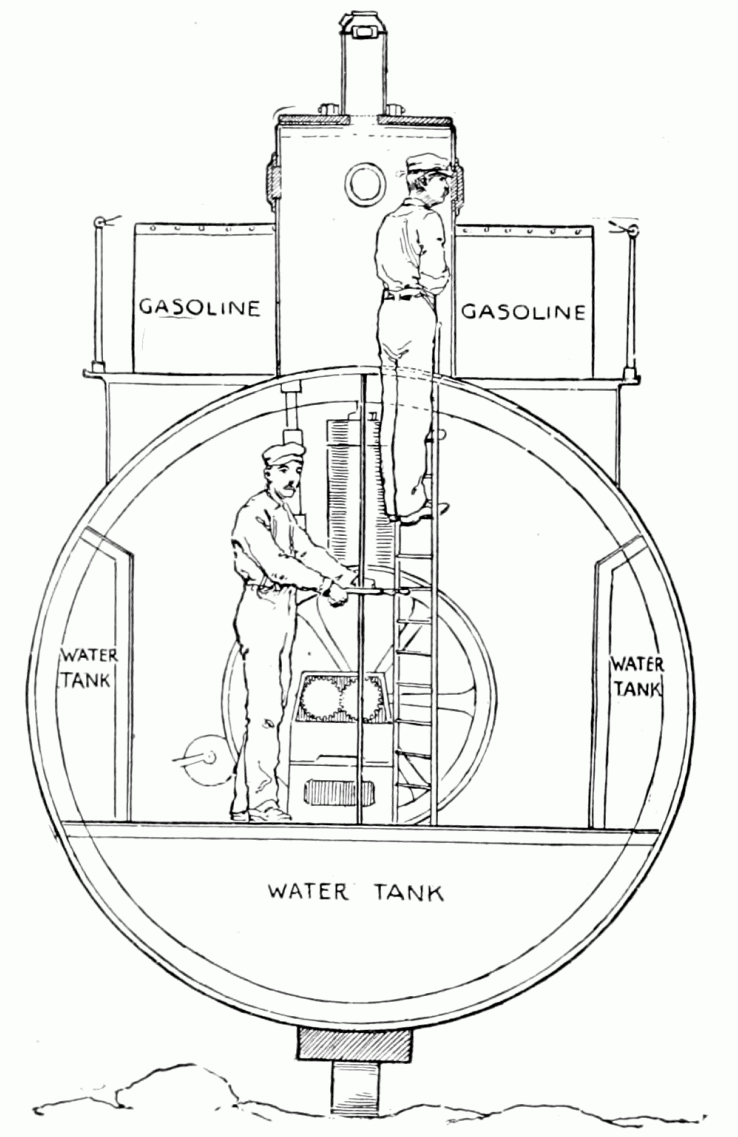
SHIPWRECK CENTRE
& MARITIME MUSEUM

EVOLUTION OF SUBMARINES: A SUMMARY TO 1946



HERITAGE FUND

The huge loss of shipping in the First and Second World Wars established that submarines were deadly weapons, but the concept of an underwater armed vessel goes back to the 16th century. However, up to circa 1900, submarine development was primarily experimental. Some early examples from American and European engineers and entrepreneurs to prove and develop the concept of a viable underwater vessel are presented below. Although Military Navies trialled some early vessels with limited success, it was not until after 1900 that submarines were developed by Naval Authorities in earnest as a weapon.

Figure 1: Giovanni Borelli Submersible Boat 1749

Source: Public Domain

https://commons.wikimedia.org/wiki/File:Giovanni_Alfonso_Borelli_De_Motu_Animalium_1680.jpg

William Bourne (c.1535-1582) was an English mathematician, writer of navigational manuals, and former Royal Navy gunner who in 1578 published his design for a submarine which was essentially a wooden framed vessel with a leather covering to be rowed under water. Modern submarines operate on the principle of flooding and evacuating chambers, whereas Bourne envisaged decreasing its volume.

Giovanni Borelli (1608-1679), Italian physicist and mathematician, whose design was not published until 1749, Figure 1, was first with the idea of a ballast tank. It was never built; the idea was that goatskins in the hull would be filled with water allowing the craft to submerge and would then be evacuated by twisting a rod.

