US WW2 Subs in General

**How many submarines did we have in WW2?**

We started with about 50 operational submarines. We built 221 and we lost 52. We ended the war with 179 boats in service with about 40 more in sea trials or still being completed. Definitions vary so it can be difficult to get consistent, definitive numbers. Contracts for many more of the Balao and Tench class boats were cancelled when it became apparent that they would not be needed for the war.

This refers only to operational boats. At the beginning of the war, we still had some old R-class boats and most of those were being used for training. Some S-class boats were being used for training while others were still operational boats at that time. (The R-boats go back to the early part of WW1 and the S-boats were built during and right after that war.) However, both classes had shorter range and many other limitations. The operational S-boats would become training boats as new construction could replace them.

**What was built after the R and S class boats?**

We had built about 40 “fleet boats” in the 1930s. This includes the Porpoise, Perch, Salmon, Sargo and Tambor classes. These are the boats that were built as we incorporated new technologies and what we learned through operational experience. These boats were larger than the S-boats, had greater range and carried more torpedoes. They were almost the size of the Gato/Balao/Tench boats we built during the war and had similar capabilities. A table, below, compares the sizes of our submarine classes in WW2.

The fleet boats were operational at the start of WW2 along with some of the S-boats. About 16 of the fleet boats were lost during the war. Many of the others were still in active service at the end of the war.

**NOTE:** The name “fleet boats” generally refers to the various classes of US submarines built between WW1 and WW2. The reference is to the fact that these boats were intended to sail with the fleet, or ahead of it, and engage the enemy first. It was rarely practical for these boats to sail with the fleet, but the name stuck. The name was sometimes also applied to the Gato, Balao and Tench classes that we built during the war.

There were also a few larger boats built after WW1. These larger boats had two six-inch guns and they were slower and less maneuverable. Therefore, they were more likely to be used for minelaying and for special operations.

**What did we build during the war?**

The first of the newest WW2 classes, the Gato boats, were just being commissioned when the Japanese attacked Pearl Harbor. The design had been set in 1939 and then we started building the new class. This class, plus the Balao and Tench classes, were what we built during the war. All three classes were very similar, other than the thickness of the hull, and look the same to most observers. Sometimes all three classes are referred to as Gato boats.

The Balao class boats had a thicker hull, at 7/8 inch rather than 11/16 inch. The hull was also strengthened to allow the boat to sit on the bottom. The Tench class kept those improvements and had some ballast tank piping rerouted for safety.

We completed a total of about 77 Gato class, 119 Balao class and 25 Tench class boats during and shortly after the war.

**What is a class of ships or submarines?**

A class is a group of ships built to essentially the same design. There may be some small differences, often depending on the shipyard where the vessel was built.

Classes are normally named after the first ship in the design that was ordered. In an oddity, the USS *Drum* (SS-228) was the first Gato submarine completed and commissioned. However, the USS *Gato* (SS-212) was the first of the design ordered and the class is named after her.

**How do these classes of submarines compare to each other?**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Class** | **Surfaced Displacement** | **Length** | **Max. Surface Speed (Knots)** | **Range (nautical miles)** | **Test depth (feet)** | **Crew (officers and enlisted)** | **Torpe-does** |
| R Class | 569 | 186 ft. 2 in. | 12.5 | 4,700 | 200 | 33 | 8 |
| S-1 Class | 876 | 231 ft. | 15 | 5,500 | 200 | 42 | 12 |
| S-18 Class | 930 | 219 ft. 3 in. | 13 | 3,420 | 200 | 43 | 12 |
| S-42 Class | 963 | 225 ft. 4 in. | 12.5 | 2,510 | 200 | 43 | 12 |
| S-48 Class | 903 | 240 ft. | 14.5 | 5,000 | 200 | 38 | 12 |
| Argonaut | 2,710 | 381 ft. | 15 | 8,000 | 300 | 80 | 16 |
| Porpoise | 1,316 | 287 ft. | 19.5 | 6,000 | 250 | 54 | 16 |
| Perch | 1,350 | 300 ft. 6 in. | 19.25 | 11,000 | 250 | 54 | 16 |
| Salmon | 1,435 | 308 ft. | 21 | 11,000 | 250 | 59 | 24 |
| Sargo | 1,450 | 310 ft. 6 in. | 21 | 11,000 | 250 | 59 | 24 |
| Tambor | 1,475 | 307 ft. 2 in. | 20.4 | 11,000 | 250 | 60 | 24 |
| Gato | 1,526 | 311 ft. 9 in. | 21 | 11,000 | 300 | 80 | 24 |
| Balao | 1,525 | 311 ft. 9 in. | 20.25 | 11,000 | 400 | 81 | 24 |
| Tench | 1,570 | 311 ft. 8 in. | 20.25 | 11,000 | 400 | 81 | 28 |

