line of position was the sounding lead, by plotting observed soundings on the chart and comparing results to known bathymetric contours.

Between fixes, position was estimated by dead reckoning; this process advances an estimated position from the last fix by course and speed, with a correction for the effects of current and tide factored in. Course was measured by compass, the H-Class having both a magnetic compass and the newly invented gyrocompass. No information regarding the method used for the measurement of speed has been found; however, estimated speed by shaft RPM is assumed, as deck logs refer to speed as RPM.[176] Compared to modern navigation, position calculations performed on H-Class boats were primitive and prone to navigation errors.

Submerged navigation was based solely on dead reckoning, or as some navigators referred to it "By guess and by God" which was essentially guessing the ship's position and praying that they were correct.[177] Several factors influenced the accuracy of this method; the

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[176] NARA, D.C., *H-2* Deck Log.
[177] Carr, *By Guess and by God*, xiii.

original position on submerging needed to be understood, speed and course had to be accurately measured, and the effects of tide and current factored in. Errors in any of these factors caused a circle of uncertainty which grew in diameter with speed and time. Theoretically, when the circle got near a navigation hazard the boat was brought to periscope depth and a fix obtained, resetting the circle to the expected accuracy of the fix. Based on the significant number of groundings in the early days of submarine navigation, navigation practice was likely less disciplined.

The periscope was critical for both navigation and weapons delivery. Two periscopes were installed in the H-Class submarines, one in the conning tower and the other in the control room just aft of the conning tower. The periscopes could be rotated but were of fixed height and could not be raised or lowered.[178] The viewing aperture at the top of the control room periscope was nine inches (23 cm) taller than the conning tower periscope, allowing an unobstructed view from the prior.

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[178] NARA D.C., Bureau of Construction and Repair ltr. reguarding new periscope for USS *H-1*.

A name plate, recovered by fishermen in Mexico indicates that one of the periscopes in *H-1* was manufactured by the Keuffel and Esser Company of New York was a retrofit dated 1917, (Figure 72).

Figure 72. *H-1* periscope name plate. Courtesy of: Alfredo Martinez.

Another *H-1* periscope artifact, the portion of the periscope tube containing the telemeter lens etched with vertical and horizontal gradations, was returned by local fishermen in Mexico. The gradations indicated degrees of true field (Figure 73). Range to an object was critical both in navigation and weapons employment and the telemeter allowed submariners to estimate the range to a ship or structure based on the number of degrees of field occupied by the object, if the target object's height or length were known. It also provided a method of measuring bearings to terrestrial objects; these bearings could be referenced to either the magnetic or gyrocompass, and could then plotted on the navigation chart, to establish or "fix" ship's position.

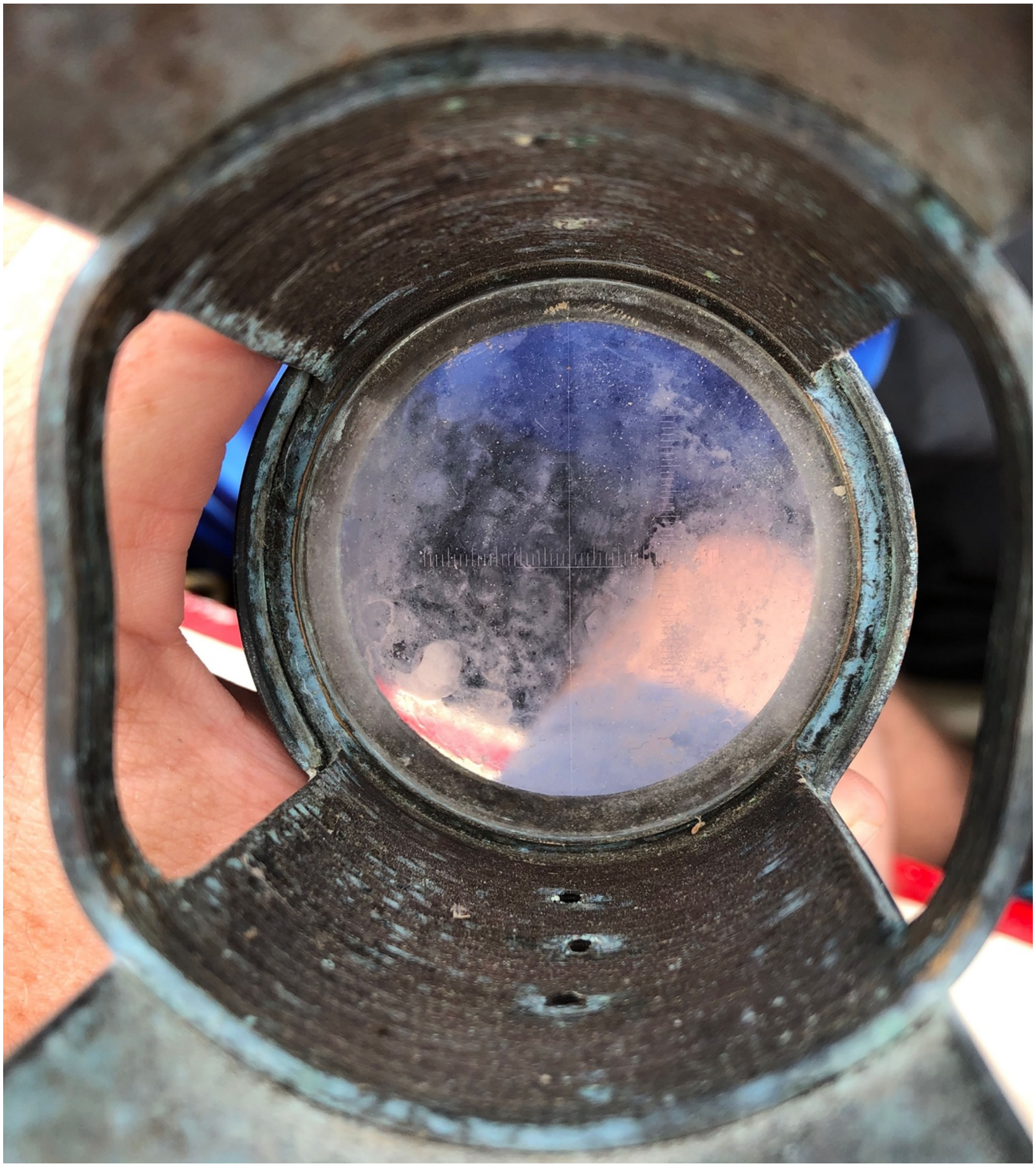

Figure 73. *H-1* telemeter lens. Courtesy of: Paul Gottfried.

Weapons

As their main battery, H-Class boats carried torpedoes and also carried small arms, usually rifles and pistols for ship's defense and boarding parties. Stowage was available for eight torpedoes; however, four were normally carried in peacetime.[179] Records for *H-1* show that, in March of 1920, it was caring four Bliss-Levitt Mark 7 Mod 4 torpedoes, six Springfield rifles, three Colt pistols and approximately 2500 rounds of ammunition.[180] Additional small arms were issued to some H-Class boats, what appears to be a Lewis light machine gun can be seen mounted on the port side of the control room in *H-5*; the machine gun may have been carried to fulfil specific mission requirements (Figure 74).

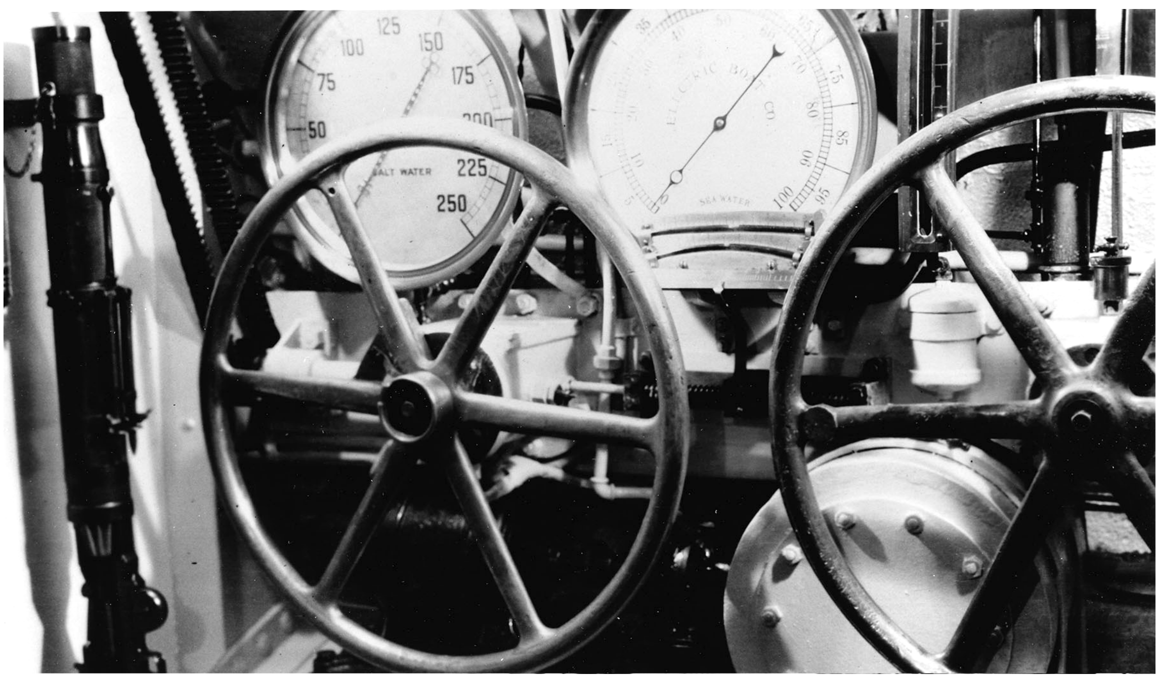

Figure 74. *H-5* Lewis Gun. Courtesy of: NARA.

[179] U. S. Navy, *Gunnery Instructions*, 113.
[180] NARA D.C., *H-1* Sinking BOI. 31.

Torpedoes were loaded into the boat via the torpedo loading hatch located forward of the sail. In preparation for loading torpedoes, a temporary skid was mounted in the hatch. A crane was used to lift the torpedo onto the skid where it would be secured by straps. A strap would then be wrapped around the back of the torpedo and the handling crew would lower the torpedo into the torpedo room, using the deck mounted davit and block and tackle (Figure 75).[181]

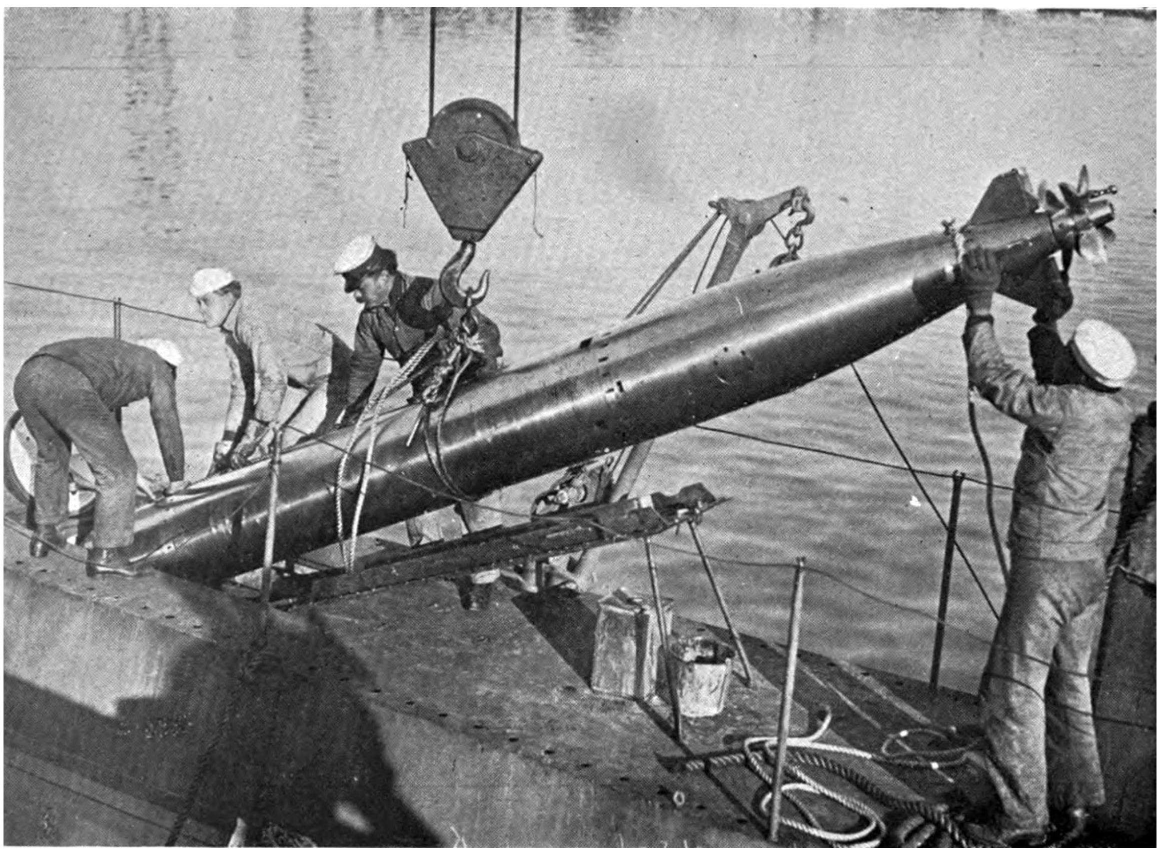

Figure 75. *K-5* loading torpedo. From: Hoar.

[181] Hoar, *The Submarine Torpedo Boat*, 100.

If eight torpedoes were to be carried, four were loaded into the tubes using the chain falls and rails seen in the upper part of the image (Figure 76). Prior to loading either an exercise or explosive warhead would be fitted, maintenance checks conducted, and the torpedo coated liberally with grease to protect it. Depending on circumstance (war or peacetime) spare torpedoes could be stowed, with or without warheads installed, in the cradles seen at the bottom of Figure 76.

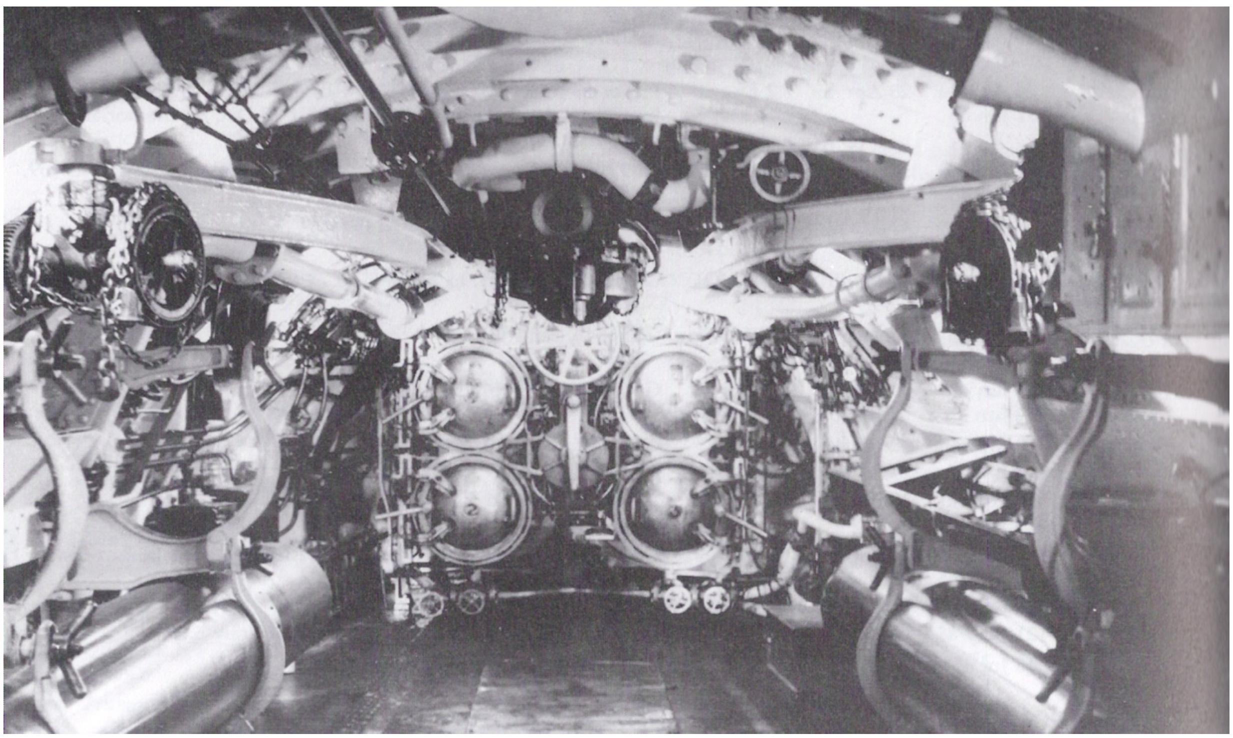

Figure 76. *H-5* Torpedo Room. Courtesy of: NHHC.

In the center of the image, between the breech doors, is a large handwheel and below it a hand crank. The handwheel moved the bow cap forward, unseating it from the tube muzzles, and allowing it to be rotated into firing position with the hand crank. Opening the bow cap flooded all four torpedo tubes, thereby wetting all tube loaded torpedoes. As with the D-F Class boats the bow cap was designed to have two diagonally opposed tubes open simultaneously, allowing them to be fired in rapid succession (Figure 77). Any torpedo that was tube loaded, and not fired, needed to be pulled from the tube for maintenance before it could be returned to the tube for storage.

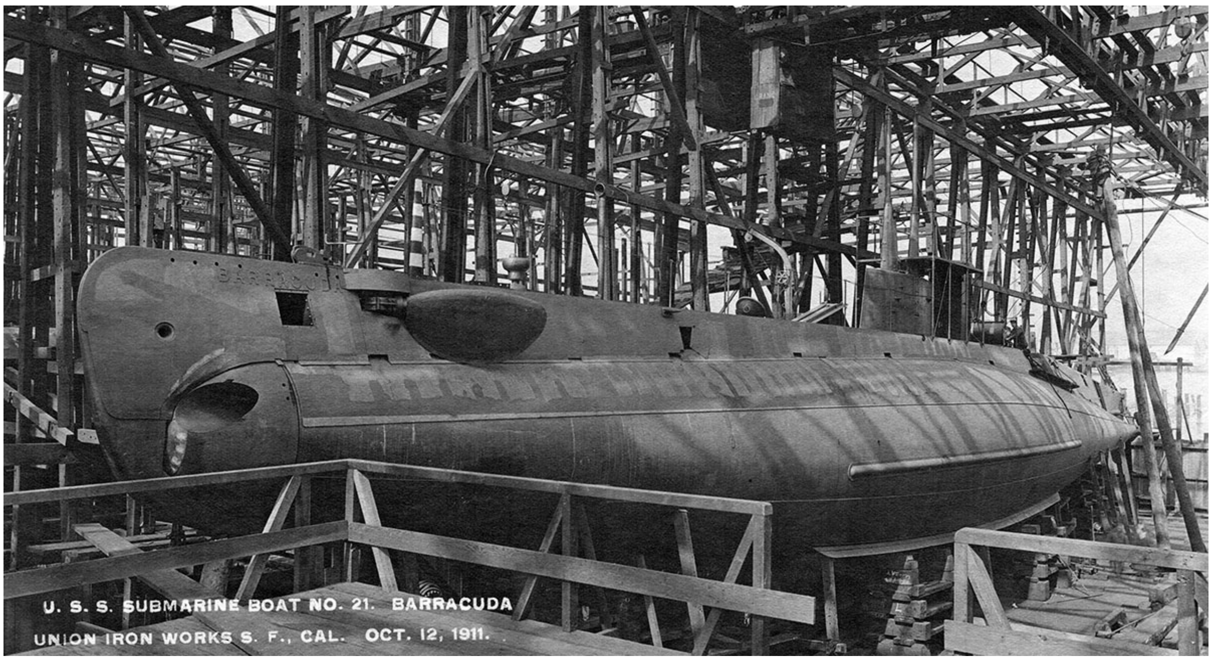

Figure 77. *Barracuda* bow cap. Courtesy of: Vallejo Naval & Historical Museum.

The torpedo tubes functioned much like a breech-loading smooth-bore cannon. Both cannon and torpedo tube were crew-served weapons, requiring a dedicated team to load and fire them. They differed in the stored energy used to impulse the projectile; cannons used gunpowder, and torpedo tubes used compressed air. Lastly the torpedo after firing was self-propelled, whereas the cannon ball was not. A significant concern for a submarine firing a torpedo was the necessity to manage the post-launch environment of the torpedo tube for the sake of maintaining diving trim.

Figure 78, developed using L.Y. Spear's 1911 patent # US997713A, is provided to illustrate the torpedo tube firing cycle. This illustration presents a simplified schematic depiction of a single tube and the associated plumbing for air and water.

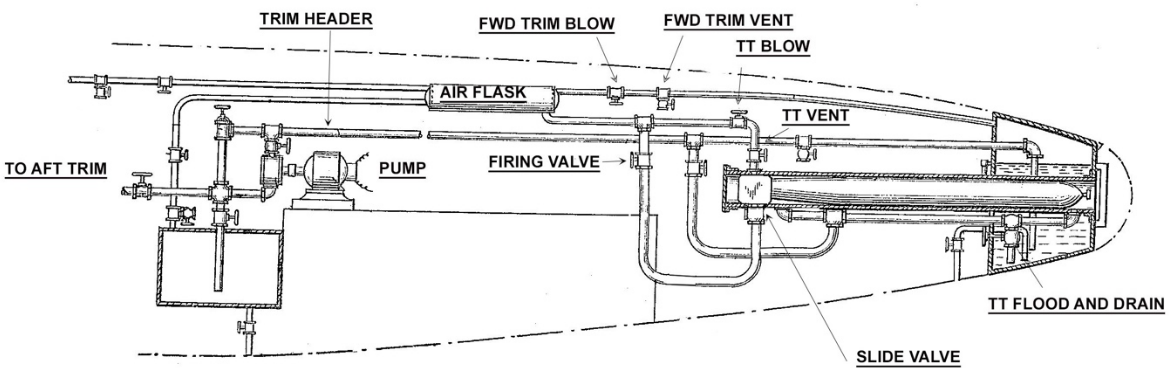

Figure 78. Torpedo tube plumbing schematic view. Author after Spear.

In preparation for firing, all of the torpedo tubes needed to be flooded. Several methods existed to do so: flood from the forward trim tank, or flood direct from the sea from either via a sea valve or by unseating the bow cap. The method effecting trim the least was to flood the tubes from forward trim; to do so, the vent valves located above the tubes were opened as were the flood valves, and water flowed from the pressurized forward trim tank into the tubes until it came out the vents.

To fire the tube, compressed air was released from its flask by the firing valve porting it through the slide valve at the back of the tube, launching the torpedo. As the torpedo left the tube, water flooded the tube, thereby compensating for the loss of weight of the now-running torpedo. Before the tube could be drained it was necessary to rotate and secure the bow cap, closing the muzzle of the tube. Water from within the tube could then be blown from the tube back into the forward trim tank and shifted to appropriate trim tanks, via the trim header, by either pumping or blowing to maintain diving trim.

Most torpedoes fired in peacetime were exercise weapons. Torpedoes and targets, the latter usually a ship or another submarine, were neither cheap nor expendable. To facilitate repeated use of both, the exercise torpedo warhead section was filled with water instead of an explosive charge, and the torpedo was designed to float when the run was complete.

The boats were often responsible for recovering their own exercise torpedoes at sea. Just as with loading torpedoes in port, the davit and strap method was used to recover exercise torpedoes after their use. Once the torpedo was located, and if no boat was available from the target ship, an able swimmer jumped into the water with a rope to lasso the torpedo, a task which was likely complicated by the well-greased state of the torpedo. Once captured, the torpedo was lifted aboard using the hand-cranked winch on the torpedo loading davit where it was either lashed to the deck or returned to the torpedo room (Figure 79).

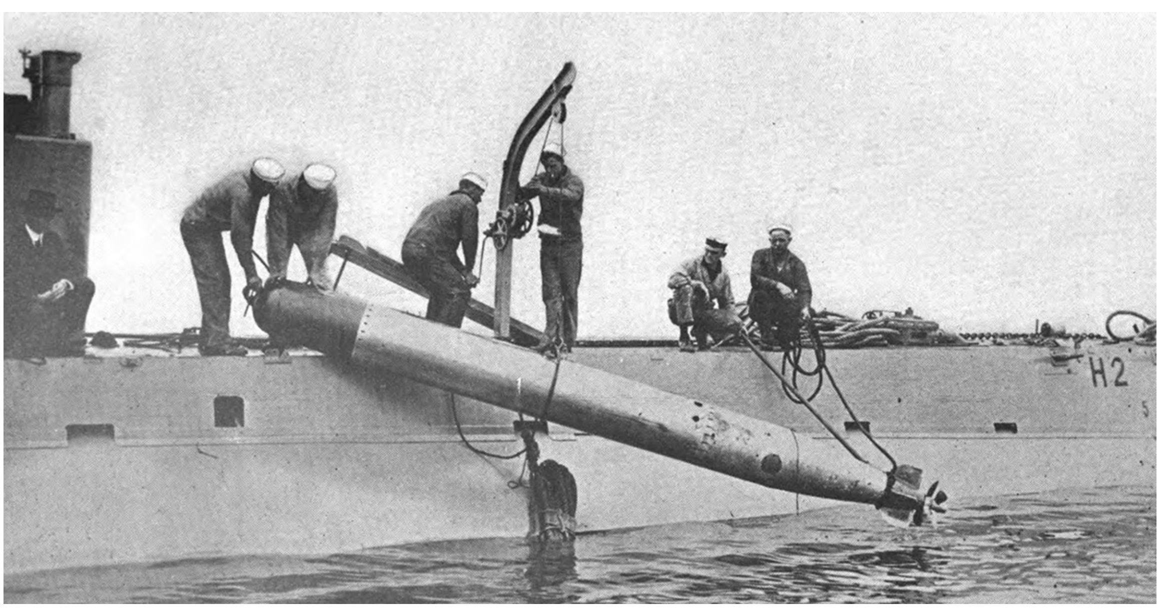

Figure 79. *H-2* retrieving exercise torpedo. From: Hoar.

A rather complex geometry, called the fire control problem, had to be solved in order to properly aim a torpedo to hit a moving target. The torpedo had been in use in surface combatants long before its employment in submarines and torpedo directors (simple geometrical calculators) were developed to solve the surface fire control problem. The earliest known reference to these mechanical computers is presented in the 24 April 1885 edition of *Engineering,* curiously, it does not appear that this technology was directly transferred to submarines.[182]

In the early boats, solving the submarine fire control problem was done by eye, with the captain leading the target, much as a trap shooter leads a clay pigeon.[183] The stadimeter allowed the measurement of the number of degrees per minute the contact was moving across the field of view; this information was crucial to calculating the angular offset necessary to accurately place the torpedo. Shooting by calibrated eyeball was a developed skill at which some officers excelled and others did not.

Calculation aids in the form of tables were developed to augment the mental gymnastics necessary to hit the target. Torpedo directors and upgraded periscopes improved the shooting odds. Early submarine torpedo directors were initially simple circular slide rules developed to speed up and improve the accuracy of the torpedo solution. The first design that mechanically integrated the periscope and torpedo director, patented by Gregory Davison in 1909, was assigned to Electric Boat Company, but direct evidence of its use has yet to be substantiated.[184]

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[182] 'The Autobiography of a Whitehead Torpedo - No. XI', 414-415.
[183] Hinkamp,'Submarines - Improvements', 178-179.
[184] Davison, 'Torpedo-director'.

Communications

The initial H-Class boats were built with radio sets. A 1916 drawing references the 500-watt Marconi set as the "old" set, with the drawing possibly developed to facilitate installation of an improved set.[185] These radios were capable of transmitting and receiving Morse code messages over short distances. The antenna needed to be rigged up after surfacing and un-rigged and stowed below deck before diving. Visual communication by signal flag during daylight and flashing light at night were the common line-of-sight communication methods used as they required less effort than setting up the radio antenna.

Submerged communication on the first three H-Class boats relied on the submarine bell system which allowed for limited communication between similarly equipped ships and submarines.[186] The bell was mounted in the engine room between the air compressors and the main power pumps, its clapper pneumatically activated. The more effective Fessenden oscillator, the ancestor of modern sonar, would be installed on the later boats.[187]

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[185] NARA College Park, MD, *H-1* Marconi Radio.
[186] See supra pp. 92.
[187] Cathcart, 'Inter-Ship Communication by Submarine Signaling'.

Habitability

Habitability on submarines was apparently the least concern of naval architects. Although propulsion, navigation, weapons, and communications systems are meticulously fit into the boat naval architects seemed to overlook the reality that the people needed to operate the boat also needed to live on board. Consequently, crew accommodations were so spartan that the early classes of submarines came to be known as "pigboats." Figure 80, on the following page, depicts the cramped life aboard the boats.

The H-Class boats typically sailed with a crew of 25, comprised of a Commanding Officer (CO), Executive Officer (XO), and 23 enlisted men. The officers each had their own bunks, with privacy curtains, located in the aft part of the torpedo room, and they shared a lavatory, mounted on the aft port bulkhead. The enlisted hands slept primarily on pipe-and-canvas bunks in the forward battery compartment. The boat was issued 18 mattresses when it was built, with the CO and XO each having their own; this left 16 mattresses for the 23 enlisted men to share.[188] When underway the crew was broken up into watch sections, with part of the crew sleeping or attending other tasks while the section on watch operated the boat. At watch change, the oncoming watch was awakened, ate a meal, and relieved the men on watch. The men going off watch ate their meal and crawled into the still-warm beds of the men who relieved them, a practice known as "hot racking". The Chief Petty Officers (CPOs) may have had their own bunks and it is likely that some of the men slung hammocks where they could.

[188] NARA D.C., *H-3* Allowance List.

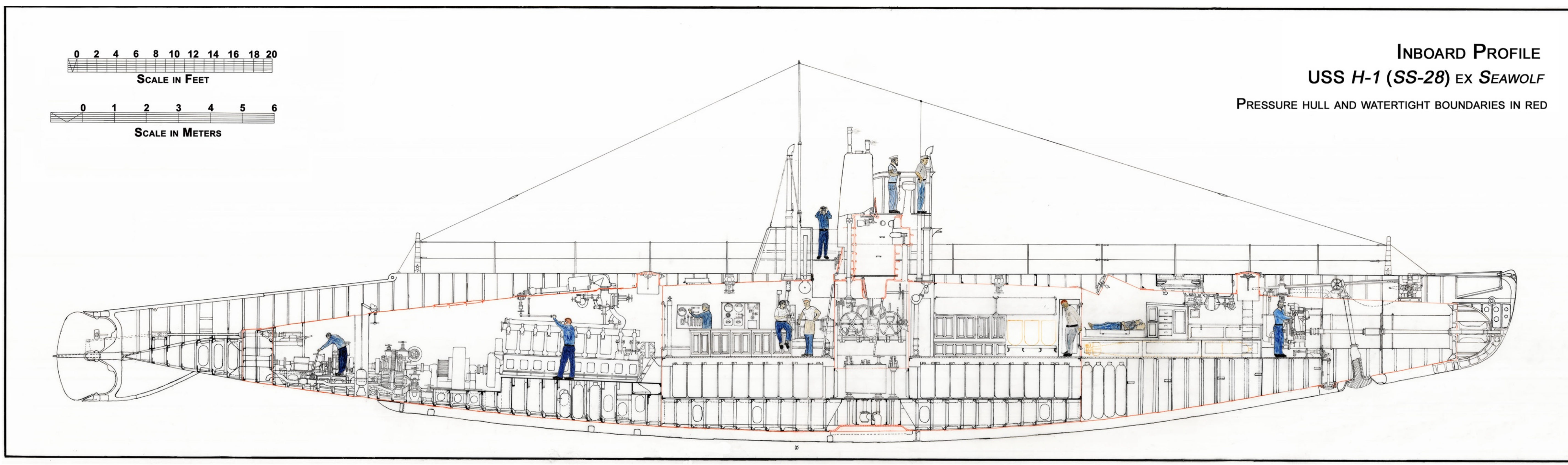

Figure 80. Life aboard USS *H-1*.