Military submarines began to be developed, including the American ***Turtle***, the French ***Nautilus***, the Bavarian ***Brantaucher*** and others, but none satisfied the military authorities. The ***Turtle*** was reported as the **world's first submersible vessel with a documented combat record**, attempting to attach a time bomb to HMS *Eagle* in New York harbor. Built in 1775, American David Bushnell, who had already designed a reliable method for detonating underwater explosives, designed it as a one-man submersible, the intention being to attach explosives to the hull of an enemy ship. With a hull length of 3m and 0.9m beam constructed from oak with wrought iron hoops, it incorporated lead ballast and displaced 91kg; the innovative hand cranked propellers were capable of 2.6 knots, with a 30-minute endurance. During the Revolutionary War, British ships controlled the Hudson River and in September 1776, *Turtle* failed in attempts to sink any of these ships. It was lost when being transported aboard an American sloop sunk on 9 October 1776 by the British. Replicas are exhibited at various American locations and a cutaway full-sized replica of the *Turtle* is displayed at the Royal Navy Submarine Museum in Gosport, Figure 2, below.

Figure 2: Turtle Replica on display at RN Submarine Museum, Gosport

Source: CC BY-SA 4.0
https://en.wikipedia.org/wiki/Turtle_%28submersible%29#/media/File:Turtle_model_at_the_Royal_navy_submarine_museum.jpg

Another American inventor, Robert Fulton, while working for the French government designed an all-metal vessel named the ***Nautilus***, which is claimed sometimes as the first modern submarine. Notably, it included new features such as diving planes to aid submerging, a cigar shaped hull, a copper observation dome resembling but not actually a conning tower, compressed air bottles for the crew, a hand operated propeller for underwater movement and also, for surface travel a collapsible mast and sail. Despite successful dives in 1800, the French Navy considered it suicidal to the crew and the British Navy was not overly impressed, so *Nautilus* was sold for scrap.

The ***Brandtaucher*** submersible is the oldest known surviving submarine in the world. A scaled back 3-man second version, 8.07m long, 2.02m beam, 2.63m draught with a hand-cranked propeller was tested to 9m depth. Launched in 1850, it was trialled in Kiel harbour but equipment failure caused it to sink on 1 February 1851. Designer William Bauer and his two crew managed to escape, thus being **the first witnessed and recorded underwater submarine escape**. Sinking within an 18 metre deep hole on the harbour bottom, it remained lost until 1887, being raised, restored and now displayed at the German Armed Forces Museum of Military History in Dresden. Other examples trialled in this period included the 1862 American ***Alligator*** which claimed a **number of firsts**, such as an air purifying system, a forward airlock allowing divers to leave and enter while submerged, and was armed with two limpet mines. The mines could be affixed by divers, transiting the airlock, to an enemy ship's hull, and a battery inside the submarine, connected to the mines by insulated copper cable, facilitated detonation. The American ***H. L. Hunley*** had the distinction on 17 February 1864 of being the **first combat submarine to sink a warship**, the USS *Housatonic* which was an 11-gun sail and steam Screw Sloop displacing 1,240 tons. The *H.L. Hunley's* weapon was a spar torpedo; dating from about 1812, the spar torpedo, invented by the same Robert Fulton who had designed the submarine *Nautilus*, was simply an explosive charge, carried by the attacking vessel on a long spar or pole, which detonated on contact when striking the target. In this case, the *H.L. Hunley* was too close to *Housatonic* and was also lost with all of its eight crew.

Pioneering mechanically powered submarines of this era include the French ***Le Plongeur***, the Spanish ***Ictineo II***, the Turkish ***Nordenfelt II***, the French ***Gymnote***, the Spanish ***Perla*** and the American ***Argonaut***.

Le Plongeur was the **first mechanically powered** submarine. Launched on 16 April 1863 and displacing 420 tons, it was 45m long with 3.7m beam, tested to 10m depth, armed with a spar torpedo and had a complement of 12 crew. This was a much larger vessel than its contemporaries due to 153m^3 needed

for 23 tanks filled with compressed air at 12.5 bar which drove a 60kw compressed air reciprocating engine, capable of driving the vessel at 4 knots, with a range of 9km. The submarine carried a small lifeboat for the crew to escape in, and the *Cachalot*, a French naval support ship followed to provide replacement compressed air. There were operational stability problems and eventually it was withdrawn on 2 February 1872.