**How many of each did we have during the war?**

The number of submarines we had as combat boats, as nearly as we can determine, is approximately:

|  |  |
| --- | --- |
| Pre-WW2 boats | 50 |
| Gato class boats complete | 77 |
| Balao class boats completed | 119 |
| Tench class boats completed | 25 |
| Built during and right after WW2 – Gato/Balao/Tench | 221 |
| Total WW2 boats | 271 |
| Completed too late for combat:  24 Balaos and 16 Tench | 40 |
| Total combatant submarines | 231 |
| Lost to all causes | 52 |
| Percentage lost | 23% |
| Combat ready total at the end of the war | 179 |
| Total at the end of the war plus those still being tested or completed | 219 |

**What did we do with our submarines at the end of the war?**

We had a huge Navy and decided to keep only about half of it active. That included aircraft carriers, cruisers and destroyers as well as submarines. Many of the ships we didn’t keep were added to the reserve fleet. Others were used in live weapons tests or sold to friendly nations.

The boats that we kept active after the war would be upgraded starting in the early 1950s. Guns were removed; the sail was streamlined and made more efficient. Snorkels were added so that boats did not have to surface to recharge the batteries or get fresh air in the boat. With a snorkel, that could now be done from periscope depth. Later, there would be a GUPPY program to improve battery capacity.

**What was the reserve fleet?**

The reserve fleet, sometimes called the “mothball fleet”, were boats that we kept on hand in case of new hostilities. The boats were unloaded, covered in protective coatings and then sealed up as much as practical. The idea was that it would be cheaper and faster to reactivate these boats and upgrade them to current standards than it would be to build new ones. Reserve fleets are being dismantled and the ships sold for scrap.

**Did we use any of the reserve fleet submarines after WW2?**

We did. We reactivated and recommissioned a number of these boats for service during the Korean Conflict in the early 1950s. A few of those were kept active after the fighting ended but most went back into the reserve fleet.

Other boats were sold to allies and friendly nations. Some of those were given upgrades first. Other boats from the reserve fleet were used as targets when testing new torpedoes. Still others were used in the atomic bomb testing in the Pacific. Lastly, some of the WW2 boats became museum submarines, such as the USS *Pampanito* (SS-383) here in San Francisco.

By the late 1950s, we were building nuclear powered submarines. That meant that the WW2 boats were quickly outdated. By the end of 1973 nearly all of the World War 2 submarines had been decommissioned. However, some of the new classes of diesel submarines that we had built after the war were still in service in the U. S. Navy as late as 1988.

Two of our WW2 submarines, the USS *Tusk* (SS-426) and the USS *Cutlass* (SS-478) were transferred to Taiwan and are still in service as of 2023. However, since they are now 80 years old, they are limited in their capabilities. Taiwan is now building new, non-nuclear submarines.

**NOTE:** Some of the battleships that were in the U. S. reserve fleet were returned to service as late as the First Gulf War. They had been upgraded to carry and launch tomahawk missiles. All of the Iowa class battleships, the last class, are now museums.

**How many submarines were built in each shipyard?**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Shipyard** | **Gato** | **Balao** | **Tench** | **Total** |
| Electric Boat Co., New London CT. | 41 | 40 | 1 | 82 |
| Portsmouth Naval Ship Yard | 14 | 44 | 23 | 81 |
| Manitowoc Shipbuilding Co., Manitowoc, WI | 14 | 14 |  | 28 |
| Mare Island Naval Ship Yard, Vallejo, CA | 8 | 9 |  | 17 |
| Philadelphia and Boston |  | 12 | 1 | 13 |
| **Totals** | 77 | 119 | 25 | 221 |

It seems rather ironic that most of our submarines were built in shipyards on the Atlantic side of the country while nearly all served in the Pacific.