Author after U.S. Navy.

Cooking and dining took place in the aft battery compartment. Meals were eaten communally on the table amidships, with the men seated around it on folding camp stools. It appears that the officers took their meals with the men, contrary to the practice on surface ships and later submarines. The food, much of it canned, was prepared on the electric range in the forward port corner. Fresh food would not have lasted long. Designed for short coastal missions, the boats were equipped with an ice box but not refrigeration. The only sink on the boat was located near the galley range, on the forward port bulkhead.

The H-Class boats were originally designed with two toilets (heads) located on the port side of the forward battery compartment to provide relief while submerged.[189] When the boat was surfaced, typically, the men took a walk topside. It is questionable if the crew's head was ever installed, as a later drawing shows the radio located in the space and does not show a second head on the boat.[190]

The head on a submarine is a necessarily complex device that must perform the function of a toilet, flushing waste overboard, while keeping the sea from flooding in (Figure 81).

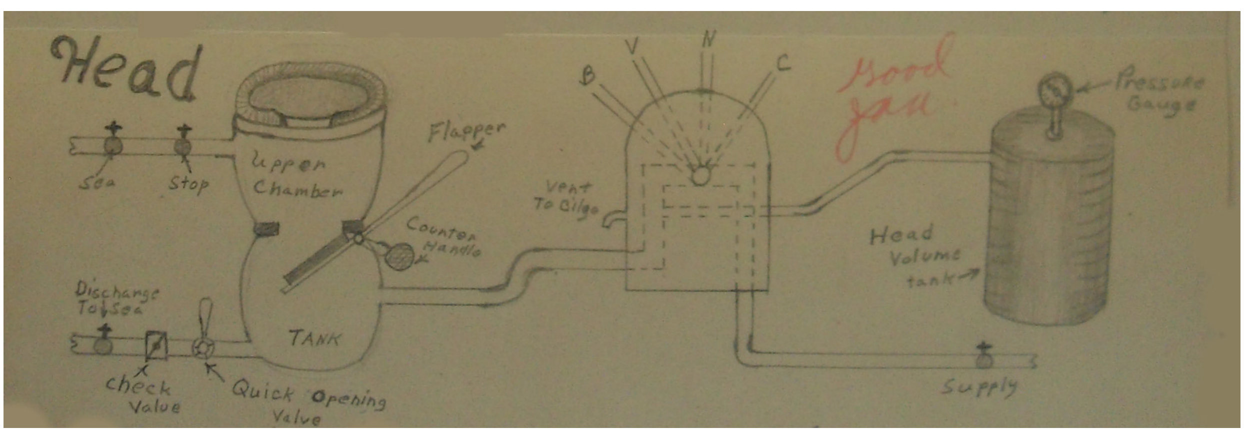

Figure 81. USS *O-1* Head. Fretz, Courtesy of: Ric Headman.

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[189] NARA College Park, MD, *H-1* General Plans,1913.
[190] NARA College Park, MD, *H-1* General Plans, 1918.

Research has thus far failed to uncover a drawing of an H boat head; however, a drawing from the qualification book of Robert E. Fretz details the head on USS *O-1* and is considered comparable. Flushing the head required the skillful manipulation of the valves in proper sequence, and failure to follow the procedure exactly could result in the operator wearing the contents of the bowl or water coming into the boat.

Fresh water was a rare commodity, with approximately 350 gallons (1325 l) carried, and the boats having no method to distil it from sea water. Ships plans do not differentiate between the distilled water necessary to make up battery electrolyte solution lost during normal operation, and general-purpose potable water. Were the boat at sea for 10 days each man's daily share of water would be 1.4 gallons (5.3 l). Out of that share would first come battery water, were that not carried separately, followed by water for cooking and rinsing dishes, leaving barely enough for drinking, let alone personal hygiene. Bathing was rare due to the paucity of fresh water, and this coupled with an environment that was always damp, often hot, and filled with pungent machine and human odors gave submariners a unique bouquet. When the opportunity presented itself, saltwater baths or quick swims were welcome luxuries.

While spartan, some aesthetically pleasing features were likely fitted in the Union Iron Works boats. A memorandum for joiner work called for primavera, ash and Port Orford Cedar to be used for joinery. The specifications require the work to be plain and without molding or fluting with smooth, well rounded edges. The memorandum mentions many components which would have been fabricated in wood, among them china lockers, a chart table with drawers, chests, lockers, and berth fronts.[191] Unfortunately, research did not uncover any plan detailing the joinery and its location.

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191 San Francisco Maritime National Historic Park, H-Class Submarine Joinery.

There was no privacy on the boats. The tight quarters and communal messing and berthing required men who could live and work elbow to elbow in an often-stressful environment and maintain their composure. Submarining lays both soul and body bare for all shipmates to see; the modern concept of 'safe space' simply did not exist (Figure 82).

Figure 82. Work in the Dog Watches, HM Submarine *L7*
Courtesy of: F. Dodd © IWM Art. IWM ART 918

CHAPTER V

OF STEEL BOATS AND IRON MEN

The first H-Class submarines were constructed for the American Navy by shipyards subcontracted to Electric Boat. Following the outbreak of the First World War, Electric Boat sold boats or licensed building rights to England, Russia, and Italy. Why the H-Class export design (EB-602) and not a newer class of submarine was sold is likely a simple matter of timing; however, some historians have speculated it was a result of government restrictions enacted to protect the latest submarine designs.[192]

The early months of the war saw submarines used effectively for the first time. On 5 September 1914, the British Scout Cruiser *HMS Pathfinder* was torpedoed by Germany's *SM U-21*, the first use of a submarine launched self-propelled torpedo in battle. It was the sinking of three Royal Navy cruisers by a single German submarine later that same month that created a sense of urgency among the Allies to rapidly bolster their own submarine forces. On 22 September *SM U-9*, under the command of *Kapitänleutnant* Otto Weddigen (1882-1915), was operating off the Dutch coast when three aged and slow-moving British light cruisers were sighted. *U-9* went to battle stations and fired a single torpedo, hitting *HMS Aboukir.* The torpedo caused one of *Aboukir*'s magazine to detonate. The crew of the fatally damaged and sinking *Aboukir*'s hastily abandoned ship. HMS *Hogue* closed on *Aboukir* and launched boats to rescue the men in the water and was promptly torpedoed. *HMS Cressey* then sped in to provide aid, running a zig-zag course and firing its guns, only to be struck by two well placed torpedoes. Weddigen noted that the entire action took less than an hour.[193] Over 1400 Officers and Men

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[192] Friedman, *U.S. Submarines Through 1945*, 78.
[193] Weddigen, *Source Records of The Great War*, 296-300. Cmdr. Nicholson (RN) presents a survivors view of the day in the same chapter.

were killed and three warships totaling 36000 tons were lost to a single adversary, a submarine crewed by 29 and displacing a mere 600 tons. Submarine warfare had come of age.

Over the next nine years H-Class submarines would be built in the United States, Canada, and England (the last was assembled in the Soviet Union), and serve in the navies of the United States, England, Canada, Italy, Chile, Holland, Germany, Russia and the Soviet Union. This chapter provides a historical outline of their construction, operation, and final disposition. The exploits presented herein provide only a small sampling of the rich heritage of these boats and the brave men who sailed in them.

The American Boats

Seawolf, *Nautilus*, and *Garfish*, renamed *H-1*, *H-2*, and *H-3,* were laid down in the early spring of 1911: *Seawolf* and *Nautilus* at the Union Iron Works in San Francisco and *Garfish* at the Moran Company in Seattle. Union Iron Works had previous submarine construction experience having built the A-Class boats *Grampus* and *Pike,* and the Moran yard was busy building *Pickerel* (*F-3*) and *Skate* (*F-4*).

The boats were built in peacetime with little impetus for immediate completion and two years passed before they were launched (Figure 83). *H-1* was christened on by the niece of the yard's president on 6 May 1913. Miss Lesley Jean Meakin of Montreal,

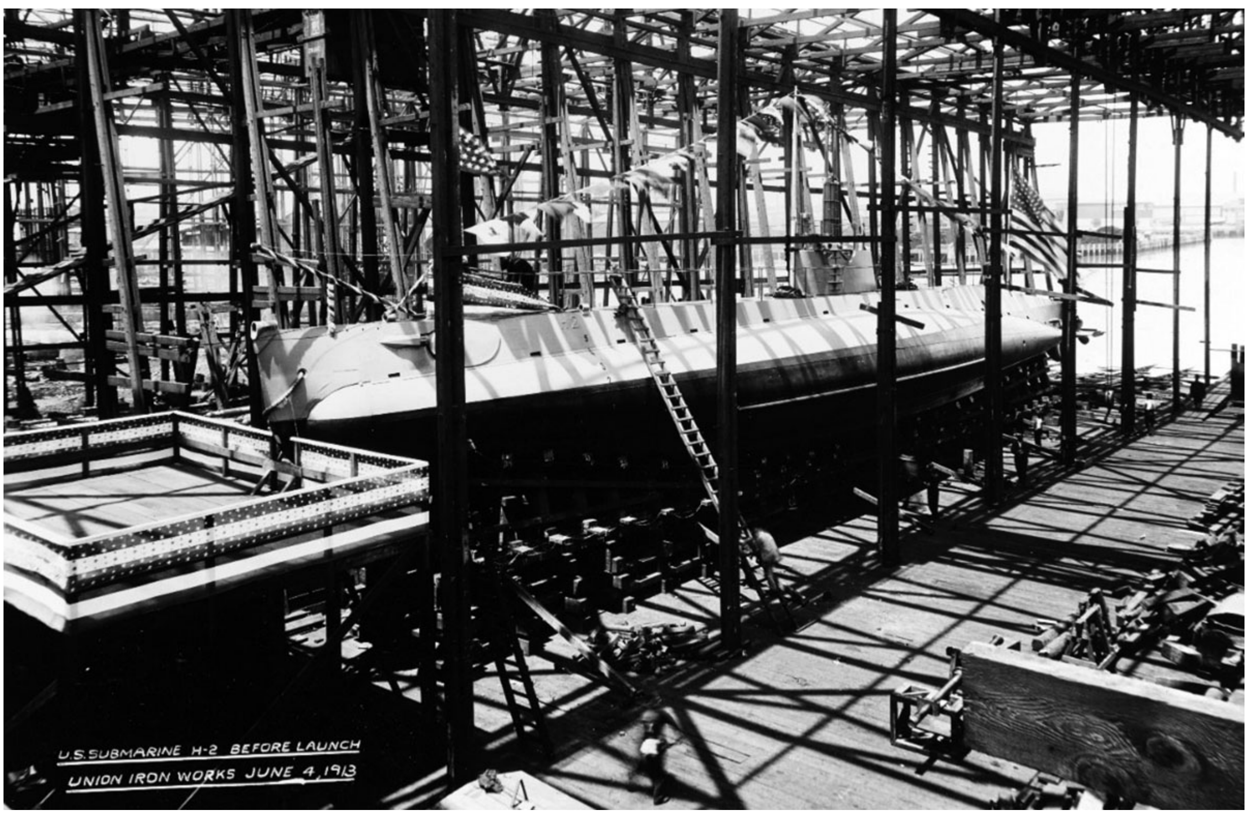

Figure 83. *H-2* Ready for Launch. Courtesy of: NHHC.

a British subject sponsoring the boat; local society pages reported this *faux pas,* allowing a foreigner this honor, as a shattering of naval tradition.[194] That aside, *H-1*'s launching, as well as that of its sister ships *H-2* and *H-3,* was uneventful. The final assembly, also known as fitting out was accomplished with the boats floating dockside. This accomplished two purposes; it opened valuable yard space for new projects and facilitated waterborne testing of the submarine's systems. Following the fit out, *H-1* and *H-2* were delivered to the Navy and commissioned on 1 December 1913 at Navy Yard Mare Island in Vallejo, California. *H-3* was delivered at Navy Yard Puget Sound in Bremerton, Washington and commissioned on 16 January 1914.[195] While the crew would have already been aboard for training and trials, commissioning a ship symbolizes its birth as a warship in its own right.

The authorized crew for H-class submarines initially numbered only 21, consisting of two officers and 19 enlisted men, although, additional trainees were commonly assigned. The enlisted men were of three rates or specialties: Gunner's mates (6), Electricians (4), and Machinist's mates (9). In 1915 an additional five men were requested to better spread the challenging workload.[196] A Chief Gunner's mate was assigned as the Leading Chief on the boat, responsible to the captain for the day-to-day running of the submarine. Submariners refer to the Leading Chief as Chief of the Boat, and in the vernacular of the service COB as in corn cob.

Training for enlisted submariners on the West Coast was provided at Camp Richardson, using *Grampus* and *Pike* as school ships. The school, located on Coronado Island in San Diego, CA was established around 1912 in response to the need for more qualified men as the number

[194] 'Navy Tradition is Shattered at Bay', *Oroville Daily Register*, 7 May 1913.
[195] Naval History and Heritage Command, Ships Record.
[196] NARA D.C., Request for increased enlisted manning on H-Class submarines.

of Pacific Fleet submarines grew.[197] The school moved to San Pedro, California when the submarine base became operational around 1917. San Pedro, while not yet a base, became a submarine homeport in 1914.

H-1 and H-2 along with their tender, the newly modified monitor, USS *Cheyenne* arrived in their homeport of San Pedro on 8 February 1914.[198] In late April the *H-3* was towed from Bremerton to San Francisco Bay and following a stop at the Mare Island Navy Yard it traveled in convoy with the tug *Iroquois* to San Pedro where it joined the H and F-Class submarines. The submarines were moored alongside the pier while *Cheyenne* was absent during the U.S. occupation of Vera Cruz, Mexico in the Spring of 1914.[199]

Submariners train constantly for a war they hope will never happen. *H-1*'s operations reports from the years preceding the U. S. entry into the First World War indicate the crew regularly conducted casualty drills, tested the engineering systems, practiced operating the ship on the surface, awash, and submerged, and fired exercise torpedoes.[200]

Maintenance also played a large part in the submariners' daily routine, with the crew and support staff from the tender making regular repairs, and occasionally tackling major breakdowns. In September 1915 *H-1*'s crew replaced the original crankshaft of the port main engine, and then the new crankshaft failed in February 1916, both failures likely due to manufacturing flaws.[201] Major maintenance and modifications were performed at the Puget Sound Navy Yard, the submarines' home yard, requiring a long ocean transit north to

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[197] 'Submarine Training School', 46.
[198] 'Ships In and Out', *Los Angles Express*, 9 Feb. 1914.
[199] 'Two Submarines Arrive as Cheyenne Leaves Port', *Los Angeles Express*, 13 May 1914.
[200] NARA, USS *H-1* Operations Report.
[201] NARA, USS *H-1* Port Main Engine Crankshaft Failure Investigation.

Washington, or at the Mare Island yard. The submarines' home yard was eventually changed to Mare Island in 1916.

As well as getting underway for training operations and maintenance, the submarines frequently visited port cities up and down the coast, goodwill visits which provided Americans with their first look at these unique vessels. In preparation for one tour in 1915 the H-Class boats and their tender *Cheyenne* departed San Diego and sailed up the coast to San Francisco to participate in Fourth of July festivities. On 30 June *H-3* ran aground off Point Sur while navigating at night in a dense fog (Figure 84). Although firmly aground, the boat rested in a rocky cradle and calm seas kept it from being damaged. *Cheyenne* attached a tow cable, took a strain, and on 1 July, *H-3* was successfully refloated and headed north under its own power.[202] Navigation errors plagued the class with *H-1* and *H-3* grounding several times over their careers.

Figure 84. *H-3* on the rocks. Courtesy of: NHHC.

[202] 'U.S. Diver and Crew Hurled off Rock', *San Francisco Examiner*, 1 Jul. 1915.

In May 1916 *Cheyenne* and the three H-Class boats arrived the Puget Sound yard for modification and repairs which were planned before the change of home yard. A repair list authorizing work on *H-1*, forwarded by the shipyard commander, approved several maintenance actions, including work on the main engines, fuel oil and exhaust systems and modification to the battery well drain system, the latter a likely response to the loss of *F-4*.[203] The overhaul ended up being more thorough and more complex than the planning document detailed. Among many significant repairs, the engines, motors, main power pumps, batteries, gyrocompass and one of the two magnetic compasses were removed for overhaul or modification.[204] The scope of the overhaul was likely an indicator that America was putting its Navy in a stronger position to go to war.

On 13 October 1916, with the overhaul nearly complete, *H-1* sailed from Bremerton to Seattle to take on fuel; on the return voyage it ran aground while navigating in dense fog. *H-1* was not damaged in the grounding. The subsequent investigation revealed that its magnetic compass had not been compensated and the gyrocompass, overhauled in February 1916 at Mare Island, was not connected to power, as the shipyard had not completed work. [205] The need to overhaul the gyro twice in six months calls into question the reliability of this relatively new technology. No action was taken against *H-1*'s commanding officer in this grounding incident.

Once overhaul work was completed *Cheyenne* and the three H-Class submarines departed Bremerton in early December 1916 for San Pedro with planned port calls in Port Angeles, Neah Bay, and Aberdeen, Washington; Astoria, and Coos Bay, Oregon; and Eureka, California. The purpose of the visits was to explore the feasibility of establishing a submarine base along the

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[203] NARA, Navy Yard Puget Sound Authorization for Work.
[204] NARA, USS *H-1* Wing Point Grounding Investigation, 9.
[205] NARA, Bureau of Navigation ltr. Regarding overhaul of H-Class Gyro Compasses.

northern coast. The visitors were well received in each port; however, the trip south did not go well.

After clearing Puget Sound and while off Cape Flattery, *H-3* suffered an engine failure and limped south on a single engine. On 10 December, prior to crossing the Columbia River bar, *H-3*'s remaining engine failed requiring *Cheyenne* to tow the boat into Astoria. A newspaper account of the engineering casualties relates that the engines failed as a result of over speed after a man fell into the switchboard when the vessel was operating in heavy swells, disrupting electrical control of the engines.[206] This cannot be discounted as a possible cause, but no evidence has been found supporting the existence of electrically operated governors for the diesels installed in H-Class submarines.[207] Therefore, it is also plausible that *H-3*'s engine simply over sped when the screws came out of the water in a pooping sea. When this occurs engine speed increases rapidly as the resistance to screw rotation is lost, requiring the operators to immediately shut the throttle.

H-1 and *H-2* departed Astoria without *Cheyenne* and *H-3* (they remained in Astoria to repair the latter's engines) and made the roughly 200 nautical mile (370 km) trip south to Coos Bay, arriving the morning of 12 December. The ships' officers were shown the local port facilities, presented briefings on available machine shops and repair facilities and enjoyed a banquet dinner with the local delegation.[208] Members of the Coast Guard stationed in Marshfield were given a tour of the boat's interior, a privilege not extended to civilians. The local paper presented a positive report on the visit, noting the only negative as the lack of a sheltered torpedo range for the submarines. *H-1* and *H-2* departed the Marshfield docks the morning of 13

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[206] 'Three of America's Diving Beauties in Harbor at Astoria', *Oregon Daily Journal*, 11 Dec. 1916.
[207] Shane,'Nurnberg Two-Cycle 450-B.H.P. Heavy-Oil Engines'.
[208] 'U.S. Submarines Visit Coos Bay', *Coos Bay Times*, 12 Dec. 1916.

December bound for Eureka, CA, which was to be their last port before returning to San Pedro.[209]

Cheyenne and the repaired *H-3* departed Astoria the night of 12 December and steamed south along the coast to meet *H-1* and *H-2* at Eureka. During the morning of 14 December, due to a combination of dense fog and navigational errors, *H-3* went hard aground on a shallow beach north of the entrance to Humboldt Bay. The beach was exposed to the heavy onshore swell common along the Pacific coast, and the swell was breaking heavily, pushing the stranded boat ashore and rolling it from beam to beam. *Cheyenne* responded to *H-3*'s SOS call but was unable to get close enough to pass a tow line due to the shallow depths. After many harrowing hours, battling both an electrical fire and flooding in the battery well which generated chlorine gas, *H-3*'s crew abandoned ship. They were rescued by the local Life Saving Service crew using a breeches buoy.[210]

Over the next month numerous attempts were made to pull the stranded submarine seaward into deeper water, but each met with failure. In a last-ditch effort, the Navy mobilized additional salvage forces which included the protected cruiser *Milwaukee* and the tug *Iroquois.* A plan was developed whereby *Cheyenne* anchored with both bower anchors in deep water and a towline from its towing engine was passed to *Milwaukee* which anchored previously outside the outermost line of breakers. The cruiser was not equipped with a towing engine so heavy towing gear connected *Milwaukee* directly to the stricken submarine. To prevent *Milwaukee* from drifting ashore in the current while it took a strain on the cable to *H-3*, the tug *Iroquois* was connected to *Milwaukee* to keep its head from falling off to the south (Figure 84).

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[209] 'Submarine Men Laud Coos Bay', *Coos Bay Times*, 13 Dec. 1916.
[210] Searle and Curtis, *Undersea Valor*, 51-82.

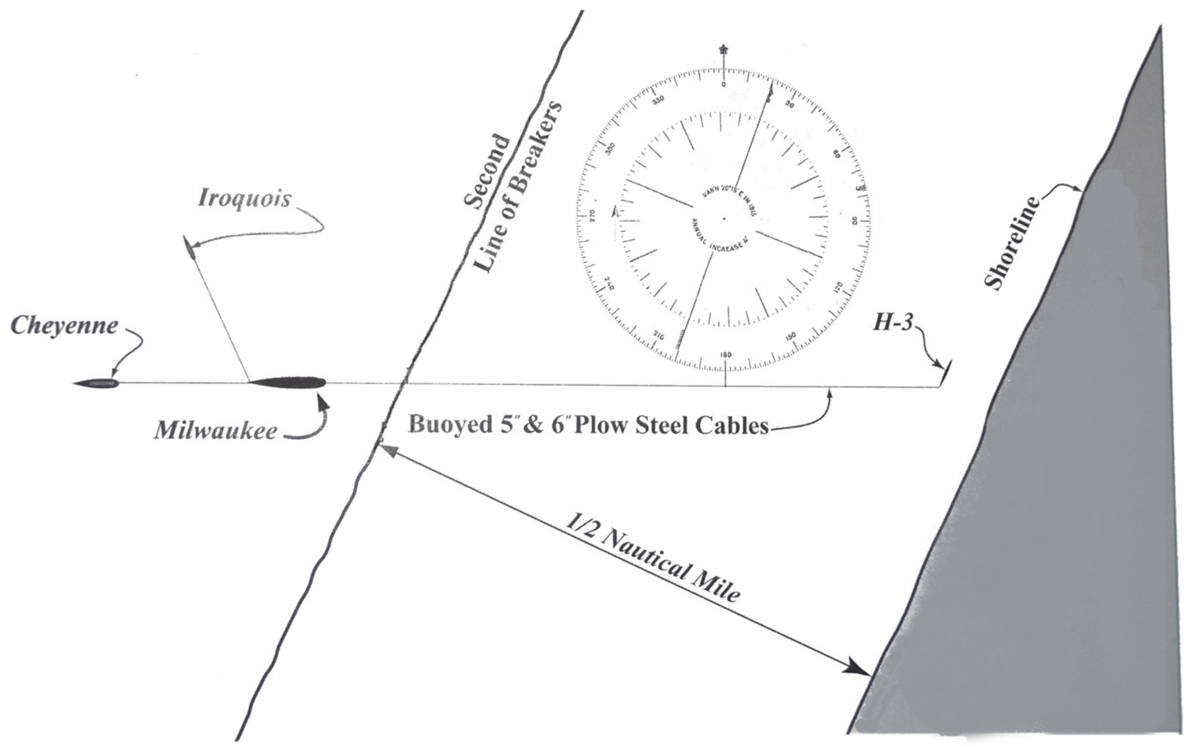

Figure 85. *H-3* Towing Plan. From: Searle and Curtis.

After several unsuccessful attempts, calamity struck in the early morning hours of 13 January. The ships pulled through the rising tide and as the tide turned began to slowly ease the strain. *Milwaukee* began to lose its head to port, and *Iroquois* could not bring it back to starboard. The cruiser tried unsuccessfully to slip the towline to *H-3* but the of lack of installed towing gear required the cables to the submarine be shackled and these shackles now could not be opened. Finally, the towing hawser from *Iroquois* parted and *Milwaukee* grounded with its beam to the sea. The crew was rescued using the breeches buoy and a surf boat, but the ship was a total loss.

H-3 was still stranded on the beach. James Fraser, a principal of the Mercer-Fraser Company, a local salvor of good repute, submitted a proposal to salve *H-3* for the sum of $18,000. Fraser proposed transporting the boat across the beach on log rollers, a distance of approximately .5 mile (.8km) and launching it into the protected waters of Humboldt Bay. The Navy accepted the bid and Fraser went to work, first lifting *H-3* which was partially buried in the soft sand and then laying a plank road and shifting it across the spit on rollers (Figure 86). *H-3* was decommissioned with a small crew assigned to look after the Navy's interests during the salvage.

Figure 86. *H-3* overland transit. Courtesy of: NHHC.

The Mercer-Fraser Company contract proved to be a good value with the job completed earlier than promised and under budget. Shortly after America declared war on Germany, *H-3* was launched for the second time, with Miss Charlotte Fraser, the contractor's daughter, doing the honors on 20 April 1917.[211] *H-3* was towed to Mare Island Navy Yard for repairs.

Although placed back in commission in August 1917 *H-3* remained out of service until the summer of 1918, as parts and personnel were prioritized for operational vessels.[212] The submarine spent the war years and the remainder of its service life on the west coast, conducting operations and assigned for a time as a training vessel at the submarine school in San Pedro.[213]

On 8 April 1917 the Pacific Fleet was mobilized for war. H-1's war diary reflects that in preparation for hostilities the ship was readied for sea, warheads were installed on torpedoes, and the boat was fully provisioned with food and loaded with stores. *Cheyenne*, *H-1* and H-2 sailed for their assigned mobilization point, Port Angeles, WA, arriving 16 April. In May the flotilla sailed to Puget Sound Navy Yard for maintenance, painting, and upgrades. The diary notes the installation of electric torpedo firing gear which 'greatly reduced torpedo firing interval.' [214] Following the maintenance period, the group got underway for San Pedro on 1 June. Summer was spent engaged in operations, training, and maintenance.

On 18 October 1917 *H-1*, *H-2*, and USS *Cheyenne* departed San Pedro for the East Coast via the Panama Canal for service with the Atlantic Submarine Force. Review of *H-1*'s transit logs show the boat was plagued with engineering problems throughout the voyage, spending a good part of the trip being towed. Arriving at Balboa in the Canal Zone on 7 November, *H-1*'s

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[211] 'Unlucky Submarine is Floated Again', *Long Beach Press*, 20 Apr. 1917.
[212] Lightfoot, *Beneath the Surface*, 190.
[213] NARA, General Organization SubBase San Pedro, 56.
[214] NARA, War Diaries of USS *H-1*.

engineers set to work overhauling the engines; once completed the group transited the canal on 15 November. Departing from Calón on the Caribbean side of Panama the next morning the small convoy headed for Key West, FL, arriving on 22 November.[215]

The submarines remained in Key West and operated with other Navy units locally and in the Caribbean over the winter of 1917-1918. Their mechanical condition was deteriorating and both boats were scheduled for a major overhaul that spring at the Navy Yard in Philadelphia, PA. An inspection of *H-1* on 25 March revealed myriad problems, including batteries in poor condition, the port engine housing cracked and unable to drive the propeller, the starboard engine housing cracked and the engine in generally poor condition, the force pumps inoperable, and the main motors in need of rewinding with copper wire. [216]

Following their much-needed overhaul *H-1* and *H-2* were assigned to Submarine Division Seven, operating out of Submarine Base New London, where they served out the rest of the war as training vessels for the submarine school. The diary reflects that on 5 December 1918, while serving as a target vessel for *H-2* and *G-2*, *H-1* lost depth control and descended to 245 feet (75m) cracking two frames and distorting the torpedo loading hatch. The hull held however, and the boat surfaced without further incident. The class experienced numerous groundings, collisions, and dives below design depth, all without significant hull damage, a testament to the strength of the design and quality of building. *H-1*'s damage was repaired and by February 1919 it was back in full operation. *H-1* and *H-2* remained in New London until January 1920 when they departed for San Pedro on the Pacific coast.

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[215] NARA, USS *Sinclair* Deck Logs.
[216] NARA, Quarterly Inspection of USS *H-1*.

The voyage to San Pedro would be the last for *H-1*; the history of that transit and the boat's ultimate demise are the subject of the next chapter. *H-2* returned to San Pedro and joined H-3 and the second tranche of H-Class submarines *H-4* through *H-9* operating along the West Coast. *H-4* through *H-9* were constructed in Vancouver, Canada in 1917 to export design EB 602 for the Tsarist government of Russia. The Bolshevik Revolution interrupted their shipment, and in April of 1918, although more modern submarines were being built, the Navy seized the opportunity to bolster its Pacific Submarine Force and purchased the vessels from Electric Boat.

The submarines were delivered to Navy Yard Puget Sound in kit form and were quickly assembled, joining the fleet in the fall of 1918. These submarines differed only slightly from the earlier U.S.-built boats. Like all EB 602 boats they lacked the bulkhead separating the forward battery compartment from the torpedo room; they were constructed with a chariot style bridge, providing improved protection for the bridge watch while surfaced; and they were equipped with rudimentary acoustic equipment. A Fessenden Oscillator, the first electro-acoustic transducer, provided improved underwater communications by allowing Morse code to be transmitted and received over a range of several miles.[217] The boats were also equipped with a rudimentary passive (listening) sonar system incorporating the Y-Tube, a fixed array, and the submarine C (SC) tube which could be rotated to discern the bearing to contacts.[218]

On 25 July 1922 all eight of the remaining American H-Class submarines departed San Pedro for Norfolk, VA where they were decommissioned. In 1930-31 the obsolete boats were stricken from the Navy List and eventually sold for scrap.[219]

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[217] Fay,'Submarine Signaling', 109.
[218] U. S. Navy, SECNAV Annual Report, (1920), 628-629.
[219] Naval History Division, *Dictionary of American Naval Fighting Ships, 231-232.*

The British Boats

H-Class submarines built for the British Royal Navy account for the lion's share of the class, these submarines, constructed in Canada, England, Scotland and the United States, filled the technology and numbers gaps that had developed between British and German submarine forces between 1910 and the outbreak of hostilities.