The Spanish ***Ictineo II*** was built in 1864 by Narcis Monturoi (1819-1885), it was a true pioneering example of a submarine, and is said to be the **first example of a submarine providing a solution to the problems of machine powered underwater propulsion**. Monturoi realised that conventional steam underwater propulsion was not possible due to the boiler fires, so he invented an air independent steam engine for submerged propulsion, with a coal powered steam engine for surface propulsion. The air independent, or chemically powered anaerobic, engine used a chemical reaction to create both heat for the engine and oxygen for breathing. Although the speeds were slow, 4.5/2.5 knots surfaced/submerged **underwater mechanical propulsion had been successfully achieved and was not replicated until the 20th century**. Another achievement was remarkable stability via four ballast tanks symmetrically disposed on each side between the outer and inner hulls, flooding to submerge and by pumping air into them to surface, supplemented by a moveable weight running along a rail controlled by the helmsman to control the pitch.

The Nordenfelt Class of four submarines were steam powered, designed by Swede Thorsten Nordenfelt based on designs by English Reverend George W. Garrett. Following the first unsuccessful *Nordenfelt,* ***Nordenfelt II*** and *Nordenfelt III* were built in parts in 1886 for Turkey, respectively by Des Vignes, Chertsey and by Vickers, Sheffield, then shipped to Turkey where they were assembled. 30m long and displacing 160 tons, steel hulled with twin torpedo tubes and coal-fired steam driven, *Nordenfelt II* was renamed Abdül Hamid. In trials, it achieved 10 knots, was able to dive for very short intervals and when submerged sank an old target ship with a torpedo, **a world first**.

Gymnote was the world's **first all-electric submarine** launched at Toulon on 24 September 1888, equipped with two torpedo tubes. Built as an experimental design, it did evolve over time with many changes in its 10-year life. Trials with the five-man crew started on 17 November 1888, displaying the need for continuous adjustments via its three buoyancy tanks and three hydroplanes proving stability was speed critical, requiring the addition of rudders. It displaced 30 tons, was 17.8m long, and included a 41kw electrical engine in its single steel hull with detachable lead keel. The internal surfaces were painted with bitumen to protect the steel from battery acid spills. Originally, there were 564 alkaline cells, using copper oxide and zinc electrodes in potassium hydroxide electrolyte, arranged in six banks weighing a total of 11 tons such that they could be connected in different combinations to vary the motor output and hence the speed. The motor, 1m diameter weighing 2 tons, was 16-pole directly connected to the propellor. Typically, range was 75 miles at 5 knots surfaced and 29 miles at 4.3 knots submerged. Damaged when running aground on 5 March 1907, the vessel was scrapped.

Argonaut was built in 1897, the second submarine designed by American inventor Simon Lake for peaceful purposes, not war, and was the first to **operate in the open sea** and was therefore a significant advance in submarine development, previous submarines having been designed to operate close to shore and harbours. The *Argonaut,* Figures 3 and 4, was 11m long, and was powered by a 30 hp petrol/gasoline engine with inlet and exhaust hoses, later converted to tubes, rising above the surface for the engine and for the crew's air supplies. Most unusually, it still had wheels for moving along the seabed. Equipped with a periscope and a diving chamber, Lake intended and used it initially for salvage of wrecks in Chesapeake Bay but its principal advantage was open sea travel, Lake achieving in 1898 about 300 miles from Norfolk, Virginia to New York.