**NOTE:** The Portsmouth Naval Shipyard is not actually in Portsmouth, New Hampshire. It is across the Piscataqua River from Portsmouth in Kittery, Maine. Nor is the submarine base at New London, Connecticut actually located in New London. It is across the Thames River in Groton. In this, we actually take after the British. Their former submarine base in Portsmouth, in the UK, was actually across the harbor in Gosport.

**Why was there such a difference in the numbers of boats built in each yard?**

The first reason is that Electric Boat and the Portsmouth Naval Ship Yard were established yards and could ramp up production more quickly. They were experienced in building submarines. The Manitowoc Shipbuilding Company had not been building Navy ships at all. They did not finalize their first contract, for just 10 boats, until October of 1940.

Mare Island Naval Shipyard was an experienced yard and had built submarines as well as ships of various types. However, it soon became apparent that the shipyard would be needed for submarine overhauls. That limited the amount of new submarine construction that could be completed.

**What is different about a naval shipyard, like the ones in Portsmouth and Mare Island?**

Naval shipyards are owned and operated by the government. Costs for building ships are based on the total costs for labor, materials and overhead. Civilian shipyards, such as Electric Boat and Manitowoc Shipbuilding, are profit making ventures. They add a reasonable profit to their estimated costs when entering into a contract with the government.

**How much did these submarines cost?**

The numbers vary. The typical cost for boats from Portsmouth or Mare Island during WW2 is generally quoted at $5 million. The first contract for the boats from Manitowoc was for about $3 million and the second was for $3.2 million per boat, plus incentives for early completion. That doesn’t necessarily mean that the boats built in the civilian yards are that much less expensive. It seems unlikely that the accounting is consistent. For example, did the private yards include the costs for the propellers, engines and batteries, which the shipyards didn’t actually build? It seems likely that Navy yards included all costs while the contracts with the private yards may have only included the hull, wiring, piping, and installation of the engines and other large items.

These prices are in 1940s dollars. $5 million in 1943 would be the equivalent of over $100 million today.

**How long did it take to build these submarines?**

in the period between the two world wars, it could take as much as two to three years to complete a submarine. There was little urgency and we were likely making changes to the designs as we learned more about how prior boats performed. There was also some incentive to take longer in order to improve planning and to maintain staffing levels in the shipyards. However, by the late 1930s, as the war was on the horizon and more boats were being ordered, the typical time to complete a submarine was down to about a year and a half.

When the war had broken out in Europe, contracts were being let to begin building ships to either keep us out of the war or to be able to fight it effectively. Construction had already begun, but not on a pace that would soon be needed.

By the time we were in the war, in December of 1941, construction had already started to speed up. Submarine designs had been frozen and soon shipyards were operating 24 hours per day, seven days per week. Shipyards would also have multiple boats under construction at any one time. There would be some boats where the work had just begun and others farther along but still in drydocks. Others may have been launched but still needed a few a few months for more work to be completed. During the war, boats would usually be commissioned less than a year after construction began.

For example, construction on the *Pampanito* began on March 15, 1943. She was commissioned on November 6, 1943. The submarine USS *Picuda* (SS-382) was started on the same day, in the same drydock. They were both launched on the 12th of July. *Picuda* was commissioned about three weeks before *Pampanito*. The Portsmouth Naval Shipyard commissioned 32 of these submarines in 1944 alone.

**NOTE:** When a submarine is commissioned, the shipyard has completed construction work. Builders’ trials and acceptance trials have been completed. The full crew is aboard and the Navy has accepted the boat. However, further sea trials may still be pending, along with the need to fix any of the issues discovered at that time. Generally, those issues are minor leaks, squeals or equipment not quite performing up to specifications. Most of these problems were resolved quickly.