Admiral John (Jackie) Fisher (1841-1920) became First Sea Lord, Britain's senior naval officer, in 1904 and remained so until his retirement in 1910. He was a fierce proponent of submarines and oversaw the development of the Royal Navy's submarine service. His advocacy for the continued growth of the submarine force continued in his retirement. Fisher had the ear of the First Lord of the Admiralty, a civilian position equivalent to the U.S. Secretary of the Navy, held by Winston S. Churchill (1874-1965) from 1911 to 1915. In the years leading up to the war Churchill lobbied Parliament and advocated within the Navy for more submarines. The outbreak of war and the near-simultaneous sinking of the light cruisers HMS *Aboukir*, *Cressey*, and *Hogue* would provide the impetus for rapid acquisition of more submarines.[220] Churchill would call Admiral Fisher out of retirement to serve as First Sea Lord a second time, from 1914 to 1915, further ensuring the future of the submarine force.[221]

On the eve of the outbreak of the First World War England had 59 submarines in home waters with 19 more under construction. Only the 17 newer boats (eight D-Class and nine E-Class) were considered fit for overseas work. In comparison Germany had 28 submarines (here after U-Boats) and was building another 24. While the numbers appear to favor England, the U-Boats had greater range and were more seaworthy vessels. [222] An entrepreneurial American arms

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[220] See supra pp. 164.
[221] Smith, *Britain's Clandestine Submarines*, 8-24.
[222] Jellicoe, *The Grand Fleet*, 17.

merchant, Charles Schwab, would offer the resources of his vast corporate empire to mitigate the disparity.

Charles Schwab (1862-1939) ran the huge conglomerate Bethlehem Steel Corporation; among its holdings were the submarine building yards Fore River Shipbuilding and Union Iron Works. Bethlehem Steel Corporation was heavily involved in the arms trade and Schwab traveled internationally making sales. In October 1914 he sailed to England. Meeting with Admiral Fisher in early November they struck a deal to build 20 H-Class submarines over the course of the next ten months. Expedited delivery came at a cost, the value of the contract exceeded $10, 000,000. To meet the aggressive delivery schedule work started immediately.

Building warships for foreign countries at war endangered the neutrality of the United States. To skirt the issue the boats were contracted to be built in sections at the Fore River Yard, then shipped to England for assembly. When news of the deal hit the newspapers, Joseph Powell, President of Fore River, when questioned by the Secretary of the Navy, denied that a contract existed.[223] This assertion was made on the same day the contract was signed, so while likely the truth at the time of utterance, Powell knew the contract was close to ratification. The newspapers of the period detail numerous arms sales to belligerent nations, none of which seem to have attracted much attention or received any government scrutiny, but this was not the case with the Fore River submarine contract.

Although American companies supplied submarines to both belligerents in the Russo-Japanese war, the Wilson Administration opposed the construction of submarines for England, on American soil, and informed Schwab's lawyers of the decision. Schwab outwardly appeared to concede without a fight, but he had already laid the groundwork to move construction to the

[223] 'No Order for Submarines', *New York Times*, 11 Nov. 1914.

Canadian Vickers Yard in Montreal.[224] A new contract was signed on 15 December, shifting construction of the first ten boats to Montreal, with the remaining ten to be constructed at the Fore River yard, with the intention that they would publicly stay under U.S. control. Exactly how and when the Fore River boats were to be delivered to England is a mystery; the principals likely assumed that America would soon enter the war, making the neutrality argument moot.

[224] Smith, *Britain's Clandestine Submarines.*

Made in Canada

In order to build the boats in Canada many disparate entities and elements needed to come together (Figure 87).

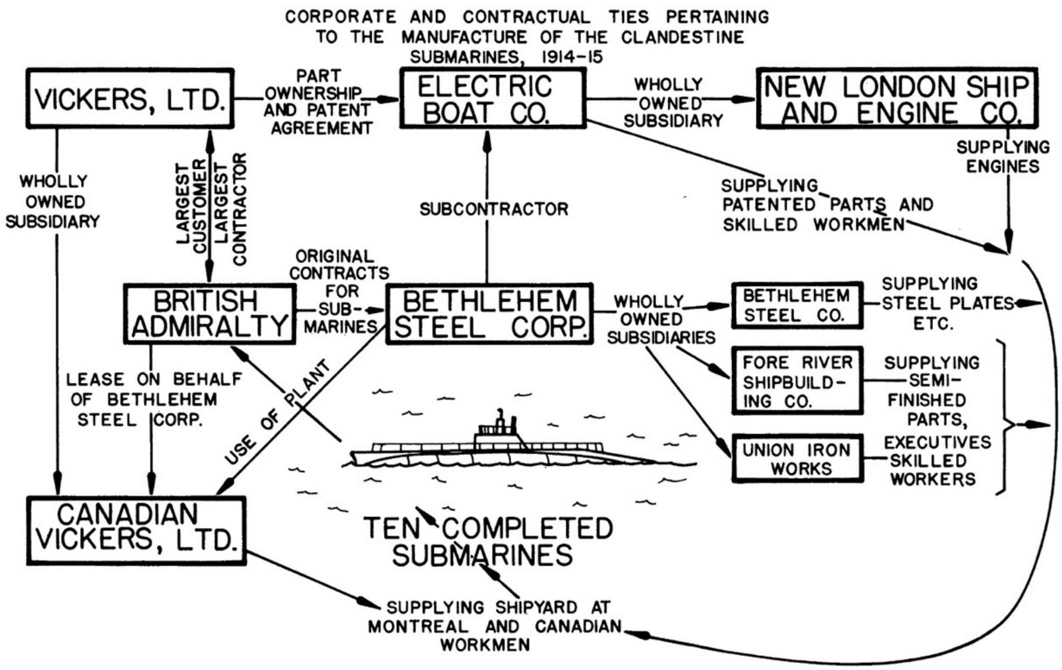

Figure 87. Corporate and contractual ties. From: Smith.

The British Government leased the Canadian Vickers shipyard in Montreal and waived all import duties on American material imported to build the boats. Experienced submarine constructors and materiel flowed into Montreal from throughout Bethlehem Steel's manufacturing empire. There was a significant bonus to be paid for early delivery and Schwab was clearly willing to demonstrate that, even with the governmental delays caused by Washington, his company could deliver ahead of schedule.

Keels for the first five boats were laid on 11 January 1915, four more were laid on 14 January, with the last keel laid on 9 February. The submarines were all launched in April and the last delivered on 29 June 1915.[225] Delivering ten boats in six months was an amazing feat, considering the complexity of systems, volume of material and amount of manpower necessary to do so in such a compressed timeline. During construction the yard employed an estimated 2800 men working around the clock in 12-hour shifts; the pace of construction must have been frenetic.[226] Comparatively, it took Union Iron Works two years to deliver America's first three H-Class submarines. This successful mass production earned the boats the moniker "Ford Submarines" among British submariners.[227]

The boats were to be sailed to England by their British crews, the first crossing of the Atlantic by submarines. Finding over 200 trained men to man the ten new submarines presented a huge challenge in the best of circumstances, but England was at war and the submarines were going to be delivered in two tranches and ahead of schedule. It was decided to provide each boat with crews of only 17 men (2 Officers, 2 Chief Petty Officers, and 13 Ratings) to make the Atlantic crossing, with additional crew to join when the boats arrived in England. In April 1915, the crews for *H-1* through *H-4,* under the command of Lt Wilfred B. Pirie, RN, sailed from Liverpool aboard the liner SS *Missanabie*.[228]

One of the few descriptions of life in H-Class submarines, heavily relied on herein, comes from the memoirs of an experienced submariner selected to crew HMS *H-1*. Chief Petty Officer Oscar Moth was serving in HMS *Attentive*, a scout cruiser, when the war started; having

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225 Akermann, *Encyclopedia of British Submarines*, 229.
226 Perkins, Canada's Submariners, 67.
227 Ibid, 95.
228 Ibid, 69.

had his fill of surface duty, when the Navy called for submarine volunteers he responded and was quickly accepted.[229] Moth had served on the A and C-Class boats and was sent to training on newer boats before receiving orders as Coxswain (Cox'n) in *H-1*. Cox'n is the British equivalent to Chief of the Boat in the American submarine service.

Missanabie arrived in Halifax, NS, and the men traveled by train to Montreal where they joined their submarines, still under construction. Moss noted that, on their arrival, *H-1* was already in the water and the yard was swarming with American workmen. The involvement of American workmen, likely Electric Boat employees continued until the completion of sea trials.

HMS *H-1*'s trials were conducted in Murray Bay, located down the St. Lawrence River from Quebec City; a civilian crew operated the boat with the navy crew onboard as trainees and observers. With trials successfully completed the boat was returning upriver to Quebec City when it collided with SS *Christine*, an ex-private yacht chartered into naval service, sinking *Christine*. Lt. Pirie relieved the trials captain and the pilot, took charge of the submarine and sailed to *H-1* to Montreal for repairs. Eight men died on *Christine* when it went down; the ship's sinking, noted on page six of the local paper, made no mention of a submarine; instead, referring to *H-1* as a "government craft".[230]

Repairs were quickly completed, and *H-1* sailed for the operating areas near Quebec where the boat completed its deep dive, prepared for the Atlantic crossing, and waited for the remaining three boats to complete trials. Once all the boats of the first group had completed trials and were commissioned in the Royal Navy, attention turned to getting them ready for the Atlantic crossing. With stores, fuel, torpedoes, and spares loaded, the submarines and their

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[229] Moth, "Wartime Memoirs of Coxn Oscar Moth".
[230] 'Steamer Sunk; Eight Perish', *The Ottawa Citizen*, 19 May 1915.

escorts departed Quebec on 10 June 1915, barely six months after their keels had been laid. The second group *H-5* through *H-10* would cross the Atlantic for England in July.

The trip across for the first group was far from smooth. On getting underway *H-1* damaged its port propeller, delaying it for a day. En route to Newfoundland the boats ran into a summer gale and *H-4* became separated from the group. An extensive search was mounted only to be called off when it telegraphed from a safe harbor that all was well. The group rendezvoused in St. John's, Newfoundland with *H-4* making its arrival on June 17. The convoy, now escorted by the troopship AMC *Calgarian* stood out of St. John's on 20 June bound for Gibraltar and duty in the Mediterranean. *H-1* and *H-3* experienced mechanical problems with their main engines. *H-1* lost both engines when, after shifting fuel tanks, the tank was found to be full of water. The engines were not damaged and once suction was shifted to a tank containing fuel the engines restarted without further issue. *H-3*'s engine casualties and a damaged propeller resulted in a diversion to the Azores for repairs and quite a bit of time spent under tow by *Calgarian*. Bad weather struck again just a few days out from Gibraltar, but the convoy pushed through, arriving in port on 2 July.

The boats sailed for Malta after ten days of maintenance in Gibraltar. In Malta each boat was fitted with a quick firing six-pounder gun (57mm), wireless radio, and jumping wires (Figure 88). Jumping wires were heavy cables allowed a submarine to penetrate submarine nets, one of the few anti-submarine warfare tools of the day. The jumping wires were attached at the bow, led tightly above the periscopes and attached at the stern, reducing the chances that the submarine would become entangled in a net. When the work was complete *H-1* sailed for Mudros on the Greek island of Lemnos and then on to Kephalos harbor, on the east side of

Imbros, from where the boat would make its attempt to enter the Sea of Marmora via the Dardanelle Strait (Figure 89).

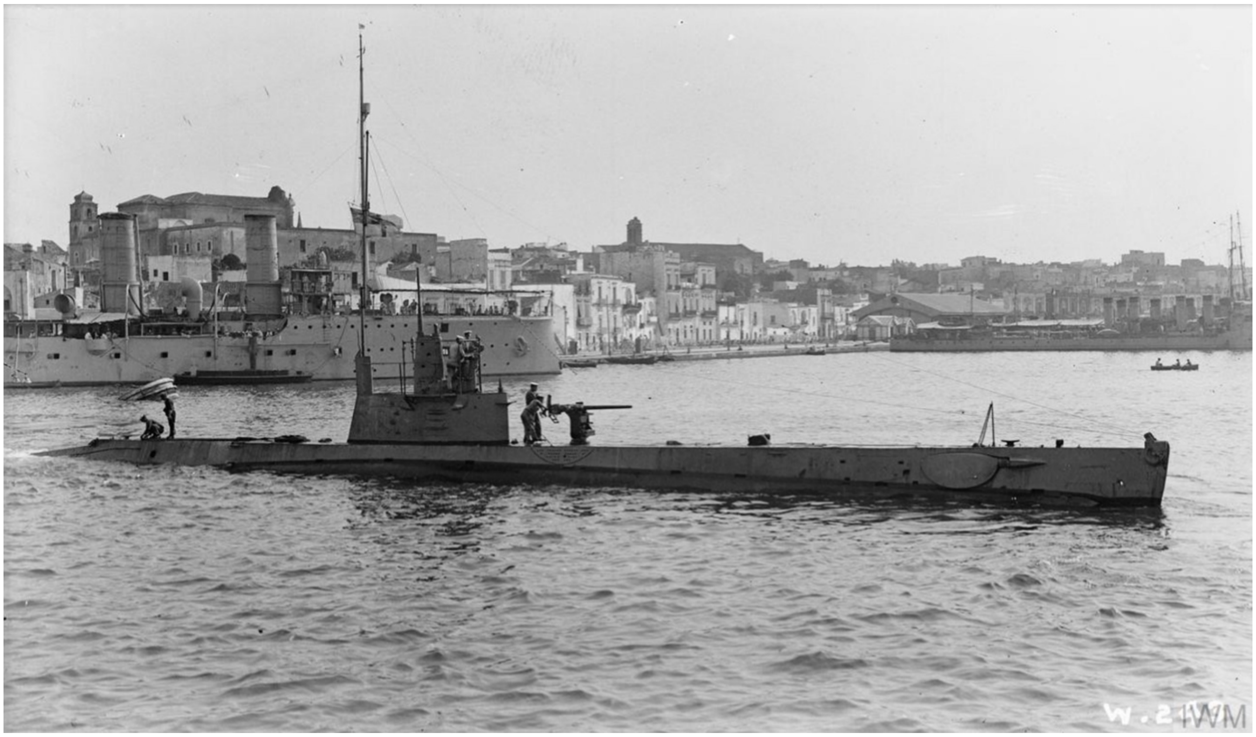

Figure 88. HMS *H-4* with six-pound gun Brindisi, Italy 1916. Courtesy of: International War Museum.

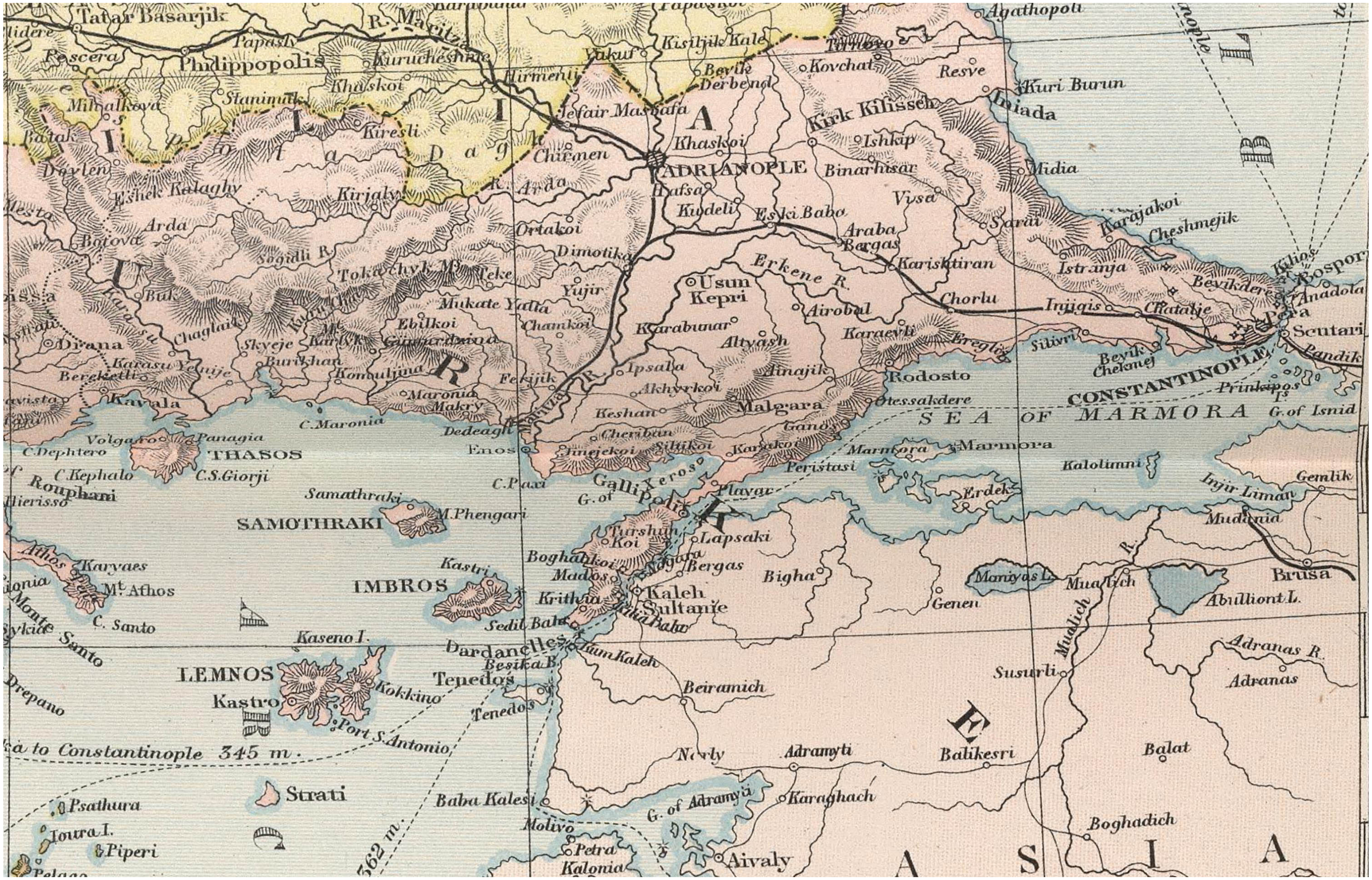

Figure 89. Area map Western Turkey. Courtesy of: David Rumsey Map Collection, David Rumsey Map Center, Stanford Libraries.

British, Australian, and French submarines operated in the Sea of Marmora in support of Allied invasion forces fighting on the Gallipoli Peninsula, with each nation losing at least one boat in the effort. The submarines' presence denied the Turks the opportunity to move supplies and reinforcements by sea and prevented Turkish warships from delivering naval gunfire against the British rear flank but getting into the Sea of Marmora was a deadly challenge.

The Dardanelle Strait separates Asia and Europe and was a submarine navigator's nightmare. Its Aegean entrance was guarded by mine fields, shore fortifications, and submarine nets and the strait itself was filled with tricky currents, inaccurately charted depths, and two sharp bends which required precise course changes. The presence of patrol craft and shore batteries made it nearly impossible to transit on the surface or take frequent navigation fixes by exposing the periscope. Submerged transit faced an added challenge of areas where salt and fresh water were stratified in what are called boundary layers; crossing these boundary layers resulted in a near-instant change in the buoyancy of the boat.

To compound the navigation challenge the boats were not equipped with gyrocompasses, *H-1* would be the first British submarine to force the Dardanelles relying solely on a magnetic compass.

Oddly, while lacking gyrocompasses, British boats were, unlike USS *H-1* through *H-3*, built with the Fessenden Oscillator installed. The configuration differences could have resulted from unavailability of gyrocompasses and radios or simply have been a cost control measure.

On 2 October 1915 *H-1* dived, and with its bow planes retracted to prevent them from becoming entangled, forced its way through the submarine nets guarding the southwestern entrance to the Dardanelles. (Figure 90).

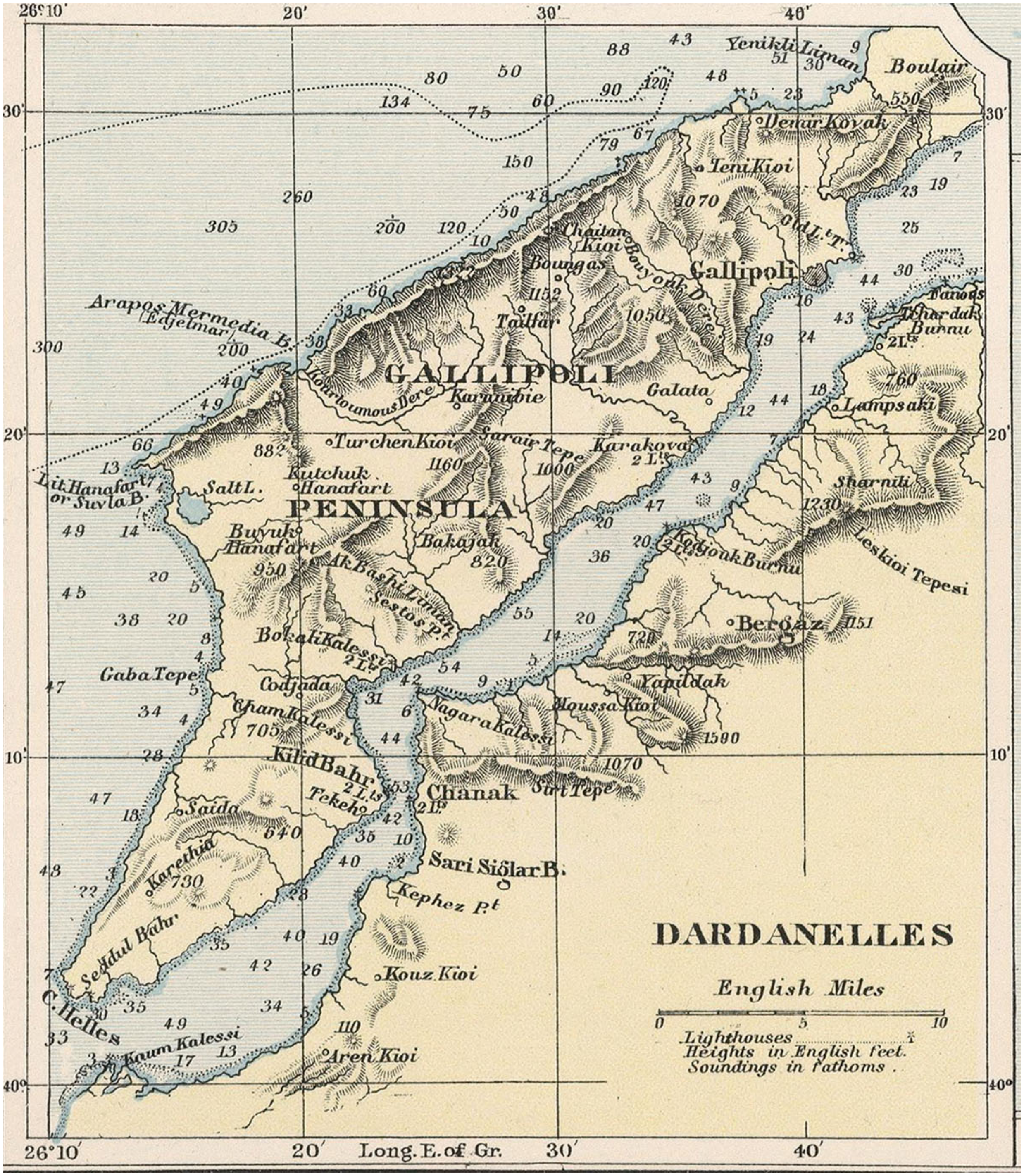

Figure 90. The Dardanelles.

Courtesy of: David Rumsey Map Collection, David Rumsey Map Center, Stanford Libraries.

H-1 touched bottom several times and grounded heavily at one point, driving herself nearly to the surface. However, Lt. Pirie was able to get the boat back into deep water before it was detected. Remaining submerged for nearly 12 hours to avoid detection by the numerous ships and shore batteries, it surfaced late in the afternoon, mounted its deck gun, and went to war in the Sea of Marmara.

HMS *E-12* was also operating in the Sea of Marmara; the two submarines worked both independently and in concert to disrupt maritime shipping and shelled the occasional train. Communication when out of sight of one another was primarily by Fessenden Oscillator; Moth notes that on one occasion the British boats successfully communicated with each other over a distance of 30 miles (48km). Small ships were either boarded and burned or sunk by gunfire, their crews given the opportunity to abandon the vessel in lifeboats; larger ships were attacked with torpedoes and in one case by ramming. They would be joined late in the month by *E-20*, *E-12*'s relief, and the French submarine *Turquoise.*

Moss relates that *H-1* performed well and suffered few mechanical casualties. The most significant problems included a leaky main ballast tank which allowed salt water to enter the forward battery well, requiring daily pumping, and a saltwater leak in the main freshwater tank, putting the men on water rations. As the boat transited down the Sea of Marmora, back toward the Dardanelles, the port motor became problematic and was placed in standby for emergency use only. On 31 October, after a month of combat operations, being harried by Turkish patrol craft and fired on by shore batteries, and with all its torpedoes expended, *H-1* pushed through the submarine nets and minefields and tied up safely alongside HMS *Triad* moored in Kephalos Bay on the Greek island of Imbros.

This operation would be *H-1*'s top achievement of the War. Lt. Pirie received the Distinguished Service Order and Cox'n Moth the Distinguished Service Medal. Moth would leave the boat in Brindisi, Italy to join a new boat under construction.

H-1 – H-4 operated in the Adriatic for the remainder of the war. In an unfortunate case of fratricide on 16 April 1918, *H-1* torpedoed and sank the Italian submarine RM *H-5*, killing 15 of the 20-man crew. RM *H-5*, also a product of Canadian Vickers in Montreal, was a near twin of HMS *H-1*. In May 1918 *H-4* also sank a submarine when it surprised Germany's UB 52 operating on the surface off the coast of Albania and torpedoed it. *H-3* struck a mine on 15 July 1916 and was lost with all hands off Cattaro (Kotor), a port city in modern day Montenegro. During the war Cattaro was a principal port for both German and Austro-Hungarian warships. *H-1*, *H-2*, and *H-4* survived the war and were sold for scrap in 1921.[231]

The submarines of the second group built in Montreal, *H-5* through *H-10,* arrived in England in early August of 1915. That fall they were fitted out for service with gyrocompasses, Forbes logs to measure speed through water, radios, and jumping wires were installed. Because they were assigned to the Home Fleet in defensive roles, the boats were not fitted with deck guns. At least two of the submarines, *H-5* and *H-10*, required replacement batteries, and improved Excide batteries were installed. A period of training followed with all of the boats being cleared for combat operations by November 1915.[232] Assigned to the 8th Submarine Flotilla, the boats conducted operations primarily in the southeastern corner of the North Sea off Heligoland to deny German vessels access to the North Sea and English Channel (Figure 91).

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231 Akermann, *Encyclopedia of British Submarines*, 232.
232 Perkins, *Canada"s Submariners*, 94-98.

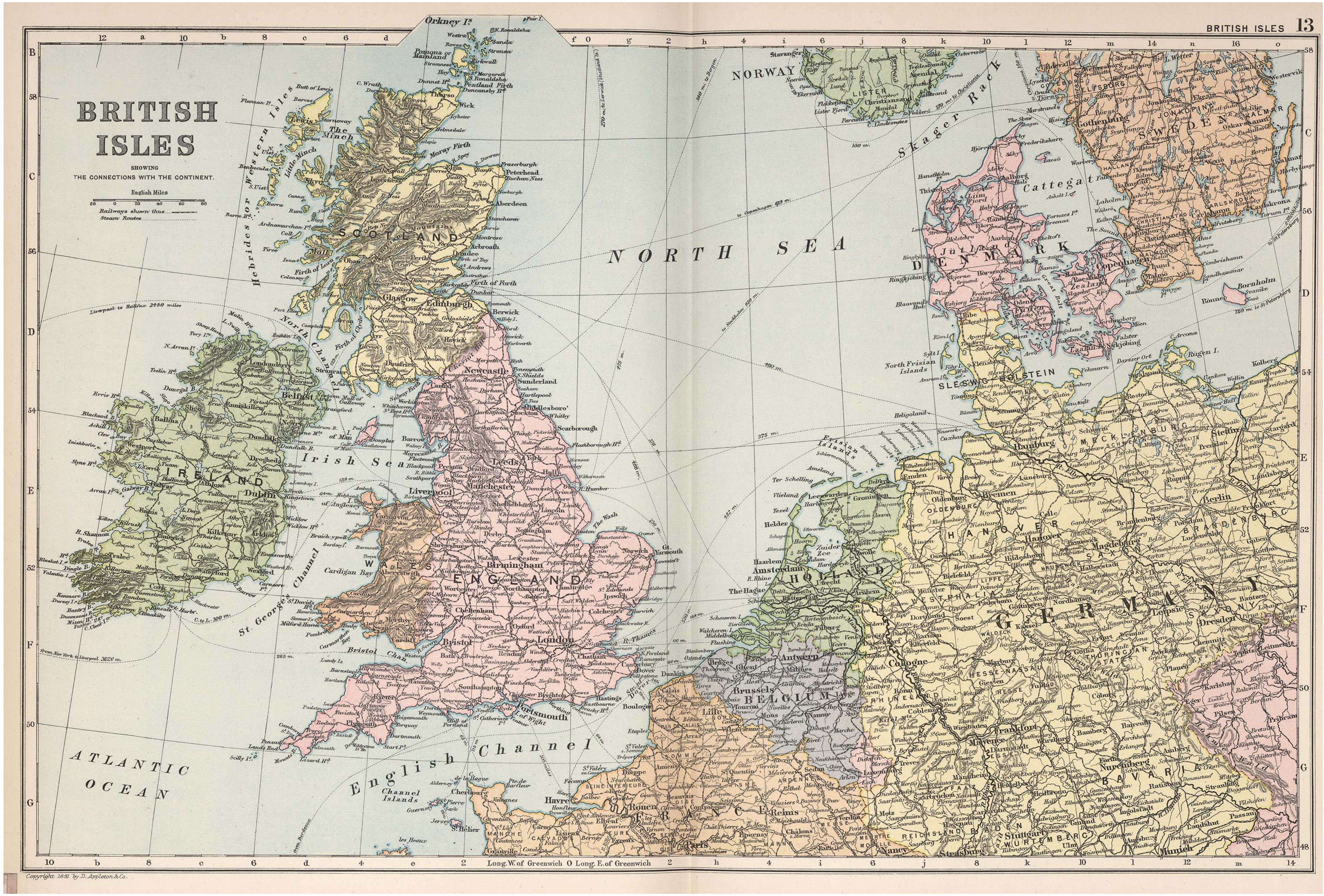

Figure 91. British Isles.

Courtesy of: David Rumsey Map Collection, David Rumsey Map Center, Stanford Libraries.

Operations in the North Sea for the H-Class boats that first winter exposed the submarines to a challenging environment. The design's short conning tower, low freeboard, and relatively small overall size made surface operations hard on both the boats and their crews. Two of the tactics employed to get some rest were to submerge and lie on the bottom or to lower the mushroom anchor to the seafloor and winch the boat down to a more comfortable depth. The term 'comfortable' is certainly relative in this case as the boats were not well insulated and had limited electric heat; however, relief from the wave induced motion must have been a welcome respite.