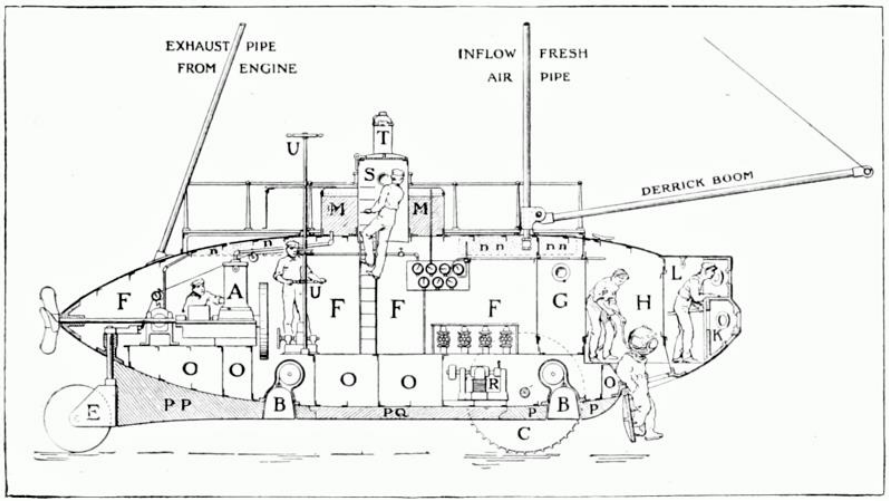


***Figure 31: Longitudinal Section of the* Argonaut**

Source: https://commons.wikimedia.org/wiki/File:PSM_V58_D177_Longitudonal_section_of_the_submarine_argonaut.png

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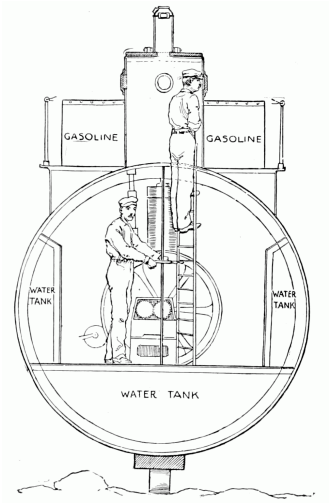

***Figure 42: Amidships Cross-Section of the* Argonaut**

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Source Figure 14: https://commons.wikimedia.org/wiki/File:PSM_V58_D178_Cross_section_of_the_argonaut_amidships.png

The submarine at the end of the 19th century was not yet a viable weapon of war, but development by **John Philip Holland** which started in about 1875 and continued despite setbacks with eventual success around the turn of the century was a **significant step forward for submarine development in several navies**. John Holland, born 1841 in County Clare, spent 56 of his 73 years working with submersibles. Initially he taught mathematics in Limerick and other locations before emigrating to America in 1873. His first submarine design was rejected by the US Navy in 1875 "*as unworkable*". Holland demonstrated his *Holland I* prototype in 1878, launching the *Holland II*, renamed *Fenian Ram,* in 1881. Navigation testing was undertaken with the *Holland III*, and this was followed by the experimental *Holland IV* financed by Lieutenant Edmund Zalinski of the US Army. The US Navy ran a design competition for a submarine in 1895, won by Holland which led to his *Holland V,* to be known as USS *Plunger*, (no connection with the later Plunger Class) constructed by his Holland Torpedo Boat Company; displacing 149 tons, 25.98m long with a steam engine for 15 knots surfaced and 8 knots submerged, equipped with 2x45cm torpedo tubes and rated for seven crew, it was launched on 7 August 1897; it was rejected by the Navy during trials and eventually the Navy cancelled the contract. During construction, Holland had realised that a steam powered engine was unsuitable and, so had embarked on developing *Holland VI* crediting the money spent on *Holland V* towards ***Holland VI* which was the breakthrough,** on a number of counts, including principal components being in one vessel, dual propulsion, a fixed longitudinal

centre of gravity, main and separate auxiliary ballast tanks, hydrodynamically efficient, and a viable weapons system.

- Dual propulsion – now a 34kw 4-stroke Otto petrol/gasoline engine for surface running and battery charging, with a 37kw Electro-Dynamic Company electric motor powered from 66 Exide battery cells for submerged running. Speed and range quoted were respectively 6 knots surfaced, 5½ knots submerged, and 230 miles at 6knots surfaced, 35 miles at 5½ knots submerged.
- A fixed longitudinal centre of gravity – previous examples had used ballast tanks which were only partially filled, allowing water to move freely forwards or aft, thus preventing stable running. Holland solved this by designing his ballast tanks to be empty or completely full, thus stabilising the vessel, with a small forward trim tank which was used for diving without significant effect on the overall centre of gravity, supplemented by stern mounted diving planes.
- Holland optimised the hydrodynamic shape for submerged operation – this included a circular cross-section maximised forward of amidships, minimal superstructure, a single propellor placed aft of the rudder, like modern nuclear submarines, but had to be changed in front of the rudder at US Navy insistence. It is thought that a naval architect, Alfred Busch, had the idea of adding about 0.6m to the bow, thus making the shape asymmetrical, Holland having followed earlier inventors having a symmetrical profile. But the majority of ideas were Holland's.
- Weapons – Holland incorporated one 45cm reloadable torpedo tube with three well-tested Whitehead torpedoes carried on board. A 21.4cm pneumatic dynamite gun was added at the bow, available through a muzzle door.