**Were all of our newest WW2 submarines identical?**

As mentioned above, the three classes built during WW2 – Gato, Balao and Tench – were very similar but not quite identical. The Balao and Tench classes had thicker hulls and Tench boats had improved piping. This enabled the Balao and Tench boats to have an approved depth limit (test depth) of 400 feet or so vs. 300 feet for the Gatos.

In addition, there could be some slight variation in equipment location. One tall skipper had the forward battery layout changed a bit so he could have a longer bunk and be able to stretch out. These variations were generally minor and were limited by functionality. Some changes depended on the preferences of the captains, most often on the commissioning (first) commanding officer.

One of the more apparent variations was the location of the large cannon. It could be located either forward or aft of the sail. It depended on whether the captain expected it to be used more often offensively (usually forward) or defensively (aft of the sail). The gun could get moved after commissioning if the current captain could talk the shipyard into making the change during a refit or overhaul.

If you knew one of these boats - or even an older fleet boat - and qualified on it, you wouldn’t need much time at all to qualify on another.

The differences among these three classes are not usually apparent to most observers.

**How could they build submarines in Manitowoc on the Lake Michigan?**

The family-owned Manitowoc Shipbuilding Co. was an experienced shipyard. They had built many ships, such as ore carriers, that operated on the Great Lakes. When the war broke out, they wanted to assist in the war effort and keep their staff employed. Although they had no experience building submarines, and originally turned down the project, they worked with Electric Boat in New London to prepare. They then built 28 submarines as a subsidiary of Electric Boat. The sailors in Manitowoc boats really appreciated the high quality of the work.

Manitowoc Shipbuilding faced multiple challenges:

* In order to understand how each piping or wiring system fit with the whole and the order of installation for each one, the shipyard first built a full-sized model of a submarine out of wood.
* They were building ocean-going submarines in a fresh water environment. Fresh water weighs less than sea water meaning that it doesn’t support as much weight. That, in effect, makes the completed submarine act as if it were tons heavier. They had to compensate for that so the boat wouldn’t go straight to the bottom when it submerged the first time.
* Manitowoc submarines had to be launched sideways at commissioning due to the location on a river. That had never been done with these boats. There was concern that the sudden roll would damage some of the battery cells or that the boat would roll over. The engineers decided to launch without the battery cells installed and calculated the expected roll of the boat. The calculations were exactly correct and everything worked out well.
* Winter conditions on the Great Lakes are harsher than in Portsmouth, New London or Mare Island. The submarines undergoing sea trials in winter collected quite a bit of ice when on the surface. Much of that had to be removed before diving because of the added weight. It made the boat top heavy and less stable. This was also an issue, although to a lesser extent, in Portsmouth and New London.
* The boats then had to be sailed or transported to salt water.

In spite of all the things the Manitowoc shipyard had to do just to be able to build these boats, they completed nearly all of them ahead of plan and under budget. All but one of the boats were completed ahead of schedule, entitling the shipyard to performance bonuses. They accepted some of the bonuses but not all, since they thought it improper to make too much profit during the war.

The shipyard was also building landing craft and heavy cranes at the same time. That construction did not interfere with building submarines or vice versa.

**How did Manitowoc get the boats to the ocean?**

Today, that would be straightforward. You would just sail the boats to the Atlantic Ocean using the St. Lawrence Seaway. However, that wasn’t completed until 1959. In 1941, the locks in the Erie Canal could not accommodate a ship longer than 300 feet and the locks on the St. Lawrence River were even shorter. These submarines were nearly 312 feetlong. Therefore, the only water route available was through the Chicago Sanitary Canal to the Illinois River and then the Mississippi down to the Gulf of Mexico. (Yes, the Chicago sewage canal.) The submarines would be towed through Chicago to Lockport, IL, loaded onto a floating drydock (somewhat similar to a barge) and towed (pushed) down the rivers. The Manitowoc shipyard needed to buy or build the drydocks.

Chicago had built drawbridges which would have allowed the drydock to navigate the Sanitary Canal had the they all been finished. The bridges were all functional for road traffic, but some of them didn’t open. The shipyard needed to complete the rest of the mechanisms to raise the bridges.