H-6 would become the first casualty of the North Sea H-boat flotilla. Assigned with several other submarines to serve as a rescue vessel during an air raid on the German island of Norderney, *H-6* ran hard aground on the Dutch island of Schiermonikoog on 18 January 1916. HMS *Firedrake* removed half of the crew and the ship's documents but the commanding officer and ten men were captured and interned by the Dutch. *H-6* was salvaged by the Netherlands, purchased from England, and renamed *O-8*. [233]

HNMLS *O-8* served in the Royal Netherlands Navy until the Second World War when it was scuttled to keep it out of German hands. The Germans raised and refitted the boat, renaming it *UD-1*. *UD-1* served in the *Kriegsmarine* as a school boat until 1943 when it was decommissioned. In 1945, after serving in three navies over two wars *H-6*/*O*-8/*UD*-1 was scuttled for the final time in Kiel.[234]

HMS *H-8* was among the H-Class survivors of the war but just barely. On 22 March 1916, in an amazing testament to the strength of the H-Class hull, the skill of its crew, the

[233] Ibid, 102.
[234] Gray, *A Damned Un-English Weapon*, 190.

leadership of Lt. Barney Johnson, its Canadian captain, and a large dose of stonking good luck, HMS *H-8* survived a mine explosion, while operating submerged off Holland.

The force of the explosion drove the bow of the submarine into the seabed and seawater flooded in from numerous major leaks in the torpedo room; in addition, the forward trim tank was ruptured and the bow planes were out of commission. Major damage appeared to be limited to the forward portion of the submarine and the crew worked to save their boat and themselves. After the largest leaks had been stopped, the captain ordered the forward and mid main ballast tanks blown, and the batteries placed in series on the motors, in full astern. The first attempt failed when the fuses for the motors blew and the forward main ballast tank failed to hold air, as it, like the forward trim tank, had been ruptured by the mine's explosion. The fuses protecting the motors were bypassed and *H-8* was successfully brought to the surface. On reaching the surface it was determined that the bow cap, bow planes, and a large portion of the forward superstructure were carried away by the explosion (Figure 92). Lt. Johnson and his crew gingerly nursed the boat back to Harwich. The extent and complexity of repairs necessary to put the back in service resulted in the crew being paid off and reassigned to other boats. *H-8* was sold for scrap in 1921.[235]

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[235] Perkins, *Canada's Submariners*,123-133.

Figure 92. HMS *H-8* mine damage. Courtesy of: Royal Navy Museum.

The early months of 1918 proved fatal for two of the Montreal built H-Class boats. H-10 departed for operations in the North Sea and never returned, the boat was presumed lost on 19 January. Two weeks later H-5 was operating in the Irish Sea on the surface when it was mistaken for a U-Boat and was rammed by SS *Rutherglen.* It sank with the loss of all hands along with Lt. E. Childs, USN, of USS *L-2*, who happened to be aboard for training. Lt. Childs was posthumously awarded the Navy Cross and was the first American submariner to die in action in the First World War. The destroyer USS *Childs* (DD-241) was later named in his honor.[236]

[236] NHHC, *Dictionary of American Naval Fighting Ships*, @ https://www.history.navy.mil/research/histories/ship-histories/danfs.html

Made in America

As Canadian Vickers was building HMS *H-1* through *H-10*, Bethlehem Steel's Fore River yard was busily constructing the remaining ten submarines ordered by England. These were referred to in newspapers of the day as submarines under construction for belligerent powers.[237] The first of them slid down the ways on 12 June 1915, the last of the group, *H-20,* was launched on 28 August 1915.[238] The boats conducted their builder's trials, attended by American naval officers to ensure they would not be sailed to England. Following trials and acceptance by agents of the British government, they were interned by the U.S. Navy at the Boston Navy Yard.

At the outbreak of hostilities in 1914 British shipyards were building several vessels for foreign navies, among them warships for the Chilean Navy. The British government, seeking to rapidly expand its fleet seized some vessels and purchased others. Warships seized through the act of preemption placed Britain in a position of debt to the countries that originally purchased the vessels.

Chile was a neutral country, and the British and Chilean governments worked out a deal in the spring of 1917 to repay the debt in H-Class submarines. Five submarines were to be gifted to Chile and the Chilean government was to purchase the sixth. The American government had concerns that the boats would somehow end up in British hands, but after much hand wringing and with assurances from both governments, the submarines were released to the Fore River yard for transfer to the Chilean Navy.

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[237] 'Belligerent Submarine Launched Here', *New York Times*, 13 Jun. 1915.
[238] 'Submarines are Ready', *New York Times*, 28 Aug. 1915.

When America entered the war the remaining four boats were released.[239] *H-11* and *H-12* would sail to England in 1918 and join the 14th Submarine Flotilla operating out of Blyth during the war. The two remaining boats, *H-14* and *H-15* were presented to Canada where they were commissioned as CH-14 and CH-15.[240] All the H-Class submarines purchased by Britain in the opening months of the war, except for the Chilean boats, were taken out of service in the summer of 1922.

[239] Smith, *Britain's Clandestine Submarines*, 132-135.
[240] Akermann, *Encyclopedia of British Submarines*, 223.

Made in Britain

The H-Class submarine was well liked by the officers and men of the British Submarine Service. Compared to many contemporary boats they dived quickly, had reliable machinery, handled well, and had significant offensive capabilities. The four torpedo tubes could be quickly fired, and four additional torpedoes were carried as reloads; however, war experience had shown that the 18-inch (45cm) torpedo lacked the explosive power to consistently produce single torpedo kills. A 21-inch (53.3cm) torpedo in service in 1916 had a much larger warhead and could travel nearly three times farther than the smaller weapon at the lowest speed setting. Seeking the best in submarines and weapons system, the *H-21* group was developed and built.

The H-21 design was essentially an H-Class, lengthened to facilitate the larger torpedoes, and incorporating a watertight bulkhead between the forward battery and torpedo room. These submarines, ordered in 1917, were 171 feet (52.1m) in length, and 15.8 feet (4.8m) in beam. The propulsion system was nearly identical to the earlier H-class, although the diesels were of British manufacture. A larger vessel with the same available horsepower, they were understandably slower than the previous design, making 11.5/9 knots (21/17 kph) surfaced/submerged.

Orders for 34 submarines in two tranches were placed, the first group *H-21* through *H-32* from Vickers in Barrow and the second *H-33* through *H-54* from five separate yards. Cancellations were issued for 10 of the boats to free the yards to build R-Class submarines. *H-41* sank alongside the pier during fit out and was never completed. The remaining 23 boats were delivered between 1918-1920, with only eight in service prior to the armistice, serving in the 8^{th} and 14^{th} Submarine Flotillas in home waters. None were lost in combat in the First World War.

The interwar years would see four of the boats lost in accidents, primarily collisions with surface vessels, and eleven would be sold off for scrap. By the beginning of the Second World

War the surviving boats, while old and obsolete, were pressed into combat service, between 1940-1941, before being relegated to training duties. Two of the old warriors *H-31* and *H-49* were lost during combat patrols, and the remaining boats were scrapped. The last British H-Class submarine, HMS *H-50*, was sold off in July 1945.[241]

[241] Ibid, 251-254.

The Russian Boats

The Russian naval losses in the Russo-Japanese war had reduced the fighting capacity of this once-prominent navy to the point where it was ill equipped to protect its limited harbors and maritime trade.[242] Russia was an early adopter of submarines and torpedo warfare, but like most countries the boats that they built or purchased were more appropriate for harbor and coastal defense than extended operations. Submarines were purchased from both Electric Boat and Lake Submarine companies for the Russo-Japanese war, by both sides, but none saw combat. In the years following the war Russia maintained relationships with multiple submarine building firms, purchasing or building American-, German-, and Italian-designed vessels as well as producing domestically designed submarines.[243]

At the outset of the First World War the Russian Navy had 37 submarines in commission, with an additional 19 under construction. The submarines and their support vessels were divided geographically into three flotillas: Baltic, Black Sea and Siberian.[244] The Russian navy faced opposition from the Ottoman Empire in the Black Sea and German forces in the Baltic; in order to rapidly bolster their submarine force, and with Russian shipyards operating at capacity, Russia turned to Electric Boat. The selection of Electric Boat was likely influenced by the expedient delivery of the Montreal built British H-Class submarines. Russia would order 17 H-Class submarines under three contracts, although delivery of the final group of six was halted by the Russian Revolution and those submarines were purchased by the U.S. Navy becoming USS *H-4* through *H-9*.

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[242] Corbett, *Maritime Operations in the Russo-Japanese War*, App. F.
[243] Spassky, *Submarines of the Tsarist Navy.*
[244] Domville-Fife, *Submarines, Mines and Torpedoes in the War*, 94-95.

Building submarines for Russia required Electric Boat to utilize business practices they successfully employed for the British orders, effectively skirting neutrality concerns. L. Y. Spear, the naval architect who replaced John Holland at Electric Boat had advanced over the years to become the president of New London Ship and Engine Company, manufacturer of the diesel engines for the H-Class submarine.[245] On 29 June 1915, Spear contacted James Patterson, then president of Seattle Construction and Drydock Company (ex-Moran), regarding the feasibility of building submarines in Canada.[246] Patterson had close ties to Electric Boat having built five submarines, including two F-Class, *H-3*, and two highly modified E-Class boats for the government of Chile. He also had close ties to Canada, having delivered the declined Chilean submarines to Esquimalt in August 1914, when he met the Premier of British Columbia, Sir Richard McBride and with whom he remained in contact.[247]

The contract for the first five Russian submarines was made with Seattle Construction and Drydock Company. Patterson contracted the British Pacific Construction and Engineering Company to act as the builder under his supervision. A shipyard complete with a railroad spur was established in Burrard Inlet, located in the small town of Barnet, east of Vancouver. The yard assembled the submarines from materials supplied by Electric Boat, their subsidiaries, and usual suppliers. Once assembled the submarines were knocked down and crated for shipment to Vladivostok. In December 1915, barely six months after Spear's request to Patterson, the first three submarines were shipped; the remaining two boats followed shortly with the last of the components necessary to complete them shipping in March of 1916.[248]

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[245] Reyburn, *Electric Boat Corporation*, 30.
[246] Lightfoot, *Beneath the Surface*, 36.
[247] Lamb, 'Building Submarines for Russia in Burrard Inlet', 8.
[248] Lightfoot, *Beneath the Surface*, 36-40.

The basis for this section comes from a subsection that Boris V. Drashpil authored in E.C. Fisher's article documenting the Russian boats.[249] The relative paucity of information regarding employment of these submarines may be the result of the literary cleansing which occurred in the Soviet Union following the Russian Civil War.

The submarines arrived in Vladivostok in kit form and were shipped by rail to the Baltic Shipbuilding and Engine Company in St. Petersburg where they were assembled. Named the *Amerikanski Golland* (American Holland) class the submarines named *AG-11* through *AG-15* were completed by the end of November 1916 and joined the Baltic Fleet, where they were based with the submarine tender *Oland* in the port of Hanko on the coast of southern Finland.

The AG Class submarines had a very short operational life; two, *AG-15* and then *AG-13* sank accidently. They were raised and returned to service with *AG-13* renamed *AG-16*, presumably for better luck. *AG-14* was lost in 1917; the exact circumstance of its loss remains unknown, but scholars postulate it likely hit a mine in July off Libau, Latvia (Liepāja).[250] In 2003, a wreck identified as *AG-14* was found east of the small Swedish island of Gotska Sandön, north of Gotland, during the effort to locate a Swedish DC-3 aircraft shot down by the USSR in the early 1950s (Figure 93).[251]

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[249] Fisher, 'Subterfuge Submarines', 208.
[250] Greger, *The Russian fleet*.
[251] Carl Douglas and Richard Hendren, pers. comm.

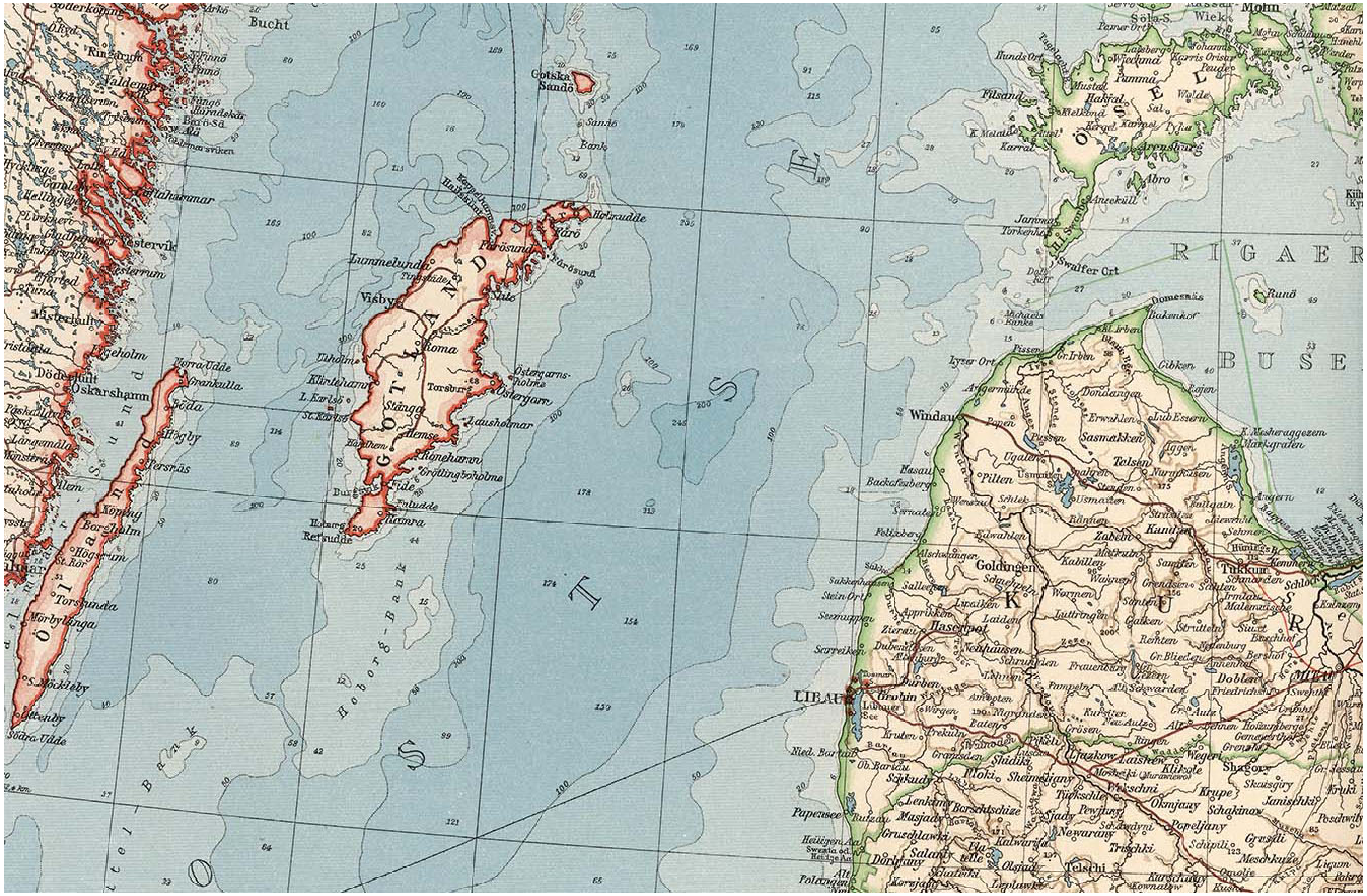

Figure 93. Gottland and Libau.

Courtesy of: David Rumsey Map Collection, David Rumsey Map Center, Stanford Libraries.

Images provided by Mr. Carl Douglas of MMT, the firm which conducted the search, supports classification of the wreck as an early submarine. The design of the propeller aperture is visually consistent with that of an H-Class submarine (Figure 94).

Figure 94. Propeller believed to be from *AG-14*. Courtesy of: Voice of the Ocean Foundation.

AG-14 is the only submarine of its type known to have been lost in that area. The forgoing details strongly suggest that this wreck is that of *AG-14*; however, additional diagnostic data is necessary to provide an absolute identification of the submarine.

The surviving boats of the group were scuttled alongside the pier in Hanko harbor on 3 April 1918, to keep them out of German hands. They were salvaged by the Finnish government between 1918-1919 and three were scrapped shortly after salvage. Finland considered repairing *AG-16* and did not scrap it until 1929.[252]

Six more AG-Class submarines built at Canadian Vickers Shipyard in Montreal were shipped to Vladivostok in a similar fashion. These kits, *AG-21* through *AG-26*, were then shipped from Vladivostok to Nikolayev on the Black Sea for assembly. Only two of this group, *AG-21* and *AG-22,* were assembled prior to the end of the Russian Civil War (1917-1920). The belligerents in this conflict which followed the Bolshevik Revolution were the pro-communist forces (Reds) and the anti-communist forces (Whites). A rising leader among the White forces Pytor Wrangel (1878-1928) became the movements Commander in Chief in 1920.

Several ships and submarines of the Russian Navy supported the anti-communist forces, among these were *AG-21* and *AG-22*. *AG-21* was captured by the British in 1919, during their intervention in that conflict, scuttled then raised by the Soviets and returned to service. *AG-22* serving with Wrangel's White Russian Fleet escaped destruction and was sailed to Bizerte in modern day Tunisia where it was interred along with the rest of the fleet by the French Government to pay for support of the defeated White Russian refugees. *AG-22* would later be sold for scrap. Five of the AG-boats would serve in the Soviet Navy into the Second World War, renamed several times their final designated were *A-1* through *A-5*.[253]

[252] Juja Joutsi and Richard Hendren, pers. comm.
[253] Fisher, 'Subterfuge Submarines', 213-215.

The gap in AG-boat numbering preceding *AG-21* reflects the six boats constructed in 1917 by British Pacific Construction and Engineering Company (Patterson) in another purpose-built shipyard in Vancouver. The Russian Revolution resulted in these vessels languishing in their crates in Vancouver until their purchase and completion by the U.S. Navy in 1918: ultimately becoming USS *H-4* through *H-9*.

The Italian Boats

In 1916, the Italian Navy ordered eight H-Class submarines in three tranches from Electric Boat. To skirt U.S. neutrality issues, Canadian Vickers in Montreal was chosen as the building yard. The first two boats were launched in October 1916, four in April 1917 and the remaining two in May. Following builder's trials and acceptance by (and training of) their Italian crews, the three groups of boats transited the Atlantic.[254]

The first two groups appear to have made the transit without incident. The last group, however, *H-6* through *H-8*, was mistaken for enemy submarines when they failed to return the proper recognition signal when challenged. USS *Nahma,* an armed yacht, was on convoy escort duty in the Strait of Gibraltar when the submarines were sighted and signals exchanged. The submarines returned the wrong signal and *Nahma* opened fire, hitting *H-6* several times; two men were killed and several more were injured.[255]

During the First World War, the H-Class submarines conducted combat patrols from Brindisi and Taranto. It was during one of these patrols in 1918 that *H-5* was torpedoed by Britain's *H-1*; only five men including its commanding officer survived. Seven boats survived the war were used primarily as training platforms during the interwar years. *H-7* and *H-3* were decommissioned prior to the beginning of the Second World War and of the remaining five boats only three were serviceable when Italy capitulated in 1943.

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[254] Bertini, *I Sommergibili Italiani,* 84-88.
[255] Clark, Diplomacy as a Career, 2-3.

The Chilean Boats

The Chilean Navy experimented with submarines before the First World War and contracted with Electric Boat to build two boats in Seattle. Those submarines failed initial acceptance testing and were sold to Canada, before it declared war on Germany, leaving Chile with no submarine force. As noted earlier, at the beginning of the war England asserted ownership of several Chilean warships being built in British shipyards, leaving a debt to Chile that was partially repaid with six H-Class submarines. The six boats were from the cohort of ten constructed at the Fore River Yard in Massachusetts and subsequently impounded by the American government, due to American neutrality. The British Foreign office negotiated the transfer of the six to the neutral government of Chile in compensation for the ships that had been seized.

A contingent of Chilean naval officers arrived in the United States on 15 February 1917 to begin the delivery process.[256] Chilean sailors assigned to the boats were billeted on USS *Constitution* at the Charlestown Navy Yard in Boston, Massachusetts during crew training and familiarization. The submarines were commissioned as *H-1* through *H-6* in the Chilean Navy on 3 July 1917.[257] After commissioning the boats transited to Submarine Base New London for trials, training and overhaul. The submarines, escorted by the Chilean cruiser *Chacabuso* and their tender, the transport *Angamo* sailed from New London on 28 March 1918, for Chile via the

[256] 'After Chilean Submarine', *Fort Worth Record-Telegram*, 16 Feb. 1917.
[257] 'Rear Admiral Gomez, for Chile, Accepts Transfer of Six Submarines at Navy Yard.', *Boston Globe*, 3 Jul. 1917.

Panama Canal.[258] The boats arrived in Valparaíso, Chile on 20 July 1918. Their home port and headquarters were in Talcahuano, a city located in the southern part of Chile's Central Zone.[259]

The new base lacked infrastructure to support the submarines and the Chilean Navy lacked the capability to train and qualify replacement crews. Although these deficits raised safety concerns the boats remained operational. Daily life aboard the Chilean submarines would have been filled with training, maintenance, and operations, similar to that experienced on the boats of other nations. Submarine life is often described as hours of boredom punctuated by moments of terror. *H-3* was conducting a routine training dive on 2 June 1919 when terror struck. [260]

As *H-3* commenced its dive, the engine room began to flood. The captain quickly blew ballast but the vents were open for diving, and the boat sank to the sea floor in approximately 52 feet (16m) of water. The source of the flooding was identified as the ventilator for the aft battery and seawater quickly reacted with the battery acid releasing chlorine gas. To escape the deadly gas the crew retreated to the control room and shut the watertight door. The crew worked to lighten the boat by blowing all tanks and the torpedo tubes, this initially resulted in the boat beginning to rise but it was still too heavy and fell back to the sea floor. By this time the chlorine gas was also contaminating the atmosphere in the control room and the crew was forced to abandon it for the torpedo room.

The vessel escorting them on the training dive reported the incident and a rescue was quickly organized. Fortuitously for *H-3* and its crew they were operating in shallow water, the

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[258] 'Chilean Ships Start for Home', *Meridian Morning Record*, 29 Mar. 1918.
[259] 'Chile', 304.
[260] Fritz, 'Recordando Al Submarino *H-3 Rucumilla*', 468-476.

stricken boat's location was known, and the port had significant salvage equipment available in the form of heavy lift floating cranes. After numerous failed attempts the salvage crews were able to lift *H-3*'s bow exposing the forward hatch; the hatch was opened, and the crew rescued. *H-3* was salvaged, repaired, and returned to service.

During the Chilean Naval Mutiny of 1931, the submarine tender *Araucano* and its attached submarines *H-1*, *H-2*, and *H-4* were among the vessels taken over by mutinous crews. During the government response *H-4* was damaged and a sailor killed when aircraft attacked the mutineers' ships in the harbor at Coquimbo.[261]

The Chilean H-Class boats were employed in the Second World War conducting patrols along Chile's coast. The last two of these boats, *Guale* (*H-4*) and *Fresia* (*H-6*), were the longest serving of the class in any nations' navy. Both were decommissioned in 1953 and broken up in 1956.[262]

[261] Sater, 'The Abortive Kronstadt, 252.
[262] Fisher, 'Subterfuge Submarines', 219.

The Canadian Boats

The history of the Canadian H-Class submarines is a short one. HMS *H-14* and *H-15* were delivered to and were commissioned in the Royal Navy in August 1918. In November the boats were ordered to sail for Bermuda which they reached on the day after the armistice ending First World War was signed. The submarines, no longer needed in the theater of war, were placed in reserve. The Royal Navy had no use for the now-obsolete submarines.

They were given to the Royal Canadian Navy and sailed to Halifax. This took two trips, likely because of personnel shortages, with *H-14* arriving in May 1919 and *H-15* in June. They were laid up and minimally maintained until April of 1920 when they were refit with most of the work likely accomplished by the boat's crews with dockyard assistance.[263] On 1 April 1921 the boats were commissioned as *CH-14* and *CH-15* and homeported in Halifax. Normal crew strength for the two boats was 50 men but a total of only 13 were mustered on commissioning day.[264]

Short of both money and qualified personnel the Canadian Navy cobbled together crews and kept the boats serviceable, but just barely. The officers assigned performed admirably, shaping crews from the inexperienced hands who were available. Following crew training, *CH-14* and *CH-15* conducted training cruises and goodwill visits around the Canadian Maritime provinces. In December 1921 they sailed for Bermuda where they remained for the winter, returning to Halifax in the spring of 1922.

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[263] Perkins, *Canada's Submariners*, 207. Perkins refers to the refit as a 'self-refit'.
[264] Ferguson, *Through a Canadian periscope*, 131-136.

A change in Canada's government in December 1921 saw the Navy budget grossly reduced, including the funds necessary to maintain the submarines in operational condition. *CH-14* and *CH-15* were placed in a reserve status and their crews paid off in June 1922. After years of rusting in place, in March 1927, the boats were ordered sold off and the Canadian Submarine Service temporarily ceased to exist.

Conclusions

H-Class submarines manufactured and delivered during the First World War, prior to the U.S. entering the conflict, strengthened submarine forces of the nations with which America was fundamentally allied. England, Italy, and Russia purchased these submarines augmenting domestic production during a period of great strain on their local resources.

Charles Schwab developed the business model which maintained the outward perception of American neutrality while providing warships to the privileged belligerents. This model of building the boats in Canada using U.S. sourced material, and to a lesser extent labor, proved efficient and resulted in handsome profits for Electric Boat and Vickers. H-Class peacetime construction took over two years from keel laying to commissioning, Schwab's business model reduced delivery time to less than six months.

H-Class submarines proved to be tough and dependable warships that usually brought their crews home from hazardous operations. They were appreciated for their ability to dive quickly, handle smartly, and for the number of torpedoes carried. The design was so well appreciated by the British that when a larger and consequently more lethal torpedo was developed the H-Class design was modified to fire it with 23 boats of the H-21 design constructed. When maintained properly the H-Class submarines had long service lives, two Chilean boats were operational into the 1950s. Several members of the class sank, some more than once, were salvaged, repaired, and returned to service, likely attributable to their robust construction and relatively simple systems. They were truly the right boat for the time.

CHAPTER VI

THE FINAL VOYAGE OF USS *H-1*

Following the First World War and an extended overhaul at the Philadelphia naval yard, *H-1* and *H-2* were serving as school ships at the submarine base in New London, Connecticut in 1919 when they received orders to return to their old homeport of San Pedro, California for duty with the Pacific Submarine Force. The submarines sailed from New London to the Hampton Roads naval base in Norfolk, Virginia where they joined with an escort vessel, the patrol craft USS *Eagle-11,* which served as their tender for the voyage. *H-1*'s Commanding Officer was senior among the three vessel's COs and would be in overall command of the small task group. Tragically, neither *H-1* nor its CO would ever reach San Pedro.

Lt. Cmdr. James Reid Webb (1889-1920) graduated from the U.S. Naval Academy in 1913 and by the time he assumed command of USS *H-1* he was an experienced submariner. Webb previously served in USS *L-4,* commanded USS *K-1* on war patrols off the Azores, and served in the pre-commissioning crew of the USS *AA-1* (ex *Schley*).[265] While serving in *AA-1* he was selected to command a surrendered German U-Boat and sail it back to the United States to participate in public exhibitions.[266] Webb's selection to command the U-Boat and later command *H-1* for its return voyage to the Pacific are indicative of a high level of trust accorded him by his seniors.

[265] U. S. Naval Academy, USNA Virtual Memorial Hall.
[266] 'Submarine Base Officers to Pilot German Subs', *Norwich Bulletin*, 3 Mar. 1919.

Passage

Unless otherwise cited, the details of the voyage presented herein are based on the deck logs of *H-2* and *Eagle-11*.[267] None of *H-1*'s logs were available as they were among the documents looted from the ship following its grounding. The logs of *H-2* and *Eagle-11* provide irrefutable evidence that the ships traveled in concert, missing however is level of specificity which would only have been available in H-1's logs.

New Year's Day of 1920 found *H-2*'s crew enjoying the Navy tradition of holiday routine at Submarine Base New London. It is normal for vessels in port to allow as many men as possible to take leave over Christmas and New Years and little work is scheduled to allow the duty section to take care of the boat until the rest of the crew returns. The holiday routine ended on 2 January and the crew started reporting back on board from leave. With the crew's return, preparations began for the voyage south: fuel and lubricating oil were topped up, two torpedo warheads were received, and two torpedoes were loaded into the lower tubes. On 6 January, with the boat at full crew strength, groceries were loaded and, at 19:08, *H-2* cast off and got underway for Submarine Base Hampton Roads. *H-2* was under the command of Lt. (j.g.) Alfred G. Lewis; *H-1*'s CO, Lt. Cmdr. Webb, being the senior officer likely got *H-1* underway shortly before *H-2* departed.

The two submarines worked their way south over the next three days transiting the 361 nm (689 km) without incident (Figure 95).[268] On 9 January at 08:20 *H-2* moored outboard of the newer submarine USS *L-11*. The boats remained in Norfolk until 13 January, the length of stay likely a result of *Eagle-11* being unable to sail due to a fouled propeller.

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[267]NARA, USS *H-2* Deck Logs; NARA, USS *Eagle-11* Deck Logs.
[268] Routes are based on positions recorded in *H-2*'s deck logs.

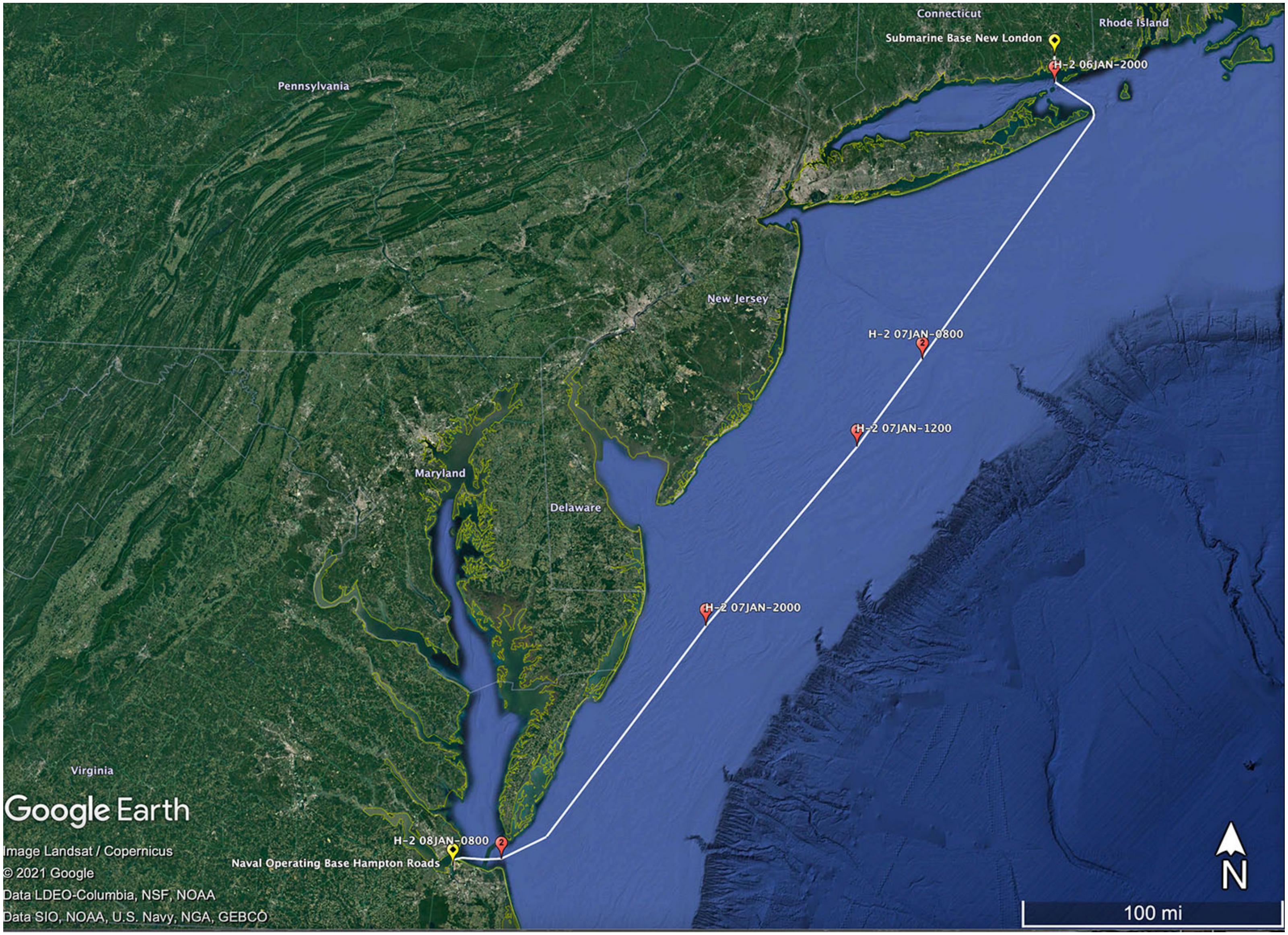

Figure 95. Route New London-Norfolk.