About the same time as Holland was fine tuning his design, the French Admiralty was continuing its active submarine development, including the ***Gustave Zédé*** and ***Narval***. The experimental ***Gustave Zédé*** was an electrically driven vessel launched on 1 June 1893, commissioned on 1 May 1900. Unusually, its hull was made of bronze with 76 ribs, to resist corrosion and to allow magnetic compasses to operate better, and its fore and aft profiles were different. Range was 250 miles at 5½ knots surfaced and 121 miles at 4½ knots submerged. Armament comprised 1x 36cm Flume torpedo and 2x torpedoes in a Drzewiecki drop collar which was an external torpedo launching system. In December 1898, the *Gustave Zédé* successfully attacked the French training ship *Magenta*, once when stationary and after travelling 40 miles, submerged with ***Magenta*** **on the move from a range of 250m, considered a "first"**. The ***Narval*** resulted from a competition set by the French Admiralty designed to overcome the disadvantages of slow surface speed and limited range, and also poor surface handling. Poor surface handling was addressed by a double hull, unlike that of the Holland designs, such that the pressure hull was optimised for pressure resistance by being circular and the outer hull, referred as "light", was more boat shaped, thus improving hydromechanics. Eventually, Navies adopted the double hull.

Holland designs were sold to America, France, Germany, Japan and Britain who built five under licence at Barrow. Regarded as too small, a larger one was launched in July 1902, named **HMS *A-1***, the story of which is on display here in the museum. The *A-1* has the unenviable distinction of being a peacetime loss off the Isle of Wight with the first loss of British submariners when struck by SS *Berwick Castle*.

Originally dismissive of the submarine as a weapon, the Admiralty between the *A-1* and the First World War, continuously developed the submarine through several distinct Classes with specific characteristics including twin screw, minimum speed of 14knots, and good accommodation. Probably one of the most important wartime lessons was the realisation that the ability to dive rapidly was essential, not considered previously as a priority. The Americans learnt that a conning tower with much improved protection against the North Atlantic weather was essential.

Germany built a formidable array of 375 submarines which nearly "sunk" Britain during the First World War. 37 German commanders each sunk more than 100,000 tons, totalling 2,685 ships and 5,927,395 tons. Contrast that with their 34 Second World War counterparts also sinking over 100,000 tons, sinking 873 ships at 4,826,177 tons. German submarines included coastal, ocean-going vessels, and mine laying vessels. Typical First World War examples were **SM UB-*81*** and **SM U-*90***, both also displayed with their histories here in the museum.

Following the war, The Potsdam Agreement prescribed that 30 of the 156 surrendered German submarines be allocated to the Allies for research and peaceful purposes, the remainder being sunk in water exceeding 100m depth. The Allies embraced arms control including submarines through the Washington Treaty of 1923 between the British Empire, France, Italy, Japan and America and the 1930 London Treaty, whereby limitations were placed on most naval vessels.

The Admiralty continued submarine development within the above constraints with nearly 30 Classes of submarines initiated before the end of the Second World War, many of these Classes overlapping beyond 1946. **HMS *Swordfish (N61)*** was launched on 10 November 1931 and was lost with all crew off the Isle of Wight, as described in the history displayed in the museum.

The Germans were able to retain their expertise post war by building submarines for export. However, despite constraints, they had by the end of the Second World War commissioned 1,156 submarines; 770 approximately were lost and 156 surrendered. Again, many were disposed of when the war ended. **U-*1195*** was sunk off the Isle of Wight the same day as it sunk SS *Cuba*, and its history is also displayed in the museum.

America also developed their submarines, but these were typically considerably larger than their European counterparts, with much increased range as they operated primarily in the Pacific in the Second World War with considerable success against the Japanese Navy. A memento of **USS *Sea Owl (SS-405)*** is displayed in the museum, as is its history.

Early experimentation of submersible "craft" prior to circa 1900 progressively led to feared weapons of war, demonstrated by the naval warfare of both First and Second World Wars.