The completed submarines on the floating drydocks still would not fit under all the bridges on the Mississippi. To solve that, the periscope shears, periscopes and radar masts were all removed before being loaded on the drydocks before Chicago and were reinstalled in New Orleans.

One interesting story concerns a delay due to high water in spring on the Mississippi. They had to wait several days for lower levels of water in the river in order to get under bridges. There was no alternative other than to tie the tug and floating drydock up to trees and wait. At times, submarine builders needed to be as resourceful as submariners.

**Did “Rosie the Riveter” help build submarines?**

She certainly did. However, just for clarification, submarines were no longer riveted as they had been in World War 1. They were welded. As a result, it might be more accurate to say that “Wendy the Welder” helped build submarines.

In any case, many women went to work in defense plants during the war. Some did administrative work and others did drawing jobs. But many others did the riveting and the welding. In fact, after initially resisting having women in the shipyards, management often found that women were better welders than the men. They were patient and some skills, such as sewing, did make the training easier.

Two of Pampanito’s engines were named, somewhat unflatteringly, after two of the women who worked in the Portsmouth shipyard.

**How big were our submarines in WW2?**

Most of our submarines were about the same size as the *Pampanito*. The boats built during the war were almost 312 feet long (311 feet and 9 inches) and 27 feet wide at the widest. The pressure hull (sometimes referred to as the people pipe) is 16 feet in diameter in most places, around 275 to 280 feet long and is tapered at the ends. The Conning Tower is about 20 feet long and 10 feet in diameter. Surface displacement is about 1,550 tons and submerged is about 2,400 tons.

These newer boats had 10 torpedo tubes – six forward and four aft – and a full complement of torpedoes was 24.

They had four main engine/generator combinations, plus a smaller diesel in the lower flats of the after engine room. The main engines produced around 1,500 horsepower each, whether they were built by Fairbanks-Morse or General Motors Winton.

The 40 or so “fleet boats” that were most of our submarines at the outset of WW2 were about 10 feet shorter than the Pampanito, a bit narrower and lacked the hard bulkhead to divide the engine rooms.

Some fleet boats had only eight torpedo tubes and others had ten. Generally, they only carried 20 torpedoes but some could carry four more in external containers. Their speed and range were comparable to the Gato/Balao/Tench boats. Many of them served throughout the war. These older boats had a higher loss rate than the Gato/Balao/Tench boats, due to the length of time they were in service.

Initially, one significant drawback to these pre-war boats was in the engines. Some of these boats were outfitted with 9-cylinder Hooven-Owens-Rentschler (HOR) diesels. These engines turned out not to be reliable. (The sailors thought they lived up to their name –HORs.) The main problem was the failure of the timing chains. After a while, these engines would be removed and replaced with the larger diesels being used in the Gato boats.

The few S-class boats still in use at the beginning of the war were significantly smaller and had less range. That is why they became training boats as soon as we could afford to do so. They varied in size. Length was generally from about 220 ft. to 240 ft. Beam was 21 to 22 feet. Displacement was 850 tons to 903 tons on the surface. Submerged displacement was 1,060 to 1,230 tons. Maximum speed on the surface was 13 to 15 knots. Range was 5,500 nautical miles at 6.5 knots.

**How were US submarines named in WW2?**

Submarines were named after sea creatures. We can’t just say they were named after fish although most were, such as the *Perch*, *Bullhead*, *Cod*, *Flying* *Fish* and *Halibut*. However, some were named after marine mammals such as the *Whale*, *Porpoise*, *Finback* (a whale), *Sea Cat* (an otter) and *Sealion*. Others were named after unusual sea creatures, such as the *Seahorse* and *Skate*. Obviously, not all could be named after ferocious sea creatures such as sharks or piranhas. We even named subs the *Seadragon* and the *Trepang*, which are nudibranchs or sea slugs.

The *Pampanito* is named after a smaller version of the pompano fish. Pampanito, the fish, is about a foot long. It is a rather mild-mannered fish that is brown or black on top and silver underneath.