Courtesy of: Google Earth Pro.

Eagle-11 fouled a propeller with a six-inch mooring line on 3 January and divers made several unsuccessful attempts to clear it. It remained fouled until 11 January, when it was finally cleared with the assistance of *H-1*'s Chief of the Boat (COB), Gunner's Mate Chief Petty Officer Walter Albrecht. Navy diving was in its infancy and Gunner's Mates were 'trained' as divers; the training consisted of as little as a single dive to 60 feet (18m) with breathing air supplied by a handpump. Growth of the Navy diving program has a close connection with the 1915 salvage of USS *F-4*.[269] This link remains today as modern submarines continue to have qualified Navy Divers among the crew.

Shortly after 13:00, on 13 January, *H-2,* which was moored outboard of *Eagle-11,* cast off its lines and headed out of the channel, assumably in company with *H-1*. They were bound for the submarine base at Key West, Florida. *Eagle-11* got underway shortly thereafter and the group headed south (Figure 96).

The ships diverted from plan, for reasons not specified in the logs, and on 15 January anchored for the night in the harbor at Mayport, Florida. *Eagle-11* moored to the docks to take on fresh water, loading 15,000 gallons (56,781 l). Steam powered vessels utilize evaporators to provide make-up feed water for the boilers and potable water for use of the crew. *Eagle-11* was equipped with two evaporators and potentially a still to desalinate sea water.[270] *Eagle-11*'s deck logs do not indicate that any of these components were out of commission; however, given the short duration of the voyage and the large quantity of water received, it is a distinct possibility.

On the afternoon of 16 January, the group got underway again for Key West, on the 2000-2400 watch *Eagle-11* stopped to wait for *H-1* as it was having engine problems.

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[269] Carter, *Pioneering Inner Space*, 2-6.
[270] Benson Ford Research Center, USS *Eagle* Booklet of General Plans.

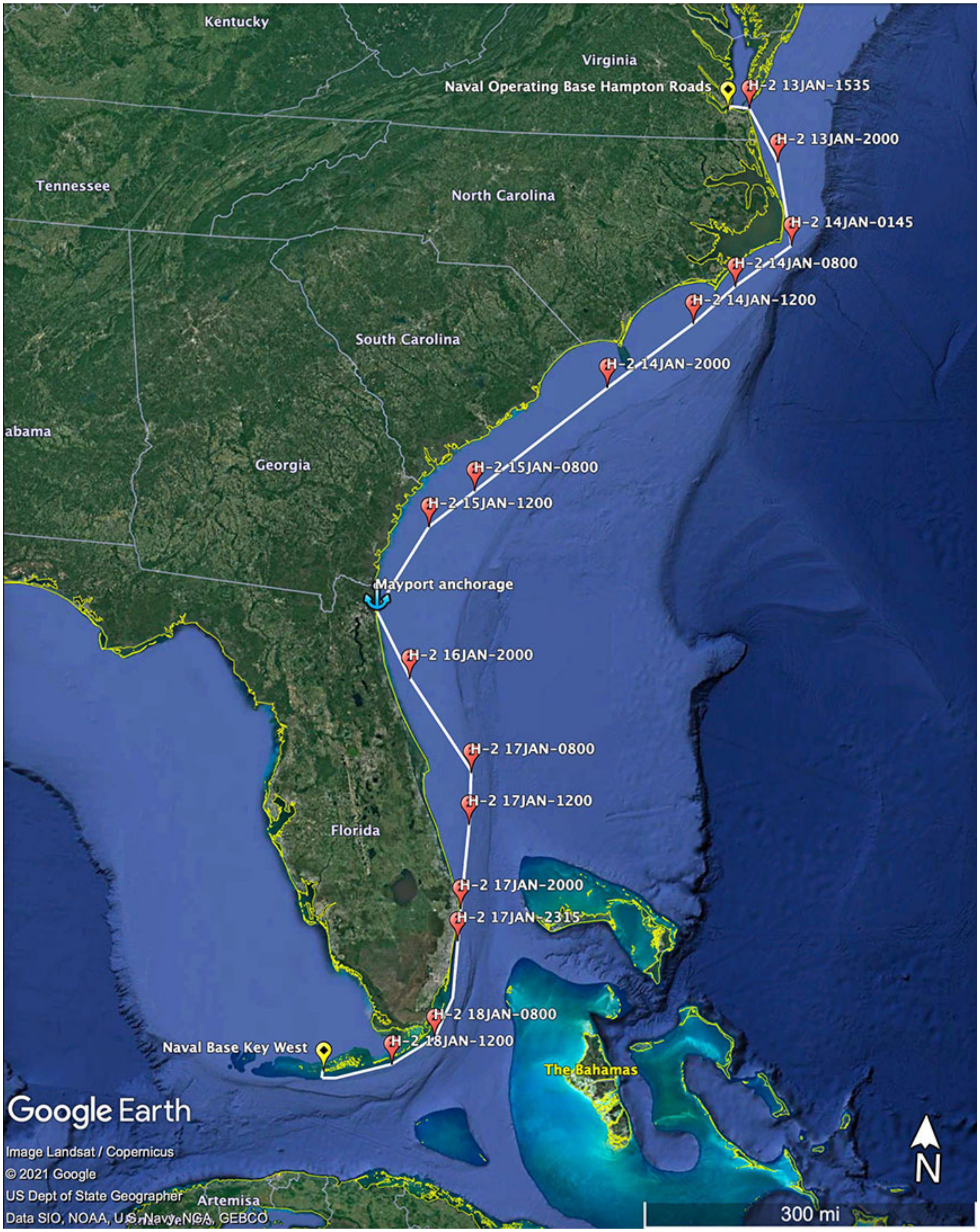

Figure 96. Route Norfolk to Key West. Courtesy of: Google Earth Pro.

H-1 broke down several times on the following day requiring the group to slow or wait as repairs were made. Repairs were apparently successful as logs for 18 January reflect normal speeds as the vessels proceeded south along the coast of Florida, arriving at Key West at approximately 18:00 that evening.

The logs for both ships while in Key West reflect a normal in-port routine with supplies being replenished, battery charges (*H-2*), and the sailors enjoying liberty when not on duty. On 23 January two of *Eagle-11*'s sailors were transferred to the Key West Naval Hospital and the ship placed in quarantine. The men's malady is not listed in the logs, however, the Spanish flu was rampant at the time. Quarantine restrictions did not appear to interfere significantly the with daily routine, for on 26 January stores were loaded and *Eagle-11* shifted to a pier-side berth. Quarantine was officially lifted at 13:00 on 27 January and the vessels sailed at 17:00 for Havana Cuba (Figure 97).

Courtesy of: Google Earth Pro.

Figure 97. Route Key West to Kingston, Jamaica.

Key West to Havana is a voyage of under 100 nautical miles (185 km), and by 09:00 on 28 January *Eagle-11* was safely anchored in Havana harbor with the submarines moored along its port side. The men went on liberty in Havana, a notoriously wild town for sailors, and some managed to find themselves in trouble. On the first night *Eagle-11*'s Chief Boatswain's Mate Bennet, who was most likely the ship's shore patrol officer, suffered a broken arm while defending a prisoner he was returning to the ship. Other events led to disciplinary actions being taken against six men from *Eagle-11* and two from *H-2*; while undocumented, it is unlikely that *H-1*'s crew comported themselves any differently. The ships departed Havana for the port of Kingston, Jamaica at 17:00 on 2 February; however, *Eagle-11* received a message from the Navy Department directing the vessels to Guantanamo Bay via Cienfuegos and Santiago on Cuba's southern coast.

The voyage to Cienfuegos was uneventful, with the vessels arriving on 4 February shortly after 11:00. While in port, *H-2* charged its batteries and conducted maintenance on the forward battery. Several of the rubber separators isolating the individual cells from each other had become saturated with battery acid effectively grounding the lead lining of the battery tank. The separators were removed, significantly reducing grounds on the battery. Reduction of grounds is critical as the higher the ground the poorer the battery will hold charge. The vessels got underway for Santiago de Cuba on the morning of 6 February.

Minor mechanical and electrical casualties plagued *H-2* on this short voyage. Shortly after getting underway the electrical steering system failed and steering was shifted to manual; the cause for the failure is not noted. Failure of the electrical ship's control systems (rudder, bow planes and stern planes), while not routine, was also not infrequent. The next morning the gyrocompass failed but was quickly repaired; then the port circulating water pump failed, requiring both engines to be stopped until it could be repaired. While none of these casualties individually were serious, they are indicative of the overall material condition of the vessel. *H-2* arrived in Santiago harbor and moored alongside *Eagle-11* and *H-1* at 17:07 on 7 February.

Santiago was a brief port visit with the vessels departing for the short voyage to naval base at Guantanamo Bay the morning of 9 February, where they moored at the fuel dock in late afternoon. *Eagle-11* took on fuel while the crew enjoyed swimming alongside. Logs reflect that the stop in Guantanamo Bay was focused on provisioning and refueling, and while the crews were granted liberty it was short, except for *H-2's* Executive Officer, Lt. (j.g.) Sexton who failed to return to the boat until 14:45 on 10 February. Sexton was restricted to the ship for five days as a result of his misbehavior. Officers were rarely restricted, referred to as "being placed in hack", but it was a common punishment for enlisted sailors. Men with active venereal disease were also restricted from going ashore. The vessels got underway for Kingston, Jamaica shortly after Lt. (j.g.) Sexton's return aboard.

The vessels made good speed on the trip south to Kingston, averaging nearly 10 knots (19 kph); *Eagle-11* moored to Royal Navy Dock No. 3 just before noon on 11 February with the submarines mooring alongside it shortly thereafter. Kingston was a liberty port for the crews and while normal in port routine was observed and some stores were loaded, no major work is reflected in the logs. Liberty was granted at the discretion of the commanding officer and typically began at 16:00 on weekdays, earlier on weekends, and expired onboard at 23:00 for enlisted men; however, officers were often allowed to remain ashore overnight.

Etiquette requires that commanding officers of ships visiting naval ports pay official calls on the Senior Officer Present Afloat, in this case a British naval officer; this visit is reflected in *Eagle-11*'s deck log but not noted in *H-2*'s. While it is plausible that *H-2*'s commanding officer failed to call and breached etiquette, it is more likely given the brevity of *H-2*'s deck logs that it was simply not recorded. On the morning of 14 February, the flotilla sailed for Submarine Base Coco Solo located near the city of Colon, Panama. The 550 nautical mile (1019 km) voyage to Coco Solo was uneventful and the three vessels arrived in port around 18:00 on 16 February.

They remained in Coco Solo until 24 February. The crew of *H-2* conducted maintenance, painted the boat, and refueled. *Eagle-11*'s log does not reflect the same level of maintenance activity or ship's husbandry, apparently another stylistic difference in log keeping. Before leaving Norfolk, Virginia *Eagle-11*'s Supply Officer brought aboard $14,000 to pay for stores and port fees, as well as to pay the crews of the three ships while in transit. Sailors were paid on the 5th and 20th of the month or as close thereto as practical if the ship was at sea.[271] There was still time for liberty, where the idle and freshly paid hands in this foreign port again got into trouble. Several men were awarded punishment for minor offences and one sailor, an engineman from *H-2*, was jailed for assault with a dangerous weapon. He remained in the Coco Solo brig until the flotilla departed to transit the Panama Canal on the morning of 24 February (Figure 98).

[271] U.S. *Navy, U. S. Navy Regulations*, 256R.

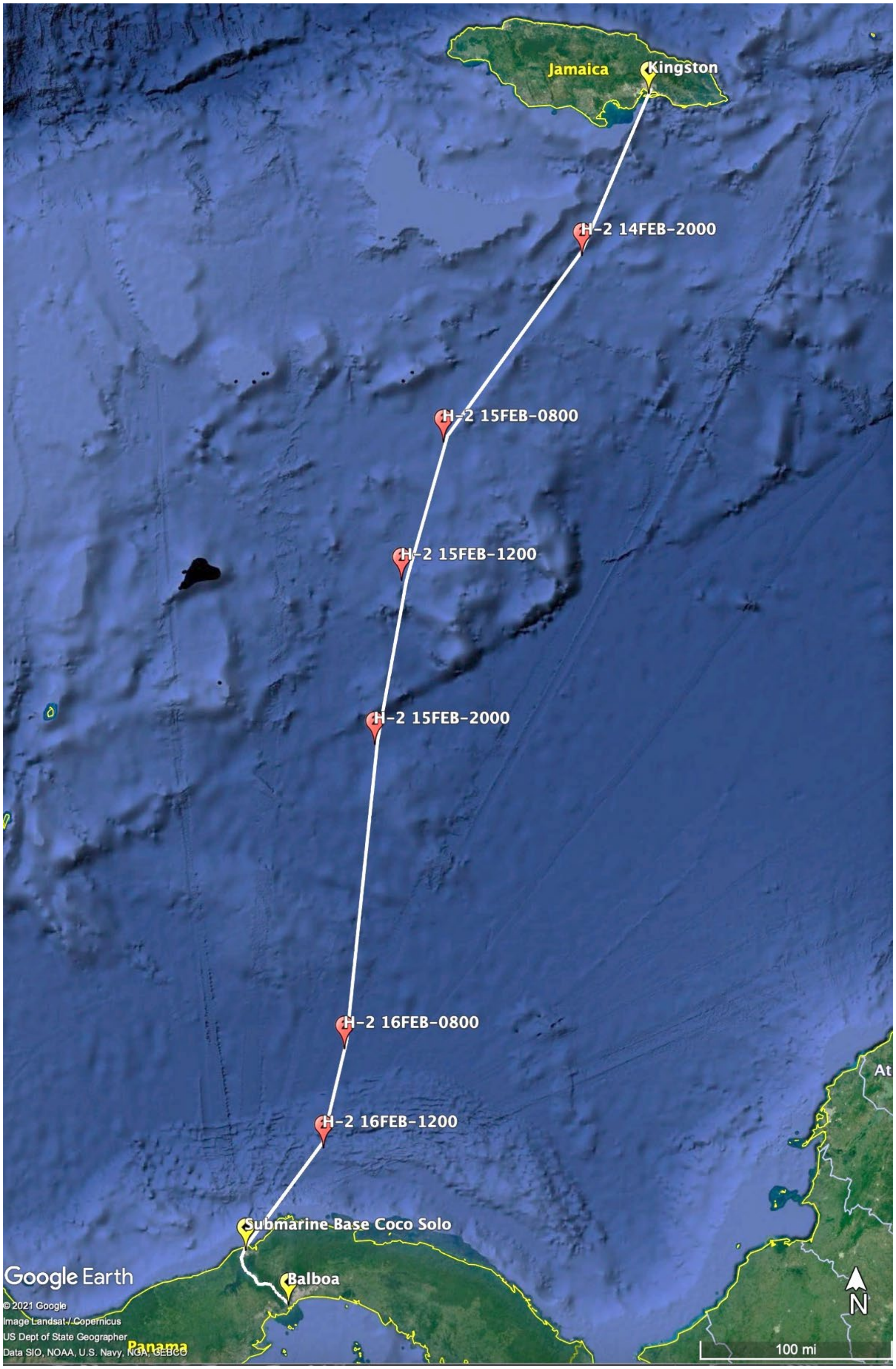

Figure 98. Route Kingston to Balboa. Courtesy of: Google Earth Pro.

The vessels entered the Pacific Ocean just after 19:00 on 24 February and spent the night moored at the pier in Balboa, departing the following morning for the port of La Union, El Salvador. This passage covered nearly 750 nautical miles (1389 km) north along the coast of Central America. Each of the vessels experienced mechanical and electrical casualties during the voyage; while none resulted in significant delays *H-2*'s log reflects that it slowed several times to wait for *H-1*. The casualties ranged from steering system and gyrocompass failures to a main bearing failure on *Eagle-11*'s propulsion turbine. The ability of the crews to keep the vessels operational at sea is noteworthy. The group arrived in La Union on 28 February, shortly after 18:00.

The port visit in La Union was punctuated by two events. On 1 March two of *Eagle-11*'s sailors failed to return to the ship and were subsequently declared deserters. Later the same afternoon a sudden gale blew in pushing *Eagle-11* against the pier. *Eagle-11*'s boxy superstructure and slab sides provided a large sail area, and it was moored on the windward side of the pier; the ship suffered non-mission limiting damage, bending lifeline stanchions and denting hull plating. *H-2* with its small sail area and large wetted surface, reported no damage.

The ships departed for Salina Cruz, Mexico the following morning leaving the deserters to fend for themselves, and the deserters' possessions were auctioned off by the Supply Officer. The ships hugged the coast on their voyage north, each experiencing minor equipment casualties. While the evidence is incomplete without *H-1*'s deck logs, it appears that *H-2* was in the best material condition of the three vessels. This assertion is based on the paucity of log entries noting significant casualties on *H-2* and fact that *H-2* frequently needed to slow or wait for both *H-1* and *Eagle-11* to maintain formation. The ships arrived in Salina Cruz on 4 March, shortly after 09:00, a voyage of 486 nautical miles (900 km) (Figure 99).

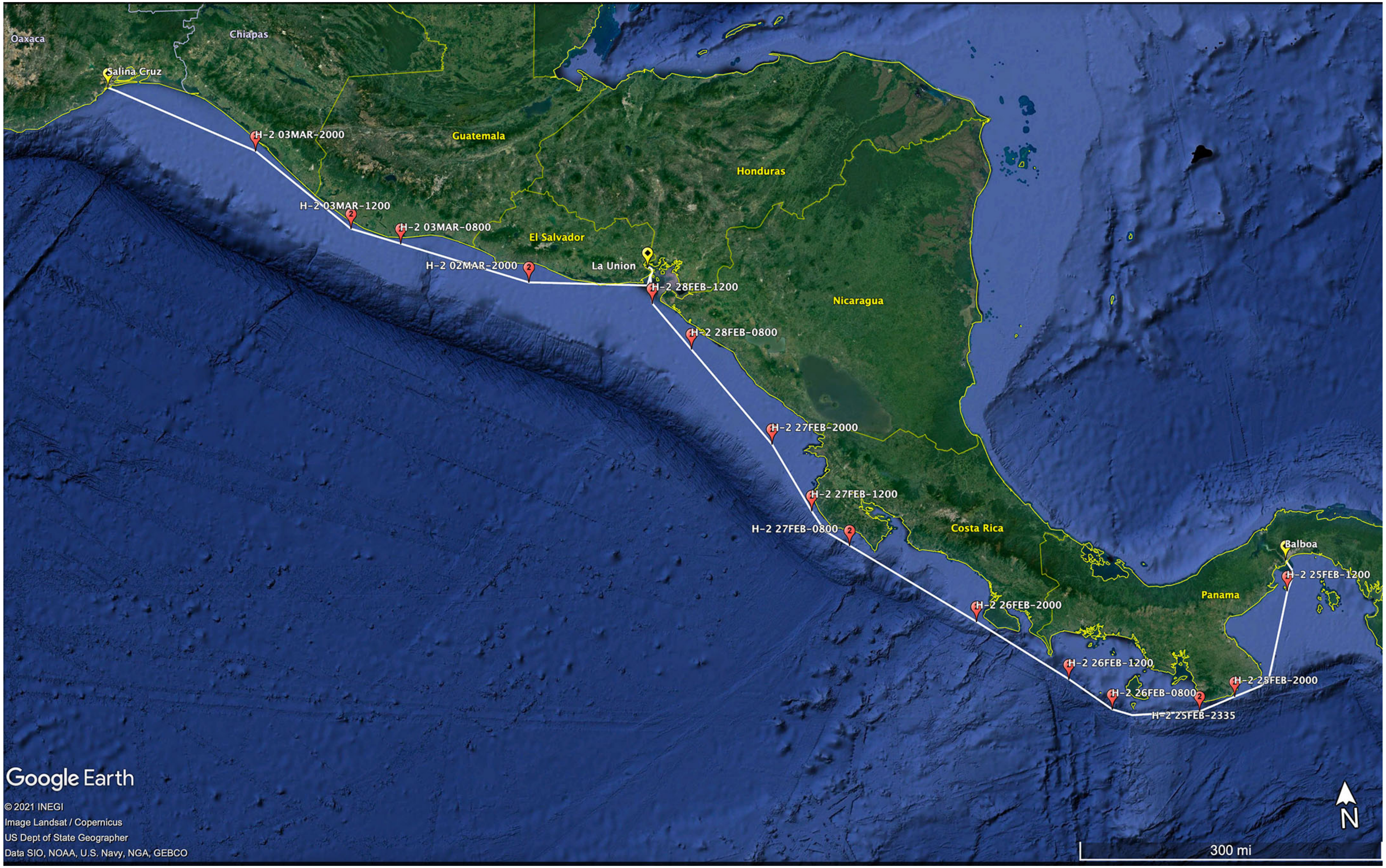

Figure 99. Route Balboa to Salina Cruz. Courtesy of: Google Earth Pro.

The port call in Salina Cruz was very brief; *Eagle-11* loaded fuel, water, lube oil, ice, and fresh eggs on the same afternoon. The morning of the 5 March several of *H-1*'s sailors received medical treatment, for reasons not documented, by *Eagle-11*'s chief pharmacist's mate, as the submarines carried no medical specialist. Following treatment, the men returned to *H-1* and, at approximately 09:30, the ships got underway for Manzanilla, Mexico.

Manzanilla Bay is approximately 590 nautical miles (1093 km) north of Salina Cruz, and the ships had an uneventful passage. While not noted in the narrative section of the log, *Eagle-11* was now using more water (likely for the boilers) than it was distilling. The logs reflect no mechanical delays and near perfect weather over the entirety this leg. On 7 March at 23:25, *Eagle-11* dropped its starboard anchor in 9 fathoms of water and *H-1* and *H-2* moored alongside.

The following morning, *H-2* blew 580 gallons (2195 l) of fuel from #2 fuel tank to #4 fuel tank. Transferring fuel from tank to tank by blowing it with air, not pumping, appears in the logs as the common transfer method. *H-2* and *Eagle-11* both loaded stores in the afternoon, *Eagle-11* from local vendors and *H-2* from *Eagle-11*. Two crew members from *H-1* received medical treatment on *Eagle-11*, but again the type of malady requiring treatment is not recorded. The fact that only *H-1* sailors are being treated raises suspicion that a communicable disease was being shared among the closely living crew. The submarines cast off their mooring lines and *Eagle-11* raised its anchor shortly after 18:00 on 8 March, getting underway for San Pedro, California.

The ships found themselves fighting both wind and current on this leg of the voyage. Northwest winds blowing at Force 2-3 on 9 March building to Force 4 by 11 March. Wind speed is reported using the Beaufort Scale which is based on observation of the effect the wind has on the surface of the sea, Force 3 equates to winds of between 7-10 knots (13-19 kph) and Force 4 to 11-16 knots (20-30 kph).[272] Current from near the direction of the wind, as was the case here, running southerly at approximately 1 knot (2 kph), tends to flatten the appearance of the sea, leading to an observation reflecting a lower wind speed.

H-1 suffered an unknown propulsion casualty shortly after noon on 9 March, requiring *H-2* and *Eagle-11* to loiter while the engine was repaired. The vessels did not resume their transit until 19:40 that evening. *Eagle-11* used more than double the amount of water than was distilled over the course of the day, likely an issue of either failing evaporators or a problem in the system which provided water to make up for losses from boiler operation.

The nest day brought increasing winds, but the group made steady progress, steaming 192 nautical miles (356 km) and making 162 nautical miles (300 km) as they sailed against the current. No equipment casualties were noted; however, *Eagle-11* expended 2400 gallons (9085 l) of water while producing only 1000 gallons (3785 l).

In the early morning hours of the 11 March *H-1* experienced more engine problems, obliging *H-2* and *Eagle-11* to again heave to and wait for the boat to regain propulsion. At 06:00 *H-1* ordered the group to divert to Magdalena Bay, evidently to make repairs in the shelter of the bay.

Water was becoming critically low for *Eagle-11*, and at 09:00 it parted company with the submarines sailing WNW to rendezvous with submarine tender USS *Beaver* from which water could be loaded. *Beaver* took *Eagle-11* in tow astern at just after 15:00 that afternoon and over the following three hours transferred 7000 gallons (26498 l) of water. By the time the submarines approached Magdalena Bay, *Eagle-11* and the two submarines were separated by approximately 40 nautical miles (74 km) (Figure 100).

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[272] Bowditch, *American Practical Navigator*, 533-538.

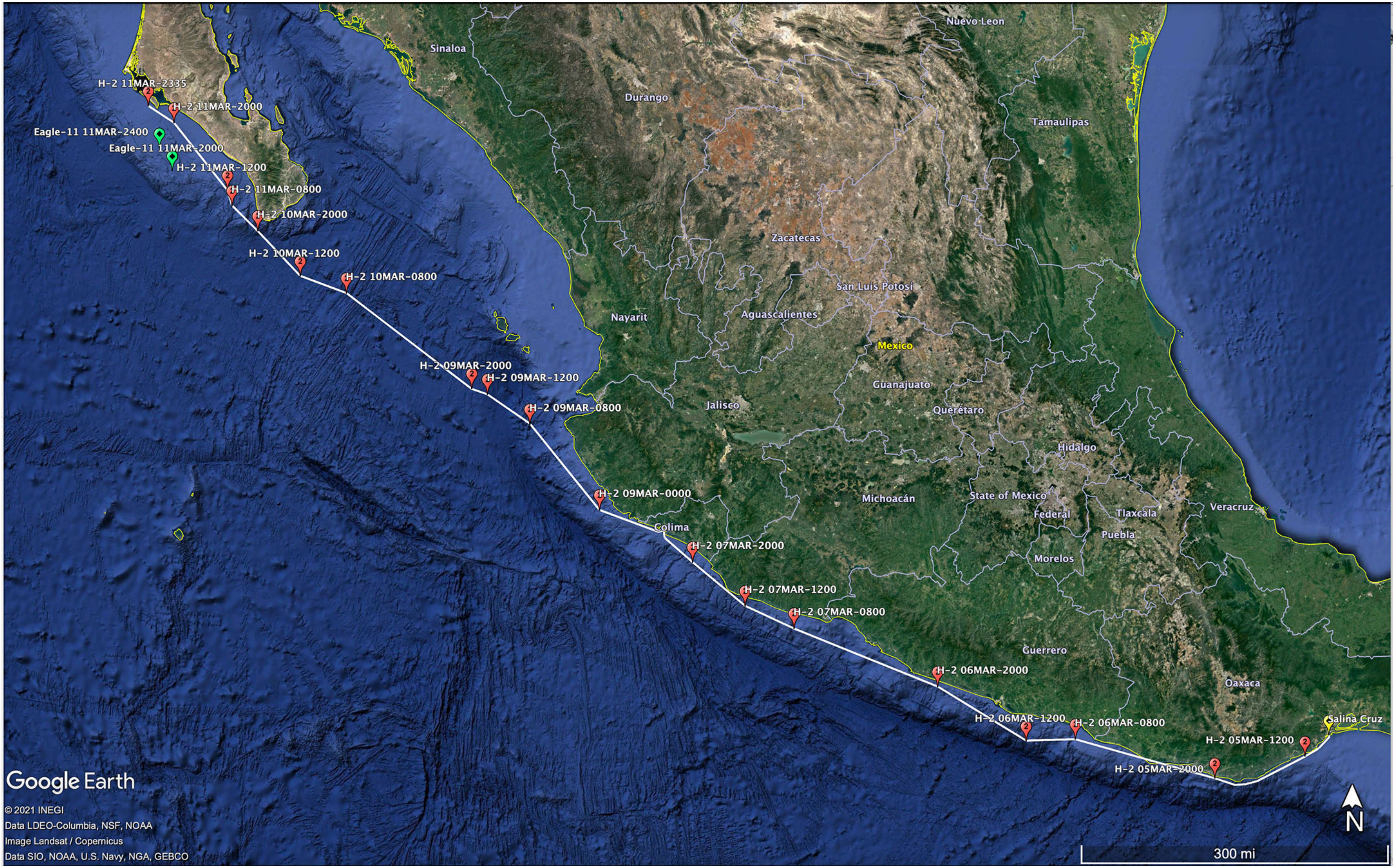

Figure 100. Route Salina Cruz to Isla Margarita. Courtesy of: Google Earth Pro.

The Grounding of *H-1*

This section relies on the deck log of USS *H-2* and on the testimony of *H-1*'s Chief of the Boat, Gunner's Mate Chief Petty Officer W. L. Albrecht, provided before the Board of Investigation inquiring into the loss of USS *H-1* during salvage operations following its grounding.[273]

H-2's log entries on the 0000-0400 watch on 12 March state that it was waiting for *H-1,* with the depth of water recorded as 19 fathoms (35 m). On arrival of *H-1*, at 01:04, *H-2* started both engines and began to follow *H-1*. Running both engines at 320 RPM typically gave the boat a speed of 8-10 knots (15-19 kph). At 01:14 the port engine was shut down and the starboard engine slowed to 300 RPM to reduce speed, the soundings indicated a depth of 17 fathoms (31 m). At 01:20 *H-2* stopped the starboard engine, and the sound of breaking waves was heard, while the soundings indicated a depth of 13 fathoms (24 m). A warning was received from *H-1* and *H-2* went astern on both motors. After backing into deeper water, the anchor was let go at 01:30 but the proximity of the lee shore must have concerned *H-2*'s commander as the anchor was raised at 02:00 to move the ship into deeper water where they anchored until daybreak.

Dawn revealed *H-1* aground to shoreward of *H-2*'s, with the crew congregated on the beach near *H-1.* After exchanging signals with the survivors ashore, *H-2* proceeded north to enter the bay and notified *Eagle-11* of the grounding. Both vessels entered Magdalena Bay, *Eagle-11* anchored and *H-2* tied up alongside; shortly after 12:00 search parties were sent ashore to locate and assist the *H-1* survivors.

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[273] NARA, *H-1* Sinking BOI, 26.

The chart that follows shows *H-2*'s approximate position where it loitered awaiting *H-1*'s arrival and shows the current position of *H-1*'s wreckage. The actual grounding site is estimated to be approximately .3 nautical miles shoreward (Figure 101).

Figure 101. Isla Margarita wreck site.

Courtesy of: Google Earth Pro.

Chief Albrecht's Board of Investigation testimony does not exactly correlate with chronology presented in the *H-2* deck log and is likely in error, as his testimony regarding *H-1*'s grounding was provided from memory. He testified that at about 00:10 Seaman J. Kosman informed him that the captain wanted him on the bridge. On his arrival on the bridge, Lt. Cmdr. Webb directed him to take soundings, which he did. The soundings reflected water depth greater than 7 fathoms (13 m). Albrecht further testified that it appeared that *H-1* was headed into the entrance to a bay as it looked like there was high ground on either side.

Isla Margarita has a very low central section that looks deceptively like an entrance; the topography of the island (Figure 101) shows that there is in fact high ground on either side of a gradually sloping plain. The 1915 Coast Pilot notes that on earlier charts the area was named "Pequena Bay" (Pequena translates to 'small' or 'little') and the northern promontory was called "Cape Judas".[274]

Albrecht testified that the boat was running on the starboard engine when he began taking soundings, and propulsion was shifted to the motors for a time, then he was told to stop taking soundings and propulsion was shifted back to the starboard engine. Albrecht went below for some coffee and returned to the deck; he had been on deck only a short time when Lt. Cmdr. Webb asked if he could see the entrance ahead and before he could respond the boat grounded, rolling heavily to port.

Lt. Cmdr. Webb tried to back off the strand using the motors, but the circuit breakers opened, and propulsion was lost. Waves began washing over the bridge and the captain ordered lifejackets be passed up; soon after giving the order, he was washed overboard along with Albrecht. Albrecht managed to get back onboard but Webb was not so fortunate. Albrecht saw

[274] U.S. Hydrographic Office, *Mexican and Central American Pilot (Pacific Coast)*, 89.

him momentarily in the breakers, but he was never seen again. Albrecht was washed overboard on two more occasions, on the last of which he could not regain the deck and clung to the stern gear for what he described as about two and one-half hours until he eventually lost his grip and swam ashore.

Reaching the beach, Albrecht found the other survivors buried in the sand to stay warm. He sent out search parties looking for missing crewmembers. Four men perished in the grounding, including *H-1*'s captain. The bodies of Seaman William H. Delamain and Machinist's Mate First Class Harvey W. Giles were recovered and buried in the sand; the search for Lt. Cmdr. Webb and Seaman Joseph Kosman was unsuccessful.

The following morning the survivors signaled *H-2* requesting the submarine to proceed into Magdalena Bay and inform *Eagle-11* of the incident. The *H-1* men would walk northward to meet their rescuers. Albrecht again sent a search party to the south (which was also unsuccessful); following this party's return the men began to walk to the north. *H-2* notified *Eagle-11* of the incident and *Eagle-11* transmitted a radio message at 11:15 informing headquarters. The message was also received by other stations including MV *Mazatlan*, which was off Isla Margarita at the time of receipt. [275]

Radio traffic between *Eagle-11* and *Mazatlan* indicate a lost opportunity to rescue *H-1*'s crew far earlier than it actually took place. Captain V. S. Terry, Master of MV *Mazatlan* offered the assistance of his ship and was initially told by *Eagle-11* that no assistance was required; released from the search, *Mazatlan* continued north. Later in the day *Eagle-11* transmitted a QST message (calling all stations), asking passing ships to be on the lookout for the missing crew.

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[275] NARA, Board of Appraisal to Consider Reimbursement due M.S. *Mazatlan*.

Mazatlan again offered to assist, although the ship was 60 miles (111 km) NW of the island. *Eagle-11* then requested it return Isla Margarita and join the search.

Isla Margarita is an inhospitable place, a desert environment devoid of water and shade, with steep terrain. *H-1*'s men walked all day over the mountains and found a short beach where they spent the night. The following morning, they split up, one group headed back toward the wreck, the other remained on the beach. Fortunately for the men, they were spotted by the MV *Mazatlan* and were subsequently rescued. The master of *Mazatlan* described the men as "absolutely without clothing" and in desperate condition suffering from dehydration and exposure.

Chief Albrecht stated that the last man rescued was identified as Seaman Second Class Holliday, that Holliday was delirious when found by a search party from *H-2*, and that Holliday was sent aboard *Mazatlan* joining the other survivors. No individual named Holliday appears on list of survivors provided by the master of *Mazatlan*, and research has failed to identify this individual. Two men, Seaman Second Class Milford Halloway and Seaman Harry Huber are the most likely among those listed, as they were the only non-rated sailors (Seaman) whose last names begin with the letter H.

Following the rescue, *Mazatlan* provided hospitable refuge and transportation for the survivors who were repatriated at Submarine Base San Pedro (Figure 102).[276]

SURVIVORS OF U.S.S. H-1

Standing L to R.

Stabler;William	Sea2c	Albrecht;Walter L.	CGM
Crow; Frank	MM1c	Jenkins; Lieut. Ex-Officer	
Bradley;W.M.	GM3c	White;John J.	EM1c
Brockhoff;August	SC2c	Hap Current LtJg.Passenger	
Brooks; Clarence	CQM	Cadwell;Edgar E	RM1c
Banks; Glen C.	Sea2c	Milligan;Edward S.	GM3c

Seated L to R.

Hulber;Harry J.	Sea2c	Wilde William F.	CMM
Delisle;James M	Sea2c	Bradley;Harry J.	MM1c
Wurmser;Paul	Sea1c	Garvey;John F.	Sea2c
Kostman;Jodeph	Sea1c	Tammaro Fredrick S.	Sea2c
O'Donnell;James T	F3c	Fred Orr F3c not in Picture	

Figure 102. Saved crew. Courtesy of: Pigboats.com.

[276] Survivors list under the photo includes SN Kostman. Survivors list from *Mazatlan* does not include a Kostman, presumably this refers to SN Joseph Kosman who perished in wrecking.

Salvage Attempts

Information on the initial 12-15 March salvage attempts, is found in the deck logs for the two principal vessels involved, the destroyer USS *Sinclair* (DD-275) and the fleet tug USS *Sonoma* (ATO-121). [277] The destroyer USS *Woolsey* (DD-7) and the collier USS *Neptune* (AC-8) provided support.

On 12 March *Sinclair*, under the command of Cmdr. F. McCrary, was in transit from the Panama Canal to its new homeport of San Diego, California. The ship was steaming in formation with USS *Doyen* (DD-280) and USS *Meade* (DD-274) and *Sinclair*'s deck log reflects that it split off from them during the 0400-0800 watch on 13 March, increasing speed and altering course toward Magdalena Bay. *Sinclair* sighted *H-1* at approximately 16:00 that afternoon (Figure 103).

Figure 103. *H-1* aground with USS *Vestal* to seaward. Courtesy of: Ric Hedman.

[277] NARA, USS *Sinclair* and USS *Sonoma* Deck Logs.

Sinclair anchored with the port bower anchor, veering 30 fathoms (55 m) of chain in 7 fathoms (13 m) of water, 350 yards (320 m) to seaward of the stricken submarine. A towing hawser was rigged from the stern of *Sinclair* to the pelican hook on the bow of *H-1*. *Sinclair* had no towing winch, which would have allowed a controlled strain to be induced via the towing gear; instead, it would need to tow bodily, using the engines. Shortly before 19:00, with daylight fading, *Sinclair* heaved up its anchor, went ahead on its main engines, and as the hawser came under strain it parted at the pelican hook. Following the failed attempt *Sinclair* anchored in Magdalena Bay, received *Eagle-11* alongside, and provided it with fuel and lubricating oil.

The following morning *Sinclair* returned to the wreck site, anchored, and passed an 8-inch (20 cm) manila hawser. This time a strain was taken on the towline by heaving in on the anchor before going ahead on the main engines. The hawser initially held and speed was slowly increased, but the line parted after 47 minutes. *Sinclair* repositioned and anchored again, this time veering 45 fathoms (82 m) of chain on the port anchor and dropping the starboard anchor veering 30 fathoms (55 m) of chain. Although seas were building, a messenger line was passed and another 8-inch (20 cm) towline was paid out from *Sinclair*. The high waves stranded the crew working on *H-1*, where they remained until the following morning.

Sonoma, an 1100-ton coal fired-fleet tug, had been working its way up the coast enroute from the Panama Canal to San Diego. It departed Balboa on 29 February towing two U.S. Coast Guard submarine chasers, one of which sunk on 9 March. *Sonoma* arrived in Magdalena Bay on the morning of 15 March, anchored the submarine chaser, and joined in the salvage effort. *Woolsey* arrived in the bay the same morning, dispatched early in morning of 14 March from San Diego with food and supplies to support the salvage operation.[278]

[278] 'Help Rushed to Wrecked Sub', *Sacramento Star*, 15 Mar. 1920.

On the morning of 15 March, *Woolsey* and *Sonoma* anchored near *Sinclair.* At 12:25, *Sonoma*'s commanding officer reported to *Sinclair,* then returned to his ship after only 20 minutes. Simultaneously, *Sinclair'*s working party secured the towline to *H-1.* After it was attached *Sinclair'*s deck crew connected a buoy and anchor to the bitter end of the towline and let it go so that *Sonoma* could retrieve it and quickly begin to work. *Sonoma* and *Woolsey* got underway clearing the way for *Sinclair* to do the same, which it did at 14:07. *Sinclair* and *Woolsey* steamed into Magdalena Bay and *Sonoma* anchored offshore of *H-1*.

Conditions were far from ideal; winds had been building and as *Sonoma* prepared to go to work it was blowing between Force 3 and Force 4. *Sonoma* laid out both bower anchors, veering 120 fathoms (219 m) of chain on starboard and 105 fathoms (192 m) on port. The long scope of chain would give significant purchase, against which the ship could exert towing force with its anchor windlasses. After retrieving the towline left by *Sinclair* and bending on its towing hawser, *Sonoma* began to heave in on both anchor chains; the towing hawser parted at 16:18 after only 18 minutes. The whaleboat was lowered to run out a new towline but was retrieved shortly thereafter, likely due to the weather and impending sunset. *Sonoma* heaved up its anchors and moved further offshore, anchoring in deeper water for the night.

Efforts to pass a wire hawser to *H-1* on the 16 and 17 March also met with failure, and on 18 March, after conferring with *Sinclair* and receiving stores from *Neptune, Sonoma* took its submarine chaser back in tow and departed Magdalena Bay for San Diego. *Neptune* and *Sinclair* sailed for San Diego as well.

While *Sinclair* and *Sonoma* had been working to refloat *H-1*, additional salvage assets were being assembled. The salvage force included the repair ship USS *Vestal* (AR-4), the fleet tug USS *Brant,* as well as *Neptune*, and *Sonoma* (which were about to get turned around). In addition to the ship's crews several men reported to *Vestal* for duty in the salvage effort including Cmdr. Julius A. Furer the Fleet Naval Constructor, Lt. John B. Cooke the commanding officer of USS *H-8*, and Chief Albrecht and Petty Officer 1st Class Harry Bradley of USS *H-1*. This salvage effort would be under the command of *Vestal*'s commanding officer Capt. W. K. Riddle. *Vestal* departed San Pedro on 18 March at 22:21, for Magdalena Bay.

Brant sailed from San Diego on the morning of 18 March with Coal Lighter #387 in tow, bound for Pichilingue Bay, just to the north of the city of La Paz, Mexico. It is apparent that the salvage plan had not been finalized before *Brant* sailed, as its logs for 18 and 19 March list the destination as Pichilingue, but this changed on the 20 March log to Magdalena Bay.[279] The route change correlates with the receipt by *Neptune* and *Sonoma* of orders to return to Magdalena Bay. *Brant*, *Sonoma* and *Neptune* arrived in Magdalena Bay the following day. *Brant* delivered the coal lighter which it had towed south to the care of *Neptune*.

Brant's coal barge was envisioned as a platform for the dewatering pump.[280] This turned out to be neither necessary, as *H-1* had little water aboard, nor possible as the submarine lay in the surf zone.

The description of this second phase of the salvage effort is based on the proceedings of the Board of Investigation convened to inquire into the loss of USS *H-1* and on the deck logs of the participating vessels.[281]

On the afternoon of 21 March, *Vestal* arrived on scene and anchored southeast of *H-1*. A planning conference was then held onboard *Vestal* to review the previous salvage work and to plan next steps.

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[279] NARA, USS *Brant* Deck Logs.
[280] NARA, Letter between Cmdr. Furer and Commanding Officer USS Vestal of 25 March 1920.
[281] NARA, *H-1* Sinking BOI; USS *Vestal* Deck Logs; USS *Brant* Deck Logs; and USS *Sonoma* Deck Logs.

Following the conference, an inspection of *H-1* was conducted by Cmdr. Furer, Lt. Cooke, Chief Albrecht, and Petty Officer Bradley to ascertain its current condition. They found it had suffered some denting damage to its superstructure and extensive internal fire damage in the forward section of the boat; however, forward bilges were dry. The fire damage was the worst in the forward battery compartment, it being completely gutted, followed by the control room and torpedo room. The control room, also referred to as the Central Operating Compartment or COC, had approximately three feet of water in the midships well directly below it. The aft battery compartment had minimal fire damage; however, the deck was bulged, indicative of a small battery explosion, likely from a buildup of hydrogen gas. The engine room suffered no fire damage and had limited water in the bilges.

The vessel had been ransacked between the time of the departure of the initial salvage vessels and the arrival of the *Vestal* group. The safe had been forced open, and all weapons ammunition, and explosives, except for the four torpedoes which were stowed in the tubes, had been stolen, as had practically anything else of value.

On Monday morning, 22 March, Lt. Cooke, Chief Albrecht, Petty Officer Schumerich, and Petty Officer Bradley, all submariners, returned to *H-1* and placed it in diving condition, shutting valves, hatches, and securing ventilation; the only exception was the bridge hatch which could not be dogged shut.

At 0830 *Sonoma* repositioned such that *Vestal* was anchored seaward and to windward. *Sonoma* took *Vestal*'s steel towing wire, secured it to its bow and backed toward *H-1* where it anchored. *H-1* was rigged with a towing bridle of 4.5-inch (11 cm) wire rope wrapped twice around its conning tower. Once secure on both anchors, *Sonoma* floated its steel towing wire to *H-1* using empty gasoline drums where it was secured to the bridle (Figure 104). A strain was successfully taken on the towing rig during the early hours of the 1600-2000 watch. The strain was slackened during the falling tide and taken up again.

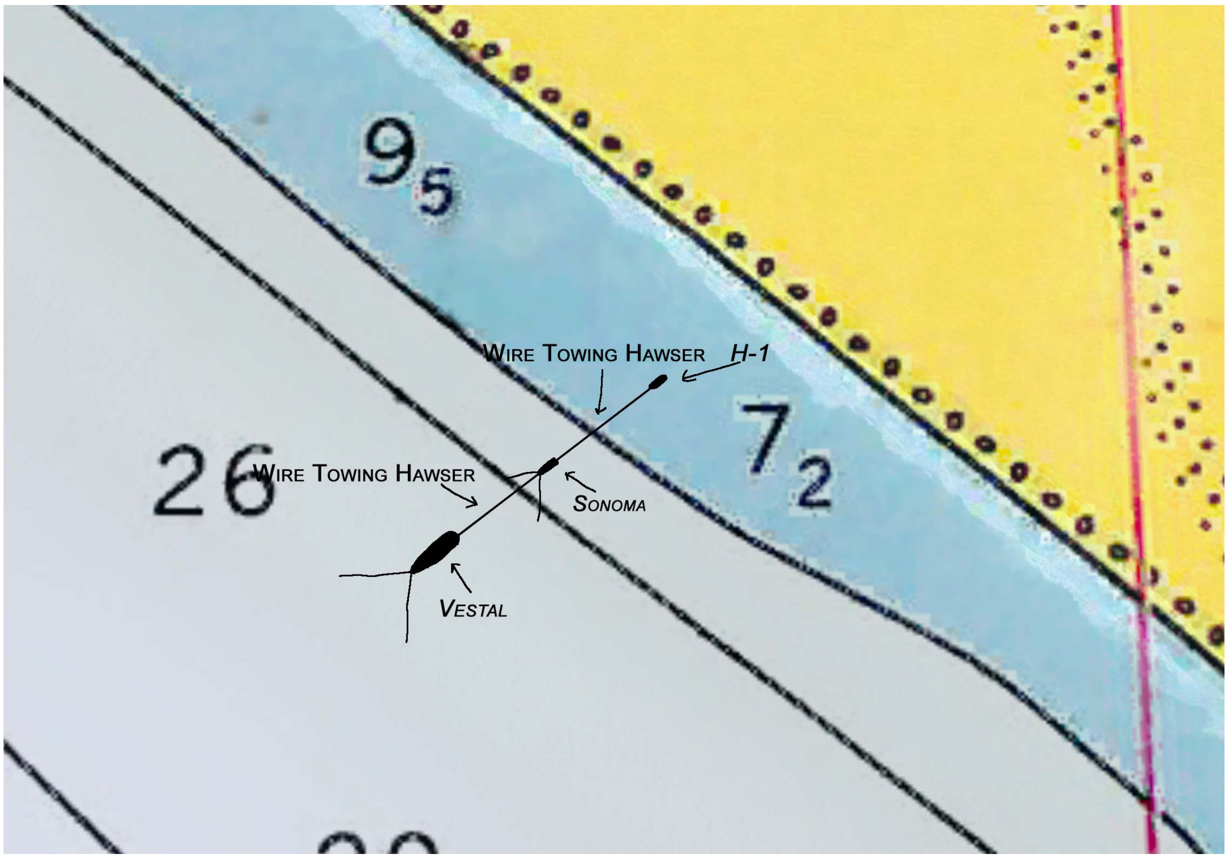

Figure 104. Initial towing configuration (Position is approximate and vessels are not to scale). Author after Searle and Curtis.

A moderate strain was maintained throughout 0000-0400 watch on 23 March, at dawn it was noticed that *H-1* had move significantly to seaward. At 09:10 with the tide flooding, *Sonoma* increased strain on the towing hawser and went ahead on its engine. At 09:40 *Vestal* went ahead on its engine as well, putting a heavy strain on the tow wire attached to *Sonoma*'s bow, damaging *Sonoma*'s anchor windlass and rendering it out of commission for hauling anchor chain. After dealing with the casualty, *Sonoma* steadily increased strain on the tow wire, moving *H-1* progressively seaward. *Vestal* directed *Sonoma* to avast heaving at 10:50 as movement had ceased due to falling tide.

Sonoma was now unable to work its anchors which left the ship potentially unable to control its bow. Both anchors were rigged to slip, breaking the chains at the inboard detachable link and attaching buoys to lines bent into the bitter ends of the chains. As an additional safety precaution, should *Vestal*'s tow wire break, *Brant* passed its 11-inch (28 cm) manila hawser to *Sonoma*; the hawser was made fast on *Sonoma*'s bow. *Brant* anchored off *Vestal*'s port quarter on a single anchor.

While the ships were preparing for another pull, a shore party disinterred the bodies of Petty Officer Giles and Seaman Delamain. Flags on the ships were lowered to half-mast as a boat delivered the sailors' remains to *Vestal*.

At 20:09 *Sonoma* began to pull, coming ahead slowly the engine reducing the load on its anchors to mitigate the risk of them dragging, while increasing the strain on its tow wire. *H-1* moved seaward; this movement continued until 22:30 when the strain on the tow wire increased indicating movement had ceased. *Sonoma* stopped its engine. *H-1* was resting on the bar with the surf breaking forward of its conning tower. The final note in *Sonoma*'s deck log for the night of 23 March notes an impending change of weather.

The weather deteriorated rapidly. *Vestal*'s deck logs for the first eight hours of 24 March reflect winds ranging from Force 4 to Force 7, the latter indicating winds in excess of 30 knots (56 kph). *Sonoma* observed the submarine pounding on the bar, the swells were becoming larger and their period greater, resulting in a high breaking surf. *Sonoma* began to pull at 05:20 as the sun rose, coming ahead on the engine at 50 RPM. As *H-1* came off the bar, *Sonoma* cast off the lines to *Vestal* and *Brant* and at 05:45 *H-1* floated free of the bar, trimmed down by the stern. *Sonoma* pulled *H-1* into deeper water, dragging its anchors toward *Vestal*. At 06:20 it slipped its starboard anchor and its port at 06:22. As *Sonoma* towed *H-1* northwest the submarine sank by the stern at 06:25.

On 26 March a Board of Investigation was convened aboard *Neptune* as ordered by Capt. W. K. Riddle, *Vestal*'s commanding officer and Senior Officer Present Afloat (SOPA). The board considered the testimonies of the officers and men involved with the salvage and found that *H-1* sank as a result of the pounding it received from the heavy seas on the morning of 24 March, not from the actions or inactions of those involved. The board further opined that given the high cost and risk of a salvage operation considered against the low probability of success and limited value of the vessel, no further salvage attempt was advisable. The report of the board was approved by SOPA and forwarded to the Secretary of the Navy.[282]

In a letter between the Chief of the Bureau of Construction and Repair and the Chief of Naval Operations, the former opined that there was no military value in *H-1*, save possibly the four torpedoes, and recommended selling the wreck for salvage, subject to return of material in which the Navy had interest.[283] On 18 May the Navy Department (Operations and Material)

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[282] Ibid.
[283] NARA, Letter between Chief of Construction and Repair and The Chief of Naval Operations of 29 April 1920.

informed the Commandant of the Twelfth Naval District that *H-1* would be sold as is except for torpedoes and torpedo material and instructed the commandant to advertise for bids.[284] Numerous parties expressed interest in salvaging the wreck; the Records of the Bureau of Construction and Repair show that on 25 June 1920 the "Bureau recommends that bid of $1050 by J. Allen be accepted."[285]

Research failed to uncover the actual contract of sale; however, it is evident that the salvor either never attempted a salvage or failed in his attempt. *H-1*'s wreck lies in close proximity to its sinking.

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[284] NARA, Telegram between Secretary of the Navy and Commandant Twelfth Naval District of 18 May 1920.
[285] NHHC, Ships Information Card.

CHAPTER VII

ARCHAEOLOGY

The archaeological study of *H-1*'s wreck site, off Isla Margarita, Mexico, is still in its early stages and there remains much to learn. The challenges of accessing the remote site and the lack of infrastructure available on the island, coupled with the hazards of working in close proximity to a lee shore, commonly exposed to breaking ocean waves, unpredictable currents, cold water, and poor visibility, were all reasons considered by the Navy when making the decision to sell the wreck for salvage.[286] While diving has become easier, the same factors of remoteness and a difficult marine environment confront archaeologists attempting to study this site. These barriers to investigation were further confounded, over the past 18 months, by both international and institutional travel restrictions resulting from the Covid-19 pandemic.

After the sinking, *H-1* was largely forgotten; this changed in 2016 when Alfredo Martínez Fernández, a photographer and diver, brought the shipwreck to the attention of Mexico's cultural heritage preservation agency, *Instituto Nacional de Antropología e Historia* (INAH).[287] Dr. Maria del Pilar Luna Erreguerena (1944-2020), Director of the Department of Underwater Archaeology at INAH, assigned Dr. Roberto E Junco Sanchez to investigate the wreck.[288] Dr. Junco visited the site in September of 2016 and formally identified the sunken vessel as the submarine USS *H-1*. He returned in January of 2018 with Dr. Kotaro Yamafune who photographed the wreck and developed a scaled photogrammetric model of the site.

It was through Dr. Junco's investigations that this author became aware of the *H-1* and developed an interest in the site as well as the history of the H-Class submarines in their broader

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[286] NARA, Letter between Cmdr. Furer and Commander-in-Chief, U.S. Pacific Fleet 1 April 1920.
[287] Dr. Pilar Luna and A. Martínez, pers. comm.
[288] Dr. Pilar Luna and Admiral López, pers.comm.

context. There is significant international interest in further exploring this unique site. The United States Navy's Naval History and Heritage Command (NHHC) and INAH have been very supportive of the investigation and continuing efforts to both understand and preserve the site. The wreck of *H-1* is the only extant example of the EB 26 design but unfortunately, due to environmental conditions and human activities, it is rapidly deteriorating.

Site Conditions

The twin factors of environment and time determine how well and how long artifacts remain in their original condition. Along with the external environment which surrounds an artifact, all objects, especially complex ones such as submarines, generate their own environment through the interaction of the materials of which they are constructed, and the interaction of those materials with the deposition environment.

Certain marine environments can preserve an artifact in extraordinary condition, which was the case with the Greek and early Roman Era ships recently found in the Black Sea. Some of the oldest and best preserved of these ships were found in deep water, greater than 3280 feet (1000 m), which was both cold and anoxic.[289] Vessels built during this time were built primarily of timber and other organic materials (except for metallic fasteners). This composition reduces the generation of an internal environment detrimental to the vessel. Black Sea vessels, while demonstrating the effect of a specific marine environment on the preservation of wooden ships, do not provide an adequate comparison on the effects of environment on century-old submarine wrecks.

[289] Pacheco-Ruiz, 'Deep sea archaeological survey in the Black Sea', 3.

HMAS AE2 Site Conditions

The Australian Navy submarine *AE2* provides a direct comparison with *H-1*. The two boats were lost within five years of each other but in very different marine environments, and today they are in very different condition. *AE2* was lost in 1915 in the Dardanelles when it was scuttled by its crew following a battle with the Ottoman torpedo boat *Sultanhisar.* Its wreck was discovered in 1998 and while exhibiting both concretion and mild corrosion was found to be in excellent condition.

An assessment in 2007 showed that over the nine years since its discovery the wreck had experienced significant damage to its superstructure from fishing activity. In areas where concretion had been accidently disturbed ultrasonic testing was conducted to measure the thickness of the pressure hull. While the measurements differed from the original thickness, the hull was considered to be in good condition. In 2014 another assessment was conducted which included recording video within the hull as well as externally. Once again the submarine was found to be in amazingly good condition.

AE2 lies in 240 feet (73 m) of seawater half buried in a silt mound. Measurements of seawater taken at depth in 2014 indicated saline levels of 41ppt, dissolved oxygen of 3ppm and a temperature of 60 degrees (16 C).[290] Current velocities in the Dardanelles decrease with depth and these deep-water currents, measured at depths greater than 197 feet (60 m) in September 2008 through August 2009, rarely exceeded .38 knots (20 cm/sec).[291]

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[290] Macleod, 'Corrosion and Conservation Management of the Submarine HMAS AE2', 868-871.
[291] Jarosz, 'Observations on the characteristics of the exchange flow in the Dardanelles Strait'.

No similar quantitative analysis of the environment surrounding *H-1* has been conducted; however, it is clear that *AE2* rests in a relatively benign environment when compared to that of *H-1*.

H-1 Site Conditions

H-1's wreck lies on a sandy bottom under 60 feet (18 m) of seawater in close proximity to the position where it sank (Figure 101). The 13-year mean salinity and temperature, calculated from 1950-1962 at 33 feet (10 m) of seawater in the area of Isla Margarita were 34.4 ppt. and 70 degrees (21 C) respectively.[292] The average level of dissolved oxygen in the area of the wreck is currently unknown. Levels of dissolved oxygen in seawater can vary significantly from the anoxic Black Sea to as high as 12 ppm. Cold water with low salinity can hold the most dissolved oxygen; raising either the temperature or salinity of the water reduces its oxygen carrying capacity. Other factors which affect dissolved oxygen are water movement and the presence of marine organisms that either generate oxygen (plant life) or consume oxygen (animal life). Considering the abovementioned factors, it is probable that the environment surrounding *H-1* has a higher carrying capacity for dissolved oxygen. Higher dissolved oxygen levels result in higher corrosion rates in steel.[293]

The marine environment in this area of Baja California is influenced by wind-driven current which flows predominantly in a southerly direction along the coast at approximately 1 knot. The northwesterly wind that drives these currents is directionally steady except for a reversal which typically occurs during November and December and another shift in December and January when strong winds from the north and northeast frequently occur.[294]

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[292] Lynn, 'Seasonal Variation of Temperature and Salinity at 10 Meters in the California Current', 161-162.
[293] Shifler, 'Corrosion Science', 2339-2342.
[294] NGA, *Pub. 153, Sailing Directions (Enroute) West Coasts of Mexico and Central Americ*a, 11 and 23-26.

Conditions observed on the site during dives made in September, November, December, and January show a southerly current flow with visible influence from eastward traveling ocean waves in the form of sand waves as well as increasing sand deposits along the seaward side of the wreck. Visibility on the site is variable but appears best in late fall and early winter; factors influencing visibility include blooms of both phytoplankton and zooplankton as well as suspended solids resulting from agitation by waves. Site hazards include unexploded ordnance from the torpedoes which remain in the torpedo tubes, derelict fishing gear, and marine life.

In the century that *H-1* has lain on the seafloor it has become part of a vibrant eco-system. It is covered with marine organisms including sea anemones, colorful soft corals and common barnacles, and its hull is developing a layer of concretion that appears almost fur-like with marine growth. Voids within the hull are also rich in aquatic life, including lobsters, octopi, eels, and many species of fish making their homes among the machinery (Figure 105).

Figure 105. *H-1*'s coral garden. Courtesy of: Alfredo Martinez.

H-1 like any shipwreck is composed of multiple micro-environments which are both surrounded and infiltrated by the wider marine environment in which it is immersed. Each of those micro-environments contribute to the overall dynamic site formation process. In simple parlance, the wreck is contributing to its own destruction.

H-1's hull, framing, and structural members were built from steel, a material composed predominantly of iron. Maritime conservation expert Dr. Donny Hamilton has frequently stated that iron is an unstable element that does not want to remain iron. Hamilton has written extensively on the multiple complex processes involved in the corrosion of iron, noting that iron corrodes far faster in salt water than in air or soil. One of these processes is galvanic corrosion which occurs when two dissimilar metals are electrically connected by an electrolyte, in this case seawater, thereby creating a galvanic cell.[295]

Galvanic cells are easily understood by considering two different metals as water tanks, one at high pressure, the other at a lesser pressure; connecting the tanks together with a hose will result in the high-pressure tank discharging into the low-pressure tank until the pressure (a form of stored energy) is equal. Metals store energy in the form of their unique electrical potentials, those with the most positive potential are called cathodic, noble, or passive metals and those least positive potential are referred to as anodic, base, or active metals. When the dissimilar metals are connected with an electrolyte the anodic metals are eaten away as a result of the electro-chemical reaction, with the particles they give up providing corrosion protection to the noble metals.

Many factors influence the rate at which anodic metals decompose as a result of this reaction, including the amount of dissolved oxygen in the electrolyte, the proximity and mass of the dissimilar metals, temperature, salinity and movement of the electrolyte, and the abrasive

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[295] Hamilton, *Conserving Underwater Archaeological Material Cultur*e, 42-47.

action resulting from solids carried in or moved by the ocean environment. Of these factors the most significant is dissolved oxygen as the process stops in its absence, and the next critical is the ratio of exposed surface area of each type of metal.

H-1 has a significant number of metals on both ends of the electrical potential spectrum, among the more noble are the cupreous (copper based) metals found in the boat's piping, torpedo tubes, conning tower and wiring, as well as lead found in its batteries. Its hull and much of its structure is composed of steel which is largely iron, a base metal, much of which is missing, more so in areas proximate to noble metals.