**How many submarines did we lose in WW2?**

We lost a total of 52 submarines from all causes or about 23%. We lost about 3,500 submarine sailors with their boats. This was the highest loss rate of any of the major American services during the war. (However, some of the smaller units, such as the Eighth Air Force over Europe, may have had a higher loss rate.) As bad as this loss rate was for our boats, most other countries lost a higher percentage of their submarines

**How were they lost?**

The most frequent cause of our submarine losses was enemy action, either to aircraft, anti-submarine warship attacks or a combination of the two. Some were lost to mines. Over the course of the war, four were lost when they ran aground on reefs although those crews were all rescued. At least two boats were lost when they were struck by their own torpedoes running in a circle, likely due to gyroscope failures. The first submarine we lost in WW2, the USS *Sealion* (SS-195), was struck by bombs while being repaired in the Philippines on one of the first days of the war. In a few cases, we don’t know why they were lost. It could have been enemy action, mines, torpedo circular runs or even operational errors.

A few notes about unusual losses:

* When the submarine USS *Pompano* (SS-181) was reported overdue, there was some confusion as to the name of the boat. It was sometimes reported in local papers as the *Pampanito*, which caused unnecessary grief for a few families until the error was corrected.
* Two older boats, the USS *Salmon* (SS-182) and USS *Halibut* (SS-232) were so badly damaged that they had to be taken out of operational service. *Salmon* became a training boat. *Halibut* was just scrapped. However, they are not included in the count of 52 since they did make it home.
* It has not been definitively established but the USS *Dorado* (SS-248) may have been sunk by one of our own PBM flying-boats when in a safe area. Other possible causes have been put forward as well but none have been substantiated.
* The USS *Corvina* (SS-226) is the only US boat known to have been sunk by a Japanese submarine. She was lost in November of 1943.
* The USS *Robalo* (SS-273) was probably sunk by a mine in 1944. 77 men died in the sinking. Apparently, four others survived, were captured and died in captivity.
* The USS *Seawolf* (SS-197) was sunk in late 1944 with 82 crewmen plus 17 US Army personnel while en route to Samar. There was apparently a great deal of confusion in the area. In any case, *Seawolf* did not, or could not, respond to interrogation signals and was sunk by US forces.

The summary of our submarine losses in WW2 is as follows:

|  |  |
| --- | --- |
| Enemy aircraft | 5 |
| Enemy ASW | 16 |
| ASW/aircraft combined | 4 |
| Bombed | 1 |
| Collision | 1 |
| Friendly fire | 1 |
| Japanese submarine | 1 |
| Mine | 6 |
| Operational | 2 |
| Own torpedo | 2 |
| Rammed | 1 |
| Ran aground | 4 |
| Shore battery | 1 |
| Unknown | 7 |

**Was everyone on board lost when a submarine sank?**

In WW2, that was often the case but not always. When we lost USS *S-36* (SS-141)*,* USS *S-27* (SS-132)*,* USS *S-39* (SS-141)and USS *Darter* (SS-227) because they had each run aground, all of the crews survived. The crew of the *Darter* was transferred, *en masse,* to the USS *Menhaden* (SS-377), then still under construction.

Nine other boats were lost with some, but not all, of the crew surviving:

* The USS *Sealion* (SS-195) was lost at the very beginning of the war in the Philippines. Four men were killed when she was hit by two bombs from an aircraft attack. The boat was in maintenance. (One man from the USS *Seadragon* (SS-194) died from the shrapnel from *Sealion.*) The rest of the crew survived and were evacuated from the Philippines.
* All 62 men of the crew of the USS *Perch* (SS-313) survived the damage to their boat. They also survived the scuttling of the boat but nine died in captivity.
* The USS *Grenadier* (SS-210) was damaged and then scuttled. All 76 men survived the loss of the boat, but four died in captivity.
* The USS *R-12* (SS-89) was recommissioned at the beginning of the war for use as a training boat. She was still being used as a training boat when she was lost in 1943. 42 men died when the boat went down, including two Brazilian Naval Officers. Five men were rescued and, fortunately, 18 others were on liberty that day and were not on board.
* The USS *S-44* (SS-155) was lost in 1943 along with 55 of her crew. Two crewmen survived.
* In a very unusual case, 43 men initially survived the loss of the USS *Sculpin* (SS-191). They were picked up by the Japanese and split into two groups and put aboard Japanese carriers for the trip to Japan. One of those carriers was sunk by the submarine USS *Sailfish* (SS-192) and only one of that group of *Sculpin* sailors survived. A total of just 21 men from the *Sculpin* survived the war. Captain John Cromwell, who was aboard *Sculpin* as wolfpack commander, had opted to go down with the boat rather than taking a chance that he might give away the Ultra secrets under interrogation. He was awarded the Medal of Honor posthumously.
* The USS *Tullibee* (SS-284) was sunk by her own torpedo when it made a circular run. 79 men were lost and just one survived. Approximately 23 circular torpedo runs were reported in WW2, although there could have been more.
* 78 men were lost when the USS *Flier* (SS-250) was sunk by a mine. Eight others made it to Mantangula Island where they made contact with friendly natives. They radioed Australia, and the survivors were extracted by the USS *Redfin* (SS-272).
* The USS *Tang* (SS-306) was hit and sunk by a circular run of her own torpedo. It was her last torpedo at the end of the patrol. Nine men survived the sinking and taken prisoner. All nine survived the war including her captain, Richard O’Kane, who was later awarded the Medal of Honor.

In the other 39 cases, the entire crew went down with the boat.

**How were they able to design such a complex ship?**

Submarines evolved. They didn’t need to be conjured up out of someone’s imagination as fully formed vessels in the 1930s and 40s. These WW2 submarines were the result of a rather lengthy process going back hundreds of years. Here is a quick summary, up to the beginning of WW2. A more detailed version of submarine history is included as Appendix 13?

The idea of a submersible, naval warship appears to go back at least to the reign of Alexander the Great. That was 300 years BCE (before the common era). Leonardo De Vinci also designed a submarine, although it did not appear to be workable.

The first attack in American submarine history was on a British ship during our Revolutionary War. It was attempted by David Bushnell’s submarine *Turtle.*  Like most of the designs at this time, *Turtle* was a small, one-man submersible powered by the man inside it. The weapon was called a torpedo but it was what we think of as a mine. It was to be attached to the target and detonated after the submersible pulled away to a safe distance. Because the speed and endurance were so limited, the attempted attack against a British ship failed.

The *USS Alligator* was the first known U. S. Navy submersible, purchased during the Civil War. (The *Turtle*, above, was apparently operated by the Continental Army.) It was also small and powered by the 12 men inside, first with oars, then with a hand-cranked propeller. *Alligator* did not contribute to the Civil War effort, and sank off Cape Hatteras with no loss of life in 1863. (Wikipedia)

The first successful attack by a submarine was the sinking of the *USS Housatonic.* The Confederate submarine *CSS Hunley* successfully approached the *Housatonic* and detonated the spar charge. The *Housatonic* sank. Unfortunately, the *Hunley* was not able to get far enough away and the crew was all killed when the boat sank. This was the third crew of thee *Hunley* to die when the vessel sank.

A breakthrough occurred in the late 1800s. Robert Whitehead had developed his motor torpedo, a self-propelled device that was a natural fit with the submarines being built. Shortly after that, at about the turn of the century, John Holland and Simon Lake were able to create workable submarines here in the US. Their boats had gasoline engines and were no longer dependent on human power. They were larger and Holland’s boats carried torpedoes.

It took years but Holland was finally able to get the Navy to approve his designs and buy his submarines. These would be the first mechanically-powered attack submarines. When he ran short of capital because of all the delays, Isaac Rice came to his rescue. Rice had been looking for more applications for his battery business. Submarines were a logical application for batteries since that was their source of power when submerged. Rice bought out Holland’s patents and the rest of his financial interests. Holland was eventually squeezed out of the company altogether. This was the beginning of the Electric Boat Company which still builds US submarines today. It was also the last of Holland’s designs.

Some nations bought Holland’s boats. Others bought the designs and developed their own boats. Britain and Germany built their own submarines based on what they learned from the Holland designs and Lake’s work. Many navies wanted to have their own input into the designs of their boats. Holland and Lake did their own designs and offered the boats for sale.