This condition is referred to as the 'area ratio effect': the greater the ratio of exposed cathodic metal to exposed anodic metal the faster the latter will decompose. The closer the dissimilar metals are in proximity to one another the greater the decomposition rate, which is also true with higher temperature and greater salinity levels in the electrolyte. The electro-chemical decomposition of the anode results in its plating the cathode, and in an environment where the electrolyte is still and no abrasion of that coating occurs, the process will cease when the cathode is no longer exposed to the electrolyte.[296]

The combined environmental conditions of high dissolved oxygen, moderate salinity, cool temperature, and very active tide, current and wave driven movement of both the electrolyte and suspended solids surrounding *H-1*, when coupled with large amounts of metals relatively more noble than steel, dispose the submarine toward rapid galvanic corrosion. After a century in this state the hull is showing the results.

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[296] Warren, *Metal Corrosion in Boats*, 98.

Human Interference

No certain date can be attached to the discovery of the wreck, but Martínez related to Dr. Junco that the presence of fish in large numbers, in and near the wreck likely drew the attention of local fishermen many years before he was informed of its existence. He further related that following the discovery, some individuals began to loot the wreck for valuable scrap metal.[297] Some of the artifacts removed from the wreck as souvenirs, have since been graciously returned to INAH.

Fishing activity has adversely impacted the wreck. Local fishermen typically anchor their boats to the wreck using a grapnel anchor. No anchors suitable for anchoring in sand were observed during the author's visit to the island. The wreck is littered with fishing equipment, lines, and anchors, as well as lobster and fish traps. This derelict equipment is damaging to both the site and the marine life as the gear continues to kill animals post abandonment (Figure 106).

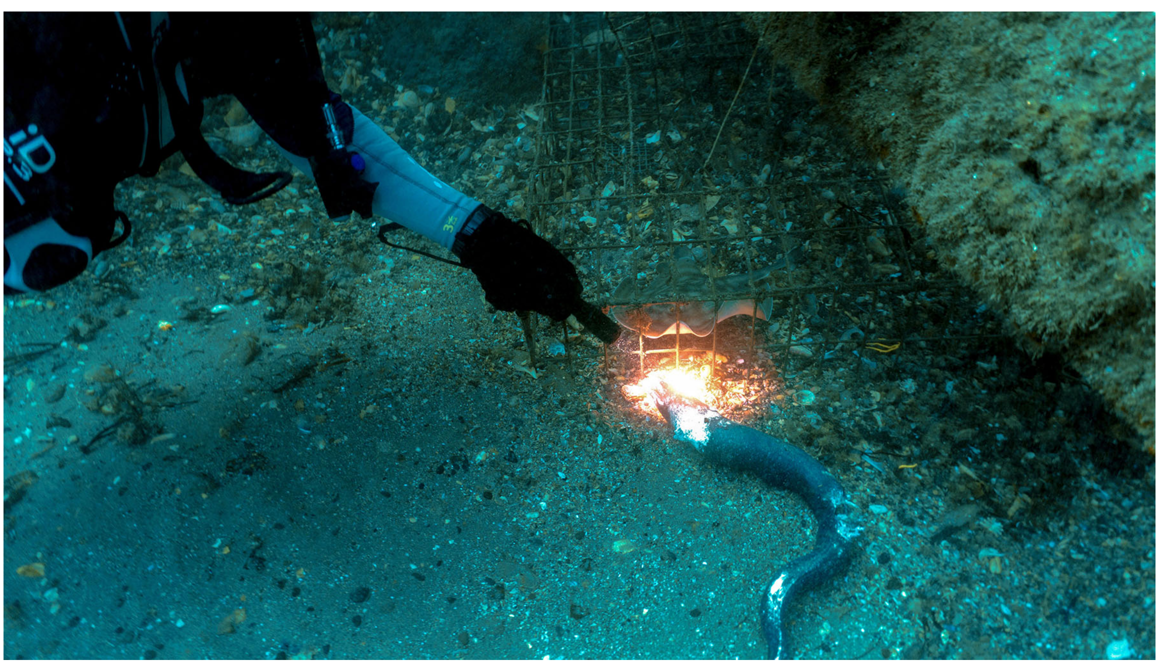

Figure 106. Entangled Moray eel. Courtesy of: Sam Haskell, Indiana University.

[297] Dr Roberto Junco and Richard Hendren, pers. comm.

The Expeditions

2018 Mapping - Junco and Yamafune et al.

National Geographic funded INAH to conduct an expedition to collect photographic images and process photogrammetry on wreck sites in the waters surrounding Isla Margarita in January 2018. The expedition, directed by Dr. Junco, departed La Paz, Mexico for Isla Margarita on 25 January and Dr. Yamafune recorded the *H-1* imagery the following day. From that imagery, Yamafune developed a photogrammetry model and site plan. This site plan is invaluable as it provides a temporal reference to the condition of *H-1* in 2018, allowing future researchers to better understand the ongoing site formation process. This author simply identified and labeled the major components listed and added a compass rose and graduated meter scale but credit for this fine work belongs to Dr. Yamafune (Figure 107).

H-1 lies on its port side with its bow to the northwest; its visible wreckage is well consolidated, as one might expect from its relatively benign sinking event. Immediately evident on inspection is the sheer magnitude of missing hull plating and framing. Little of the metal which would have formed the torpedo room and the starboard sides of the forward battery compartment, control room, and aft battery compartment remains. It is possible that the missing hull plating and framing has been displaced from the wreck and lies buried in the substrate or was removed by looters; however, given the advanced degradation of the visible hull and structure it is most probable that the loss is largely the result of galvanic corrosion.

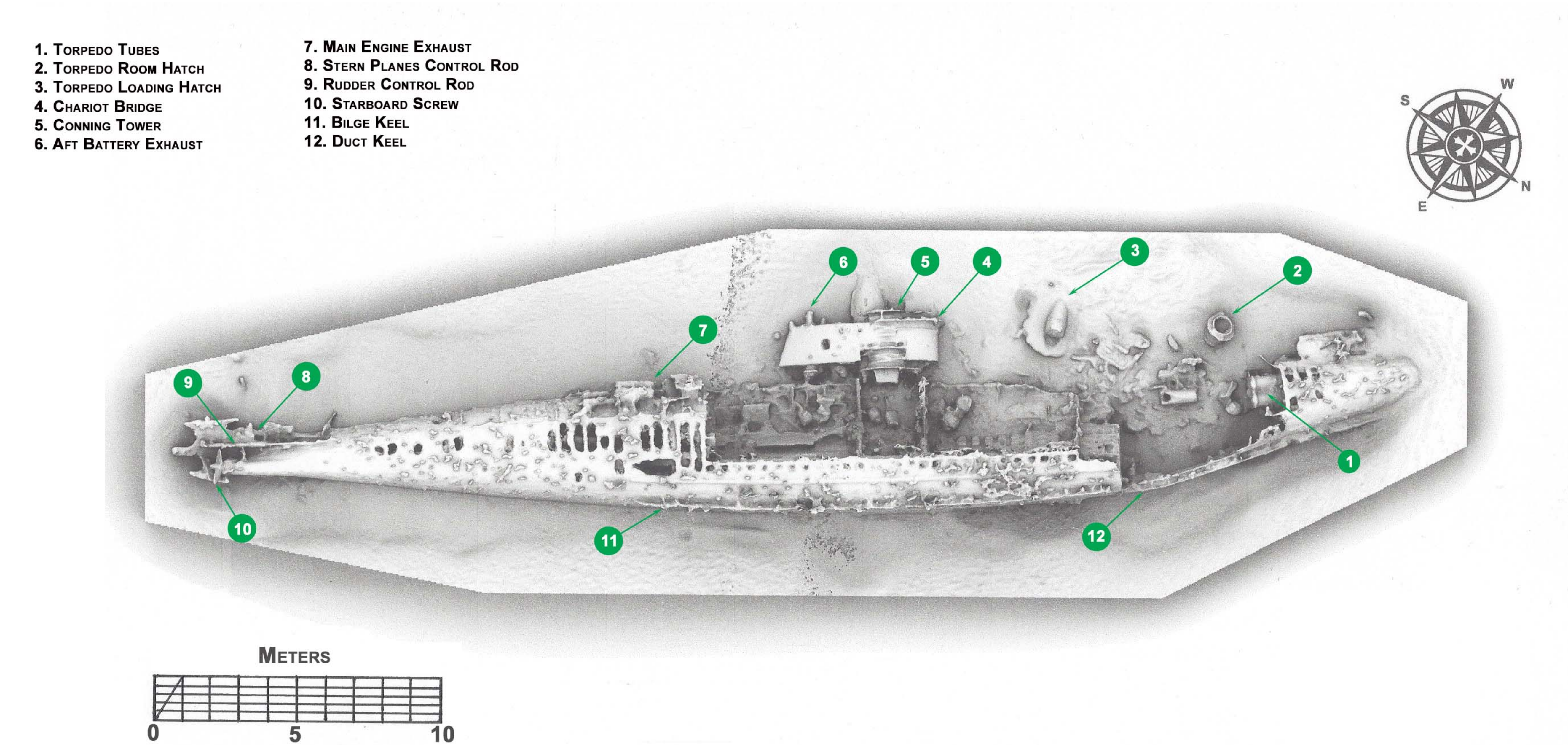

Figure 107. *H-1* site plan.

Author after Yamafune.

2019 Expedition - Hendren and Tattersfield et al.

In May of 2019 Dr. Junco introduced the author to Mr. Peter Tattersfield, one of the founders and the leader of *Kaxaan* Nautical Foundation, an international group of underwater explorers closely linked with INAH. The two were planning an expedition to Isla Margarita and invited the author to participate.

The two primary objectives of the project were to document the current condition of *H-1* and to educate the residents of Puerto Alcatraz the islands local population on the history and cultural significance of the wreck. Scope of diving operations on the *H-1* wreck site was limited to non-intrusive investigation, observe and photograph only, as no excavation permit was requested. Follow-on investigations with limited excavation were anticipated but have been delayed by the pandemic. Intrusive investigation requires permitting as the site is protected by both the United States through the Sunken Military Craft Act of 2004 and by the government of the Republic of Mexico as a signatory of the UNESCO Convention on the Protection of Underwater Cultural Heritage. Permits were not sought due to the limited time and lack of conservation resources available to the team. The intent of the second objective was to develop a sense of ownership of the site and thereby discourage looting of the wreck. Secondary objectives of the expedition included identifying other shipwrecks believed to be located off Punta Tosca on the islands southern tip. Principal among these secondary targets was the gold rush era steamer SS *Independence* which grounded and burned on 16 February 1863 with the loss of over 150 lives.

Following months of planning and coordination the expedition took place in October 2019; the team included Tattersfield and his team of avocational archaeologists/explorers, a film crew, archaeologist Samuel Haskell from the University of Indiana, archaeologist Gustavo García of INAH, and the author.

Assembling in La Paz on 10 October the team provisioned and traveled to Isla Margarita the following day. Most of the crew traveled overland and then by boat to the island; however, an advance team flew out to begin setting up operations and lodging, landing at the naval base on the island (Figure 108).

Figure 108. Expedition team. Courtesy of: Francisco Con.

On arrival the team settled into their quarters and set about readying their diving equipment. Once equipment was checked and staged for the following day's dives, the team hosted local civil and naval leadership for dinner and a briefing on the project and its goals. Following dinner, dive safety and site orientation briefings were conducted, and the team retired for the night. Accommodations were spartan most of the team slept in hammocks, but the hospitality of the local residents was generous, and greatly appreciated.

Puerto Alcatraz is a small *pueblo* of just over 150 residents. The primary economic driver of the village is fishing, which has likely been the case since the first humans inhabited the island. The waters of the protected bay are rich in marine mammals, reptiles, and fish, all of which have been harvested by both local inhabitants and visitors. The modern residents still set to sea on a near daily basis to supply fresh fish to the neighboring communities. The expedition hired these knowledgeable mariners and their boats for transport and diving operations.

During the team's short visit to the island, meetings with members of the local community and officials from the naval base informed them of our plans and solicited their assistance in protecting *H-1* and the other historical wrecks in the surrounding waters. The residents' friendliness and willingness to help the team was heartwarming. One of the highlights of these meetings was an educational event conducted for the local children, which was enjoyed by the presenters and their audience alike.

Early the next morning the team got underway for the *H-1* wreck site, a voyage of 21 nautical miles (40 km). Conditions the morning of 11 October were ideal for the trip to the dive site, with calm winds and flat seas inside the bay. A low ocean swell was running as our boats rounded the northwest point of the island and entered the open sea. On nearing the site of the wreck, it became evident how H-1's Lt. Cdr. Webb mistakenly believed that he was navigating into an entrance to the bay, the slope of the beach being so gradual and depth shoaling suddenly just off the beach (Figures 109 and 110).

Figure 109. Early morning departure. Courtesy of: Sam Haskell, Indiana University.

Figure 110. Transit to dive site.

Courtesy of: Google Earth Pro.

The group was divided into two dive teams and the days dive plan for *H-1* allotted two 50-minute dives per team. After anchoring on the recorded coordinates of the wreck, the first team of divers, including this author, descended the anchor line and did not see the submarine; visibility was approximately 25 feet (7.6 meters) and current was negligible. The team began to search for the wreck using an expanding circle search. This technique uses a line fixed to an object on the sea floor (in this case the dive boat's anchor); the diver extends the line to the limit of visibility and swims in a circle, after completion of the circle the line is extended again and the new area searched. This process continues until the object is found or (as in this case) the divers reach the time limit of the planned dive. Having not found the wreck, the first team surfaced and informed Team 2 that the wreck was not on the coordinates. The captain of Team 2's boat believed that it was slightly to the east and repositioned his boat accordingly. Team 2 descended the anchor line and this time found *H-1*'s wreck.

Following an appropriate surface interval to complete decompression from their first dive, Team 1 made their second dive and was able to observe and photograph the wreck site. Visibility was not optimal, but it was evident from initial observation that *H-1*'s hull condition had changed in the 22 months since Junco and Yamafune visited the site in 2018. In Yamafune's photogrammetric site plan hull plating remains attached, albeit with multiple holes, from the aft battery compartment bulkhead aft to the stern gear. A significant portion of this plating and its underlying structural framing, (shown in red Figure 111) was now partially separated from the hull.[298]

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[298] The photos and descriptions that follow are best interpreted when viewed with the site plan (Figure 111) or the ship's plans (Figures 49 and 50) as a positional reference.

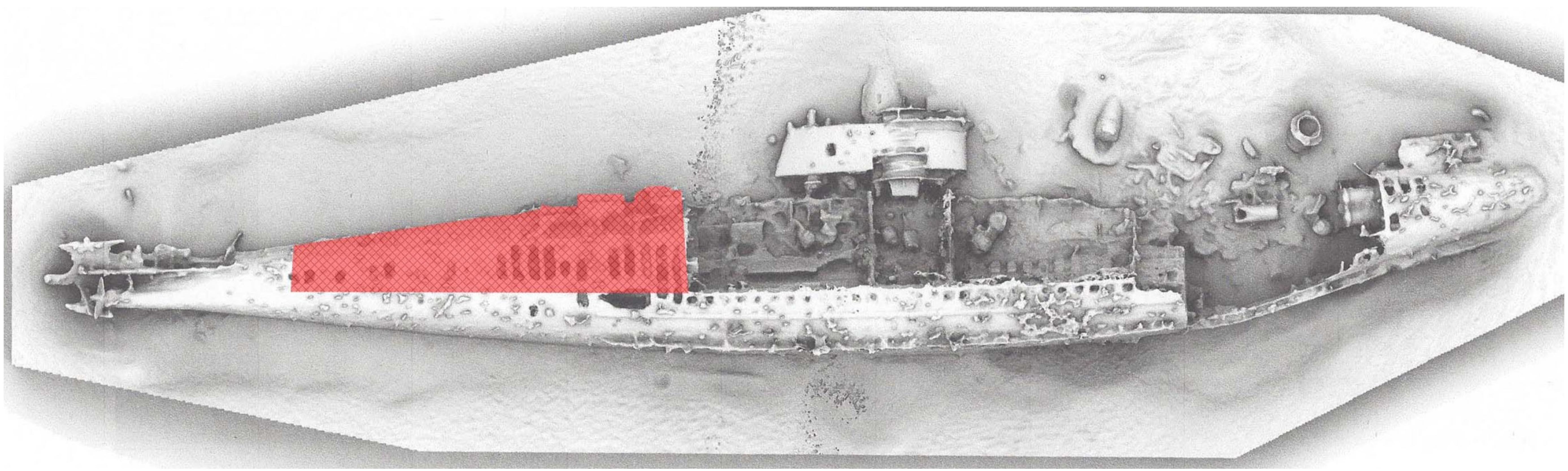

Figure 111. Site plan showing extent of disarticulated Engine Room hull plating.

Author after Yamafune.

The plating was lying concave side up in the sand along the port side of the wreck; indicating that instead of collapsing inward, it had folded away from the wreck (Figure 112). This differs from the displaced hull plating at the forward compartments, which is lying, for the most part, with the convex side to the sand. One plausible explanation for this is that with the submarine resting on its port side, the weight of the exhaust system induced a reaction force, similar to the forces induced by placing a weight on the end of a cantilevered beam, which tore the plating off at the rivet line on the starboard B-strake, rolling the plating outboard. It is also conceivable that dragged anchors or other human interference is responsible for this significant recent damage.

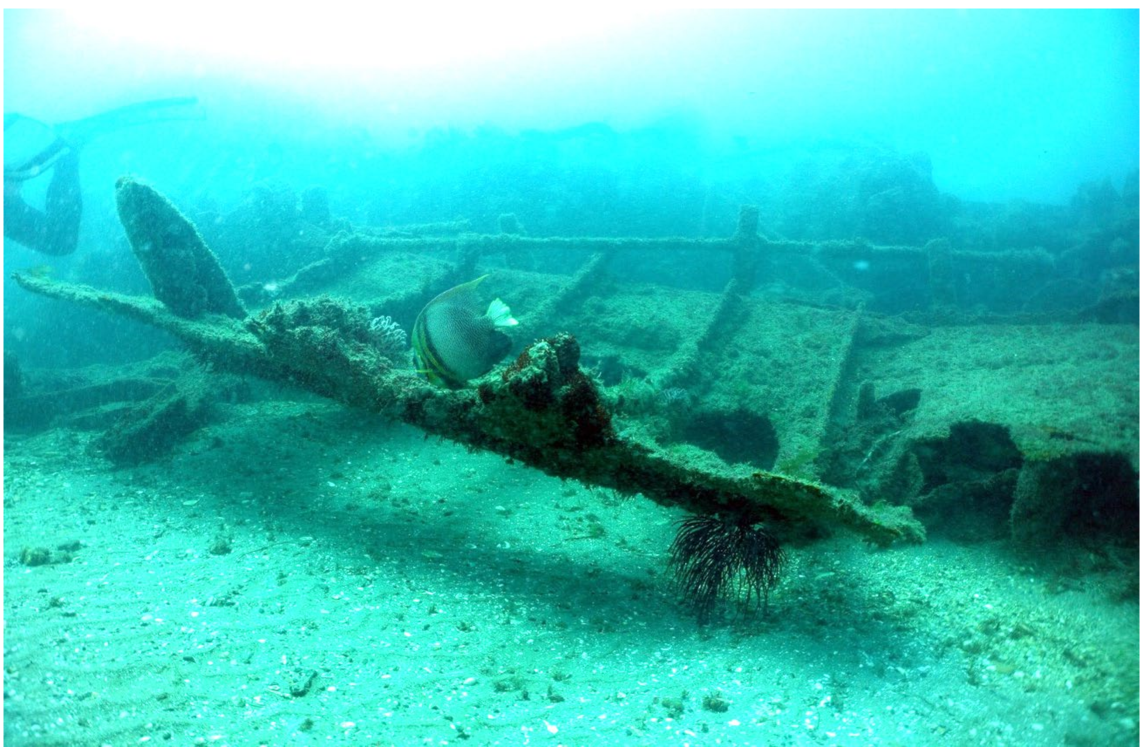

Figure 112. Engine Room hull plating. Courtesy of: Francisco Con.

Aft of the collapsed engine room hull plating, the operating shafts for the stern planes and rudder could be seen as the two linear elements originating near a yellow fan coral and running aft along the hull toward the exposed section of the stern casting in the background. This casting supported control surfaces which were no longer attached to the casting. Parts of the control surfaces, likely the port stern plane, lay detached in the debris field (seen in the background, center right of Figure 113). A piece of galvanized wire protruded from this debris field, perhaps a remnant of a modern looting attempt. The two propellers remained fitted to the propulsion shafts, which is surprising since both have considerable value as scrap and as souvenirs; detachment of the stern planes may have been undertaken to facilitate their removal.

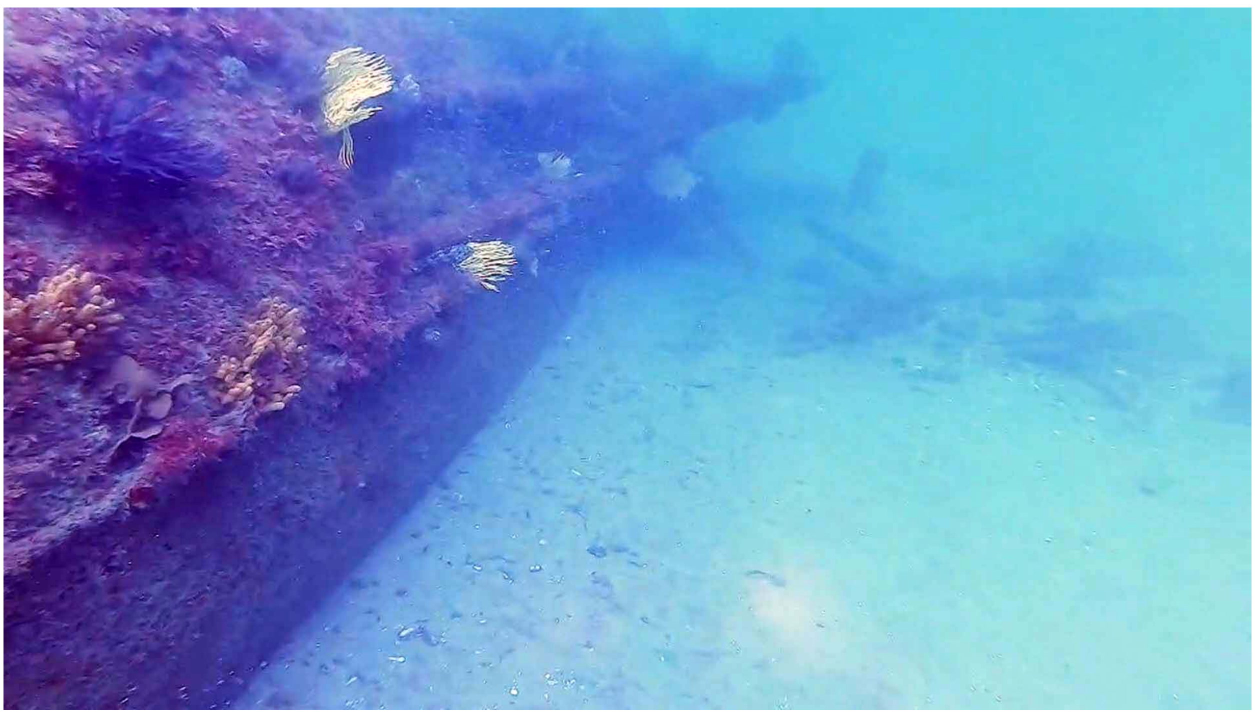

Figure 113. H-1 port side looking aft. Author.

Leaving the area of the stern gear and moving forward along the starboard side. The hull was relatively intact from the propellers forward to frame 10 and was heavily deteriorated going forward. A large open pipe (located in the center left of Figure 114) was the tube for the submarine signaling bell; situated centerline at frame 16, it provided a good visual reference for measuring hull loss and identification of engine room equipment (Figure 114).

Figure 114. Submarine signaling bell tube. Courtesy of: Francisco Con.

Further forward along the starboard side shaft line components came into view, although much more was buried under a jumble of broken pipes and collapsed sections of the hull. The structure seen adjacent to the starboard main engine, shows the B-strake of the hull overlapping a remaining fragment of the C-Strake (Figure 115). The rivet holes are empty as the rivets, formed from a different steel alloy than the hull strakes, have corroded away. A vertical butt seam in the B-strake can be seen in the lower right of this image. Also visible, astern of the aft-most fragment of C-strake, are the starboard motor-generator and the starboard power pump.

Figure 115. Starboard motor-generator. Author.

Figure 116, taken adjacent to the starboard main engine looking forward, shows the upper section of the engine, the nearly-complete transverse bulkhead which separates the engine room from the aft battery compartment, and the bilge keel. Submarines are prone to rolling, due to the circular cross section of the hull, and bilge keels were fitted on the H-Class to reduce the rolling moment. Also visible in the image are several of the fishing traps which littered the wreck.

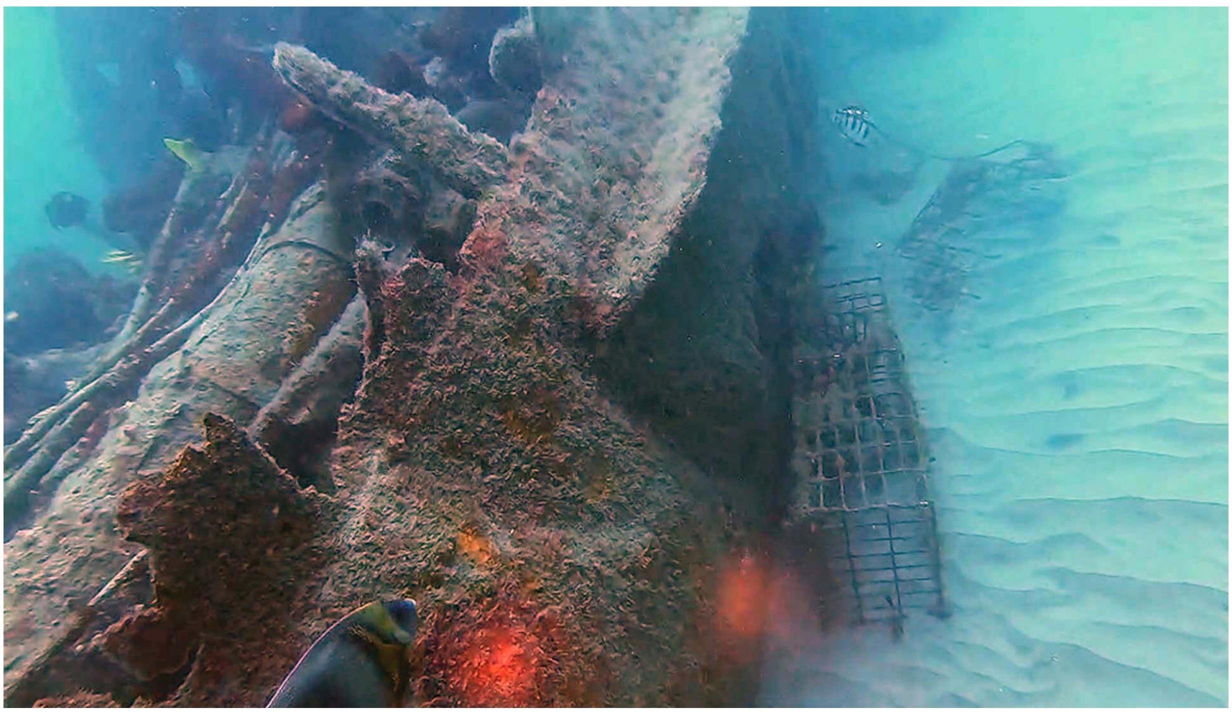

Figure 116. Starboard main engine looking forward. Author.

The image in Figure 117 was taken in the aft battery compartment looking aft toward the engine room bulkhead. The watertight door in the lower right lies above previously-deposited material on the port side of the compartment, indicating that it remained on its hinges long after *H-1*'s sinking. In the left foreground the tops of battery cells can be seen, the straight lines of their casings interrupting the marine life growing on them. To the right of the bulkhead lies the collapsed hull plating which once covered the engine room.

Figure 117. Aft Battery-Engine Room bulkhead. Courtesy of: Gustavo García, INAH/SAS.

Figure 118 shows the remnants of the aft battery-control room watertight bulkhead and the base of the conning tower in the background. The operating handwheel for an unidentified valve is visible in the foreground. Like much of the rest of the site only the major structures in the control room were identifiable due to the deterioration of the metal and the spread of corals and other marine growth.

Figure 118. Control Room. Author.

The conning tower and much of the surrounding structure was constructed using non-ferrous metal to avoid interfering with the magnetic compass. It was cast in sections; the bands where the sections join are visible to the left of the yellow coral (Figure 119). The more noble metals of the tower and surrounding structure have survived much better than the less noble hull and structural components.

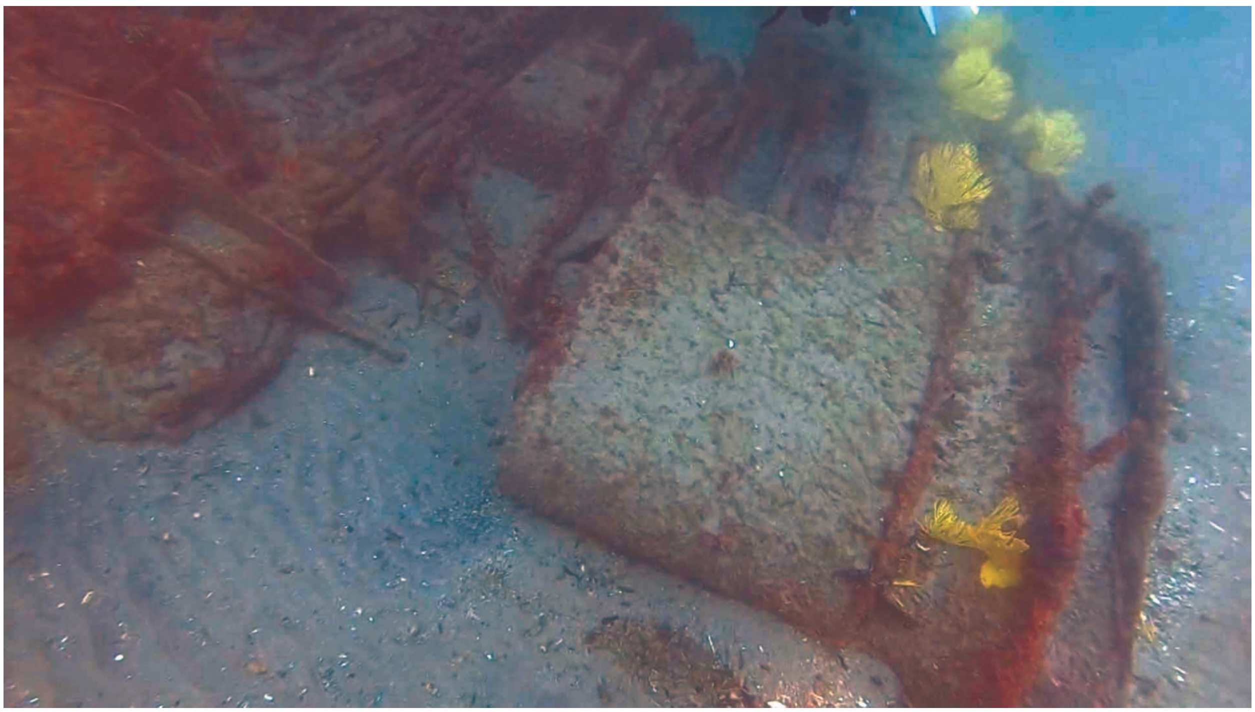

Figure 119. Conning Tower. Author.

The conning tower and surrounding bridge structure, often referred to as the sail, provide a visual indicator of a different component of the site formation process at work, the buildup of sand. Unlike the galvanic corrosion that is destroying *H-1*, this buildup of sand may serve to protect the boat's remains, first from corrosion by isolating the sail's noble metals from the less noble steel in the area, and also from looters by eventually hiding the wreck.

Comparing the 2019 image in Figure 119 with an image taken from Yamafune's photogrammetry model, imagery collected in January 2018, shows how quickly sand is being deposited on the sail. In 2018 sand was at the lower lip of the hatch, the periscope shears were substantially covered and forward ventilator pipes barely visible (Figure 120).

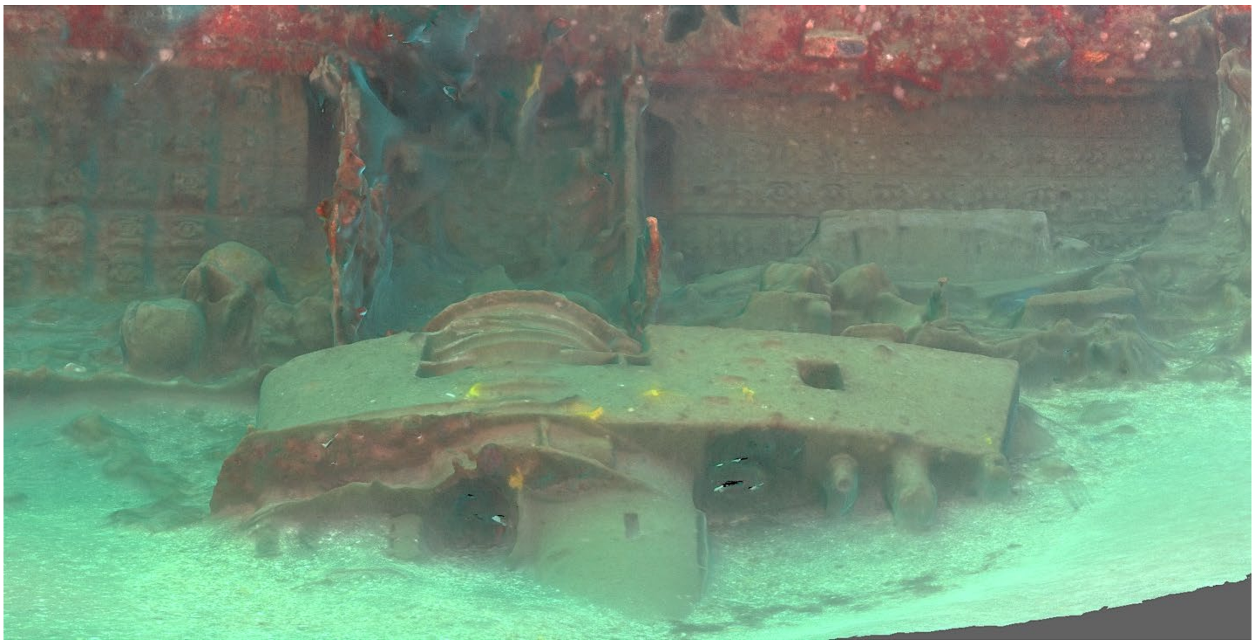

Figure 120. H-1 Bridge 2018. Courtesy of: Kotaro Yamafune.

Figure 121, the earliest available imagery of the sail taken in August 2016, shows the top of the sail with the conning tower hatch (forward) and the bridge access hatch (aft) both open. Also visible are various ventilation standpipes, the periscope shears (the large oblong pipe between the conning tower and bridge hatches) with attached navigation light, and the steering stand (the oblong access hatch forward of the conning tower hatch). The conning tower access hatch, which measures 24 inches (61 cm) in diameter is clear of the sand in this image. Due to sand encroachment, none of these details were visible in 2019.

Figure 121. *H-1* Bridge 2016. Courtesy of: Luis Sanchez.

In the forward battery compartment (Figure 122) the plates of the individual battery cells are visible (center of image), also visible (on right) is the battery well's aft bulkhead. The round object in the foreground is believed to be the motor for the bow planes based on observable physical characteristics and the object's location in the space.

Figure 122. Forward Battery compartment Courtesy of: Francisco Con.

The torpedo room was the next compartment forward of the forward battery compartment; however, as Figure 111 shows, the hull structure from the leading edge of the forward battery to the torpedo tube breech doors is missing, with the exception of remnants of the external duct keel and a small section of attached hull plating. The external keel structure is bent and partially broken, a post deposition event requiring significant force (Figure 123).

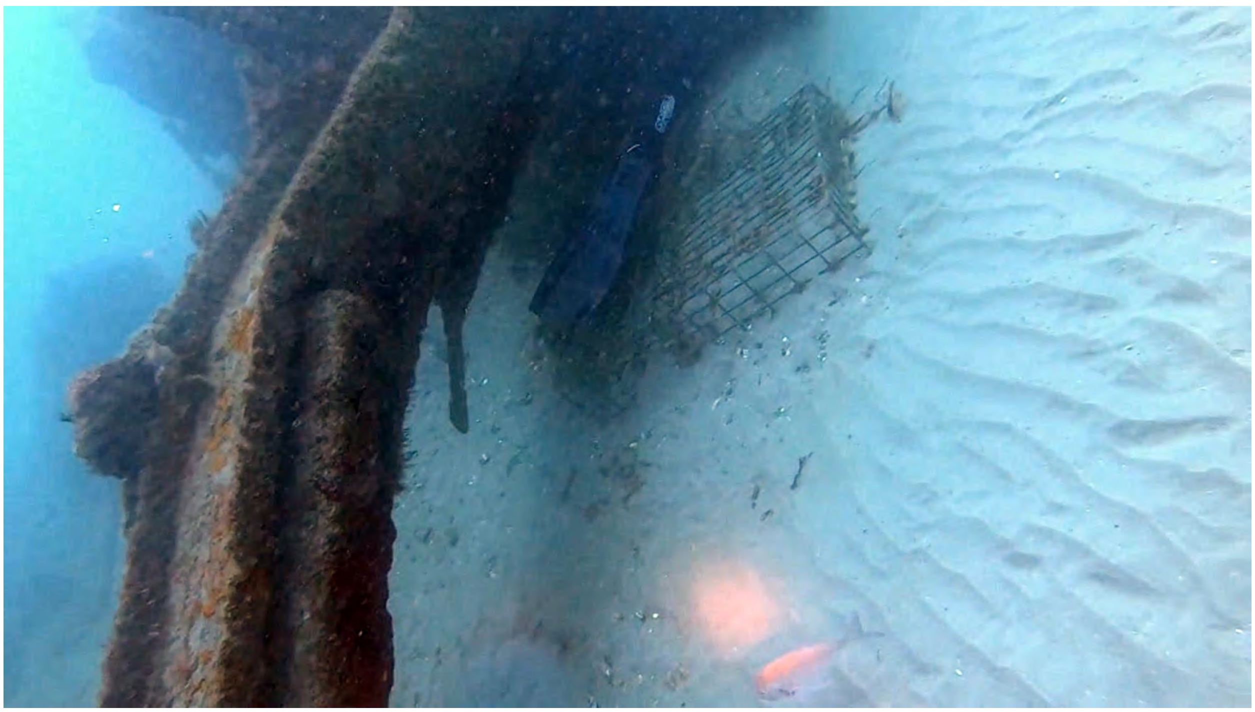

Figure 123. Deformed keel structure. Author.

It is likely that artifacts and hull structure from the torpedo room lie beneath the surface of the sand, but a disproportionate amount of that structure is not visible. This area is unique in that the missing structure was situated between the two large masses of noble metal, the lead of the batteries in the forward battery compartment and the brass of the four bow torpedo tubes, which likely resulted in accelerated galvanic corrosion of the less noble steel. The torpedo tubes and structure forward of them remain, including part of the superstructure, which is a bit odd as it is composed of a thinner steel than the missing hull plating.

Bliss Levitt Mark 7 torpedoes remained loaded in each torpedo tube at the time *H-1* sank and there are no indications that they have been removed; the torpedo tube breech doors remain shut (Figure 124).[299] This ordnance, although over 100 years old may still explode if disturbed. Results of a risk analysis conducted of the likelihood of detonation of a similar torpedo on the sunken Australian submarine HMAS *AE2* places the risk at 16% if the weapon was disturbed.[300]

Figure 124. Torpedo tubes. Courtesy of: Luis Sanchez.

[299] Figure 124 was taken 21 July 2018 and is presented as no image publishable quality was taken of the torpedo tubes taken during the 2019. The hull plating at image right was significantly diminished in 2019.
[300] AE2 Commemorative Foundation Ltd., Project Silent ANZAC, 17.

The 2019 expedition provided a single 50-minute dive opportunity to explore the *H-1* in less-than-optimal conditions. The time spent conducting a first-person assessment of the wreck and the approach to the island from seaward were invaluable in forming an understanding of what happened on 12 March 1920 and the impact of the century of site formation processes on the submarine. Significantly greater dive time and a single focus mission could have provided improved data however, neither were available.

Discoveries and the Path Forward

The *H-1* historical research has provided a clear account of the submarine's last voyage, the wrecking event and failed salvage, while the limited site investigations have given us an understanding of the factors critical in the ongoing site formation process. The archaeological research presents a clarion call to those wishing to further study or preserve elements of this unique submarine: the time left to do so is likely short as the steel hull is rapidly deteriorating. NHHC and INAH have expressed interest in a more in-depth archaeological assessment of the *H-1* site, possibly with limited excavation. Timing of future investigations will depend on the normalization of international travel.

Stabilization or preservation of the entire wreck are unlikely, since logistics and cost of conservation would make such an endeavor impractical. That said, its wreck site can and should be protected from further destructive human activity. This is best accomplished by making the submarine more valuable to the nearby local population as an item of underwater cultural heritage, education and tourism than it is as a source of scrap metal.

One of the topics discussed with residents of Puerto Alcatraz was the construction of a small museum on the island to promote an understanding of the region's rich nautical history and provide a venue for curation and display for recovered artifacts on loan from INAH and NHHC. The response was overwhelmingly positive and led to the return of numerous artifacts attributable to *H-1* that had been removed as souvenirs by community members. The recovered artifacts were turned over to INAH and are undergoing conservation. These as well as artifacts from numerous other shipwrecks in the area will be on display with bi-lingual posters explaining the wrecks, their artifacts, and the centuries old maritime culture of the island and its inhabitants.

Thanks to the efforts of Peter Tattersfield and his group of underwater explorers of *Kaxaan* Nautical Foundation, ground has been broken and construction of the museum is underway all at no cost to local residents. Funds to build the museum were provided by generous individual donations and grant funding.

Tattersfield and his team returned to Isla Margarita, Texas A&M University travel restrictions precluded this author's participation, and successfully located the wreck site of *SS Independence*. During that expedition the KNF team removed numerous fish traps and derelict gear from *H-1*. Imagery provided from this trip focused on the efforts to remove the gear and did not provide sufficient detail to monitor the ongoing site formation processes since the 2019 expedition.

Indiana University is donating a placard to inform divers of the significance of the wreck. *H-1* is a popular dive for regional dive tour operators and, hopefully, providing context for the site will reduce diver impact. Encouraging stewardship of wrecks through the local diving industry has been very successful in other areas, such as New York and Vermont's Lake Champlain, and presents a low-cost opportunity to monitor changes in *H-1*'s condition.

CHAPTER VIII

CONCLUSIONS

Development of submersible warships capable of covertly attacking the enemy has been a goal of mankind for centuries. Experimentation with human powered submarines provided the foundational knowledge to build functional yet mostly ineffective submarines. It was not until the end of the 19th century that advancements in internal combustion engines, electrical storage batteries and motors, and the self-propelled torpedo made building an effective submarine possible. John Holland's integration of internal combustion engines for surface propulsion and electric motors for submerged propulsion led to the development and sale in 1900 of USS *Holland* to the United States Navy.

John Holland was a better submarine designer and builder than he was a businessman and, in order to finance the boat that became USS *Holland*, he sold his patents to Isaac Rice, a serial entrepreneur. Rice brought two critical benefits to the relationship, money and the understanding that standardizing building processes provided the path to make more money. Rice formed The Electric Boat Company (EB) with Holland and the company built and sold successive iterations of submarine designs of steadily increasing capabilities both at home and abroad. The overseas sales resulted in an arms race with EB selling to any nation willing to pay for this experimental weapon.

It was through the sale of construction licenses to England that EB and the British firm Vickers became financially intertwined. Vickers invested heavily in EB and purchased long term construction licenses to build EB designed boats, literally keeping EB afloat when U.S. contracts dried up. This relationship played a driving role in the construction of H-Class submarines.

The U.S. Navy's submarine building program drove advancements in submarine designs in the first decade of the 20th century. By 1910 designs included diesel engines to replace the dangerous gasoline engines in previous designs and diesel nearly doubled the boats' operating range. Design speeds both surfaced and submerged in the new H-Class boats were double that of *Holland.*

That year the Navy's General Board recommended the purchase of four new submarines of the EB-26 design. Major improvements specified for the new submarines included: reversing diesels, providing storage for four torpedo reloads, increasing the size of the conning tower to facilitate installation of a walk-around periscope, and requiring speed capabilities of 14 knots (surfaced) and 9.5 knots (submerged).[301] In response, Congress authorized the four boats and the Secretary of the Navy awarded contracts for three of the EB-26 designs to be built on the west coast, and one contract, for a separate design was awarded to EB's competitor the Lake Torpedo Boat Company.

The boats contracted to EB were built in shipyards in San Francisco and Seattle. The skills necessary for construction of the hulls and installation of equipment were as applicable to building submarines as they were to steel hulled surface ships and were part of the skillset of shipyard works of the period. The ships systems were also straightforward, and it appears that the principal challenge in design and construction was fitting everything is such a small amount of space. From the time the boats were laid down until they were commissioned nearly 20 months passed.

Once commissioned the H-Class boats operated along the west coast from their homeport of San Pedro, CA. In August of 1914, England declared war on Germany in response to

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[301] Friedman, *U.S. Submarines Through 1945*, 76-78.

Germany's occupation of neutral Belgium. America did not initially join in the Great War, choosing instead to remain neutral. The submarines continued normal training and maintenance operations and visited ports up and down the Pacific coast.

The war created a strong demand for submarines. Charles Schwab ran the huge conglomerate Bethlehem Steel Corporation; among its holdings were the submarine building yards Fore River Shipbuilding and Union Iron Works. Schwab traveled to England and struck a deal to provide the Royal Navy with 20 H-Class submarines, neutrality be damned. Schwab immediately began production at Fore River but was soon stopped by the U.S. Government.

Instead of ceasing production, Schwab pivoted and, working with the British Government and EB's partner Vickers, shifted production of 10 boats to Vickers' Canadian shipyard in Montreal. This single act significantly increased the number of H-Class boats of the EB-602 export design over the coming years. Had Schwab acquiesced to government pressure and canceled the contract with England, it is quite likely that only the first three U.S. boats would have been built.

The production model required the boats be assembled in Canada to skirt neutrality, with parts and materiel provided by EB and their supply chain. EB and their contractors also provided some supervision and labor to the Canadian yards. EB was financially incentivized to produce these submarines quickly, receiving a large bonus when these 10 British boats began their passage across the Atlantic less than six month after their keels were laid. Russia and Italy also purchased H-Class boats which were built using a similar production model.

Long before America's entry into the First World War, H-Class submarines had crossed the Atlantic, a submarine first, and had been demonstrated by their crews to be outstanding warships. They were appreciated for their speed in diving, relative mechanical dependability and their heavy payload of torpedoes. The British thought so highly of the design that they modified it to facilitate the use of a larger more powerful torpedo. The H-21 design was longer and of greater displacement but otherwise a near clone of the EB-602 design.

Following America's entry into the war, *H-1* and *H-2* were transferred to the east coast. *H-3* was not operational at the time having ran hard aground in December 1916 off Eureka, CA, while returning to San Pedro following a maintenance period at the Puget Sound Navy Yard. This incident placed *H-3* out of service until the summer of 1918, effectively taking it out of the war.

While serving in the Atlantic Fleet *H-1* and *H-2* conducted local anti-submarine patrols and served as training vessels for the growing U.S. Navy Submarine Force. Both submarines were extensively overhauled in the Philadelphia Navy Yard, but some modifications were withheld as the boats were quickly becoming obsolete. New classes of submarines in large numbers were entering service.

In January 1920 *H-1* and *H*-2 departed from the submarine base at New London, where they had been serving as training boats, for the return voyage to Submarine Base San Pedro a voyage of over 6000 nautical miles (11112 km), for further service with the Pacific Submarine Force. After rendezvousing with their escort, USS *Eagle -11* in Norfolk VA, the group, under the command of H-1's Lt. Cmdr. James Webb, proceeded south along the east coast of the United States, crossed the Caribbean, transited the Panama Canal, and made their way up the Pacific coast.

Each of the vessels suffered mechanical problems over the course of the voyage, *H-2* less so than the others. As the group worked up the coast of Mexico *Eagle 11*, unable to distill enough fresh water to supply its boilers, left the submarines to meet and transfer water from USS

Beaver. Lt. Cmdr. Webb ordered the group to detour to Magdalena Bay, on the western coast of Mexico to regroup and effect repairs. Webb was unfamiliar with the area, having served his career in the Atlantic, yet he made the decision to enter the bay at night. This decision cost him and three of his crew their lives and resulted in the loss of *H-1*.

H-1 ran aground in the early morning hours of 12 March. *H-2* narrowly avoiding the same fate. Initial attempts to back *H-1* into deeper water failed when the circuit breakers providing power to the electric motors opened. Webb and the helmsman Seaman Kosman were soon washed overboard in the heavy surf and lost, while the remainder of the crew abandoned ship, swimming ashore. Petty Officer Giles and Seaman Delamain drowned while abandoning ship. The survivors were eventually rescued by the civilian vessel *Mazatlan* and repatriated at San Pedro.

Following several failed attempts to salvage *H-1* the submarine was dragged to seaward during periods of rising tides through the combined efforts of USS *Vestal*, USS *Sonoma* and USS *Brant*. On 19 March with seas building and weather worsening, *H-1* was towed to seaward into the last line of breakers, pounding heavily in the surf in the early morning hours of 20 March the submarine as towed off the strand and into deeper water, and shortly thereafter permanently sank.

At the time of the sinking *H-1* was in poor condition having suffered a fire that damaged a significant amount of the boat forward of the engine room. Its hull had been pounded for hours in heavy surf which likely opened seams or damaged the stern gear with fatal results. After the deep-water sinking of 20 March, the Navy considered the boat of no further military value except for the four torpedoes that remained in its tubes, and sold the wreck for scrap, retaining ownership of the weapons. *H-1* was not salvaged.

H-1's wreck came to public attention in 2016, nearly a century after its sinking. Investigations have shown that the wreck is rapidly deteriorating, the pace of that process likely accelerating as the wreck becomes more fragile. It appears that the significant hull loss seen over the past several years is a result of galvanic corrosion. This destructive process is the result of dissimilar metals exchanging ions via an electrolyte, and is, barring significant investment, unstoppable. Looting of the wreck and damage from fishing activity also contribute to the worsening condition of the submarine.

The path forward for this magnificent relic of early submarining is narrow. A small but committed group of archaeologists and adventurers is working closely with INAH and NHHC to develop a museum on the island to highlight the area's rich maritime traditions and display artifacts from the several wrecks located in the surrounding waters. The goal of establishing the museum is to educate the inhabitants of Isla Margarita and local dive operators of the value of protecting the wreck. Hopefully, making *H-1* more valuable as an irreplaceable artifact of underwater cultural heritage and diving destination than it is for scrap, or as an anchor for fishing boats, will protect it from further human interference.

Discussions with INAH and NHCC, with the goal of further investigation including limited excavation, continue. Exploration of the site is on hold pending a return to normal international travel, leaving room for future studies and publication.

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APPENDIX A

H-CLASS SUBMARINES

Information for the following table is sourced primarily from E.C. Fisher's article 'The Subterfuge Submarines'.[302] Submarines delivered to Russia were renamed several times following the Russian Revolution resulting in minor conflicts in the data which were resolved using Polmar and Noot's *Submarines of the Russian and Soviet Navies, 1718-1990*.[303]

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[302] Fisher, 'The Subterfuge Submarines'.
[303] Polmar and Noot, *Submarines of the Russian and Soviet Navies*.

Count	Nation of Service	Ordered By	Designation	Completed	Building Yard	Disposition	Final Year
1	United States of America (USA)	USA	USS *H-1* (ex *Seawolf*)	1913	Union Iron Works San Francisco	Grounded, sank in salvage effort	1920
2	USA	USA	USS *H-2* *(ex Nautilus)*	1913		Scrapped	1931
3	USA	USA	USS *H-3* *(ex Garfish)*	1913	Moran Bros. Seattle	Scrapped	1931
4	USA	Russia	USS *H-4* (ex *AG-17*)	1918	British Pacific Engineering and Construction Co. Barnet, BC Assembled by Puget Sound Navy Yard	Scrapped	1932
5	USA	Russia	USS *H-5* (ex *AG-18*)	1918		Scrapped	1931
6	USA	Russia	USS *H-6* (ex *AG-19*)	1918		Scrapped	1931
7	USA	Russia	USS *H-7* (ex *AG-20*)	1918		Scrapped	1931
8	USA	Russia	USS *H-8* (ex *AG-27*)	1918		Scrapped	1931
9	USA	Russia	USS *H-9* (ex-*AG-28*)	1918		Scrapped	1931
10	England	England	HMS *H-1*	1915	Canadian Vickers, Montreal	Scrapped	1921
11	England	England	HMS *H-2*	1915		Scrapped	1921
12	England	England	HMS *H-3*	1915		Sunk in Adriatic	1916
13	England	England	HMS *H-4*	1915		Scrapped	1921
14	England	England	HMS *H-5*	1915		Sunk in Irish Sea	1918
15	England/ Netherlands/Germany	England	HMS *H-6* Dutch *0-8* Germ. *U-1*	1915		Salvaged by Dutch 1916, renamed *O-8*; to avoid capture, scuttled 1940; Germany salvaged renamed *U-1* then scuttled in Kiel	1945

Table 2. H-Class submarines including H-21 variants.

Count	Nation of Service	Ordered By	Designation	Completed	Building Yard	Disposition	Final Year
16	England	England	HMS *H-7*	1915	Canadian Vickers, Montreal	Scrapped	1921
17	England	England	HMS *H-8*	1915		Scrapped	1921
18	England	England	HMS-*H-9*	1915		Scrapped	1921
19	England	England	HMS *H-10*	1915		Sunk in North Sea	1918
20	England	England	HMS *H-11*	1915	Fore River, Quincy	Scrapped	1921
21	England	England	HMS *H-12*	1915		Scrapped	1922
22	England/Chile	England	HMS *H-13* Chile *H-1*	1915		1917 to Chile as H-*1*; Scrapped	1955
23	England/Canada	England	HMS *H-14* Canada *CH-14*	1915		1919 to Canada as CH-*14*; Scrapped	1925
24	England/Canada	England	HMS *H-15* Canada *CH-15*	1915		1919 to Canada as CH-*15*; Scrapped	1925
25	England/Chile	England	HMS *H-16* Chile *H-2*	1915		1917 to Chile as *H-2*; Scrapped	1955
26	England/Chile	England	HMS *H-17* Chile *H-3*	1915		1917 to Chile as *H-3*; Scrapped	1956
27	England/Chile	England	HMS *H-18* Chile *H-4*	1915		1917 to Chile as *H-4*; Scrapped	1956
28	England/Chile	England	HMS *H-19* Chile *H-5*	1915		1917 to Chile as *H-5*; Scrapped	1956
29	England/Chile	England	HMS *H-20* Chile *H-6*	1915		1917 to Chile as *H-6*; Scrapped	1956
30	England	England	HMS *H-21*	1917	Vickers, Barrow	Scrapped	1926
31	England	England	HMS *H-22*	1917		Scrapped	1934
32	England	England	HMS *H-23*	1918		Scrapped	1934
33	England	England	HMS *H-24*	1917		Scrapped	1934
34	England	England	HMS *H-25*	1918		Scrapped	1929
35	England	England	HMS *H-26*	1917	Vickers, Barrow	Scrapped	1928
36	England	England	HMS *H-27*	1918		Scrapped	1935

Table 2. (cont.) H-Class submarines including H-21 variants.

Count	Nation of Service	Ordered By	Designation	Completed	Building Yard	Disposition	Final Year
37	England	England	HMS *H-28*	1918	Cammell Laird, Birkenhead	Scrapped	1944
38	England	England	HMS *H-29*	1918		Scrapped	1927
39	England	England	HMS *H-30*	1918		Scrapped	1935
40	England	England	HMS *H-31*	1918		Combat Loss WWII	1941
41	England	England	HMS *H-32*	1918		Scrapped	1944
42	England	England	HMS *H-33*	1918		Scrapped	1944
43	England	England	HMS *H-34*	1918		Scrapped	1945
	~~England~~	~~England~~	~~HMS *H-35*~~	**Cancelled**	~~Cammell Laird, Birkenhead~~	**Contract Cancelled**	----
			~~HMS *H-36*~~				
			~~HMS *H-37*~~				
			~~HMS *H-38*~~				
			~~HMS *H-39*~~				
			~~HMS *H-40*~~				
	England	**England**	**HMS *H-41***	**1918**	Armstrong Whitworth, Newcastle Upon Tyne	**Never Commissioned; Scrapped**	**1920**
44	England	England	HMS *H-42*	1918		Accidental Loss – Collision	1922
45	England	England	HMS *H-43*	1919		Scrapped	1944
46	England	England	HMS *H-44*	1919		Scrapped	1944
	~~England~~	~~England~~	~~HMS *H-45*~~	**Cancelled**	~~Armstrong Whitworth, Newcastle Upon Tyne~~	**Contract Cancelled**	----
			~~HMS *H-46*~~				
47	England	England	HMS *H-47*	1918	Beardmore, Dalmuir	Accidental Loss – Collision	1929
48	England	England	HMS *H-48*	1919		Scrapped	1935
49	England	England	HMS *H-49*	1919		Combat Loss WWII	1940
50	England	England	HMS *H-50*	1919		Scrapped	1945

Table 2. (cont.) H-Class submarines including H-21 variants.

Count	Nation of Service	Ordered By	Designation	Completed	Building Yard	Disposition	Final Year
51	England	England	HMS *H-51*	1918	HM Dockyard, Pembroke	Scrapped	1924
52	England	England	HMS *H-52*	1918		Scrapped	1927
	~~England~~	~~England~~ d	~~HMS *H-53*~~	Cancelled	~~HM Dockyard, Devonport~~	Contract Cancelled	----
			~~HMS *H-54*~~				
53	Russia	Russia	AG-*11*	1916	Barnet, Vancouver, BC/Baltic Works, St. Petersburg/Petrograd	Scuttled 1918 at Hango; Raised by Finland then Scrapped	1918
54	Russia	Russia	AG-*12*	1916		Scuttled 1918 at Hango; Raised by Finland then Scrapped	1918
55	Russia	Russia	AG-*13* *AG-16*	1916		Accidentally sunk 1917, then salvaged; 1917 renumbered *AG-16;* Scuttled 1918 at Hango; Raised by Finland 1924; Scrapped	1929
56	Russia	Russia	AG-*14*	1916		Sunk off Gotska Sandön	1917
57	Russia	Russia	AG-*15*	1916		Scuttled at Hango	1918
	Russia	Russia	AG-*16* (ex *AG-13*)	1916		*AG-13* accidentally sunk 1917; Salvaged in 1917 and renamed *AG-16*; Scuttled 1918 at Hango; Raised 1924 by Finland, but never repaired; Scrapped	1929

Table 2. (cont.) H-Class submarines including H-21 variants.

Count	Nation of Service	Ordered By	Designation	Completed	Building Yard	Disposition	Final Year
	USA	~~Russia~~	AG-*17* USS *H-4*	Purchased by USA	Barnet, Vancouver, BC	**Purchased by USA; renumbered USS *H-4***	1932
			AG-*18* USS *H-5*			**Purchased by USA; renumbered USS *H-5***	1931
			AG-*19* USS *H-6*			**Purchased by USA; renumbered USS *H-6***	1931
			AG-*20* USS *H-7*			**Purchased by USA; renumbered USS *H-7***	1931
58	Russia/U.S.S.R.	Russia	AG-*21* *No. 16* *Metallist* *A-5*	1918	Barnet, Vancouver, BC/Nikolaev Shipyard	Scuttled by British in 1919 at Sevastapol; salvaged by USSR in 1928 restored to service 1930 and designated as *No. 16*; named 1931 as *Metallist;* designated *A-5* in 1934; Scrapped	1950
59	Russia	Russia	AG-*22*	1919		Wrangel fleet 1920 to Bizerta; Scrapped 1924 by French	1924
60	USSR	Russia	AG-*23* *Trotskiy* *Nezamozhniy* *Shakter* *No. 12* *A-1*	1920	Barnet, Vancouver, BC/Russian Shipbuilding Co	Comm. by USSR in 1920 as *Trotskiy*; Changed 1922 to *Nezamozhniy*; Changed 1923 to *Shakter*; Designated 1923 as *No. 12*; Changed 1934 to *A-1*. Scuttled 1942 at Sevastapol	1942

Table 2. (cont.) H-Class submarines including H-21 variants.

Count	Nation of Service	Ordered By	Designation	Completed	Building Yard	Disposition	Final Year
61			AG-*24* *Lunacharskiy* *Kommunist* *No.13* *A-2*	1921	Barnet, Vancouver, BC/Russian Shipbuilding Co	Comm. by USSR in 1922 as *Lunacharskiy;* later *Kommunist*; Designated 1923 as *No. 13*; renamed 1934 as *A-2*. Decommissioned 1946; Scrapped post war	
62			AG-*25* *Marksist* *No. 14* *A-3*	1922		Comm. by USSR in Mar. 1923 as *Marksist*; Designated in Jul. 1923 as *No. 14* and renamed in 1934 as *A-3*; Cause of loss unknown, potentially sunk 1943 by Germans	1943
63	USSR	Russia	AG-*26* *Kamenev* *Politrabotnik* *No. 15* *A-4*	1923	Barnet, Vancouver, BC/Russian Shipbuilding Co	Comm. by USSR in 1923 as *Kamenev*, then May 1923 changed to *Politrabotnik*. Designated Jul. 1923 as *No. 15*, then Sep. 1934 changed to *A-4*. Scrapped post-war	
	USA	~~Russia~~	*AG-27* USS *H-8*	**Purchased by USA**	Barnet, Vancouver, BC	Purchased by USA; renumbered USS *H-8*	1931
			AG-*28* USS *H-9*			Purchased by USA; renumbered USS *H-9*	1931

Table 2. (cont.) H-Class submarines including H-21 variants.

Count	Nation of Service	Ordered By	Designation	Completed	Building Yard	Disposition	Final Year
64	Italy	Italy	H-*1*	1916	Canadian Vickers, Montreal	Scrapped	1947
65	Italy	Italy	H-*2*	1916		Scrapped	1947
66	Italy	Italy	H-*3*	1917		Scrapped	1937
67	Italy	Italy	H-*4*	1917		Scrapped	1947
68	Italy	Italy	H-*5*	1917		Accidental Loss	1918
69	Italy	Italy	H-*6*	1917		Scuttled by Germans	1943
70	Italy	Italy	H-*7*	1917		Scrapped	1930
71	Italy	Italy	H-*8*	1917		Sunk at LaSpezia	1943

Table 2. (cont.) H-Class submarines including H-21 variants.