By the time of World War I, there had been many improvements. Boats had periscopes and both bow and stern planes for depth control. They were larger. They were still somewhat primitive but more habitable. Germany, in particular, had created very effective boats. This became very apparent in September of 1914, only about six weeks into WW1, when Otto Weddigen in command of the *U-9* attacked three obsolete British cruisers in the space of about an hour. All three sank rather quickly with the loss of almost 1,500 men.

Germany then proceeded to show how effective a weapon of war a submarine could be. They almost severed the supply lines to Britain and France. British ships could find German submarines with ASDIC, which we call sonar. However, they were still developing weapons to attack subs in the depths. Escorts could only hope to ram submarines or force them to the surface and attack with guns. Sometimes, it was good enough to just keep the U-boats down and unable to attack while the convoy escaped.

Eventually, the Allies managed to defeat the Central Powers on land and end the war. As the spoils of war, the Allies received examples of the German U-boats. After the war, when we compared our new submarines to the German U-boats, we realized how limited our boats were. One analysis found that in every category the German submarines were superior. In many aspects they were far superior. We had no choice but to begin the work of improving our designs.

The two most basic issues were the need to determine what types of submarines we should have and then finding an appropriate and effective means of propulsion for them. Some of the other challenges we had to address were the quality of periscopes, communications, detection gear (sonar) and habitability over long distances

Perhaps the most important outcome of the analysis in 1926 was the creation of the Submarine Officers Conference. This was a group of experienced submarine officers that included senior commanders, naval engineers and officers who had commanded boats. For the first time, American submarine officers would have input into the needs of the submarine force and the designs of the submarines themselves.

By 1934, they had settled on a design of approximately 1,500 tons surface displacement. This would provide the range needed to carry the fight across the Pacific and Atlantic if needed. The boats needed to be large enough to carry the fuel for a long journey and to carry enough torpedoes to make the trip worthwhile. This would be the eventual size of the Gato/Balao/Tench class boats of WW2, such as the *Pampanito*.

The propulsion issue wasn’t easily solved. The surface navy at the time was primarily steam-driven and had difficulty imagining anything else. However, steam isn’t practical in a submarine dependent on fossil fuels. Restarting a steam plant after being submerged takes way too long. Keeping a steam plant running while submerged makes the submarine too hot for the crew.

**NOTE**: Our modern submarines do use steam for propulsion. However, since they are not using fossil fuels to produce the steam, they don’t need oxygen for combustion. The turbines are always using the steam, and the boat is most often at a comfortable temperature.

Gasoline was also impractical as a fuel source. It is too volatile; it tends to catch fire too easily and the fumes in a closed space are toxic and can be explosive.

The answer came from improvements in diesel engines. Then it was a question of the cost of designing and producing these specialized engines. Fortunately, railroads were also looking for diesel engines that would fit in their locomotives and produce a similar amount of power. The railroad engines were similar enough to those for our submarines to spread development and manufacturing costs.

The Submarine Officers Conference opted to design the power transfer, from the engines to the propeller shafts, as mostly electrical. On our WW2 boats, the engines are not connected physically to the propellers. They were essentially electric submarines with four large engine/generator combinations to provide the electrical power. The arrangement and the flow of power is:

[Engine] [Generator] 🡪 [Cubicle] 🡪 [Main Motors] [Reduction Gear] 🡪 [Propellor Shaft]

This arrangement provides multiple advantages:

1. There is no clutch to be engaged or to break down. A clutch would have been needed when diving to disconnect the engines from the propellor shafts.
2. The engines can be run at a high speed for efficiency.
3. The engines can run at a consistent speed even when the propellors need to turn slowly.
4. It allows for four engines to be installed in two separate engine rooms.
5. Four engines can provide a higher maximum speed for a larger submarine.
6. Any combination of engines can be used depending on power requirements.
7. The batteries can be recharged on a circuit separate from the one operating the boat.

At this point, we had a workable design for a long-range submarine with space for sufficient fuel and weapons. It was also large enough to provide some measure of habitability for the crew. This is what we built just before and during WW2.