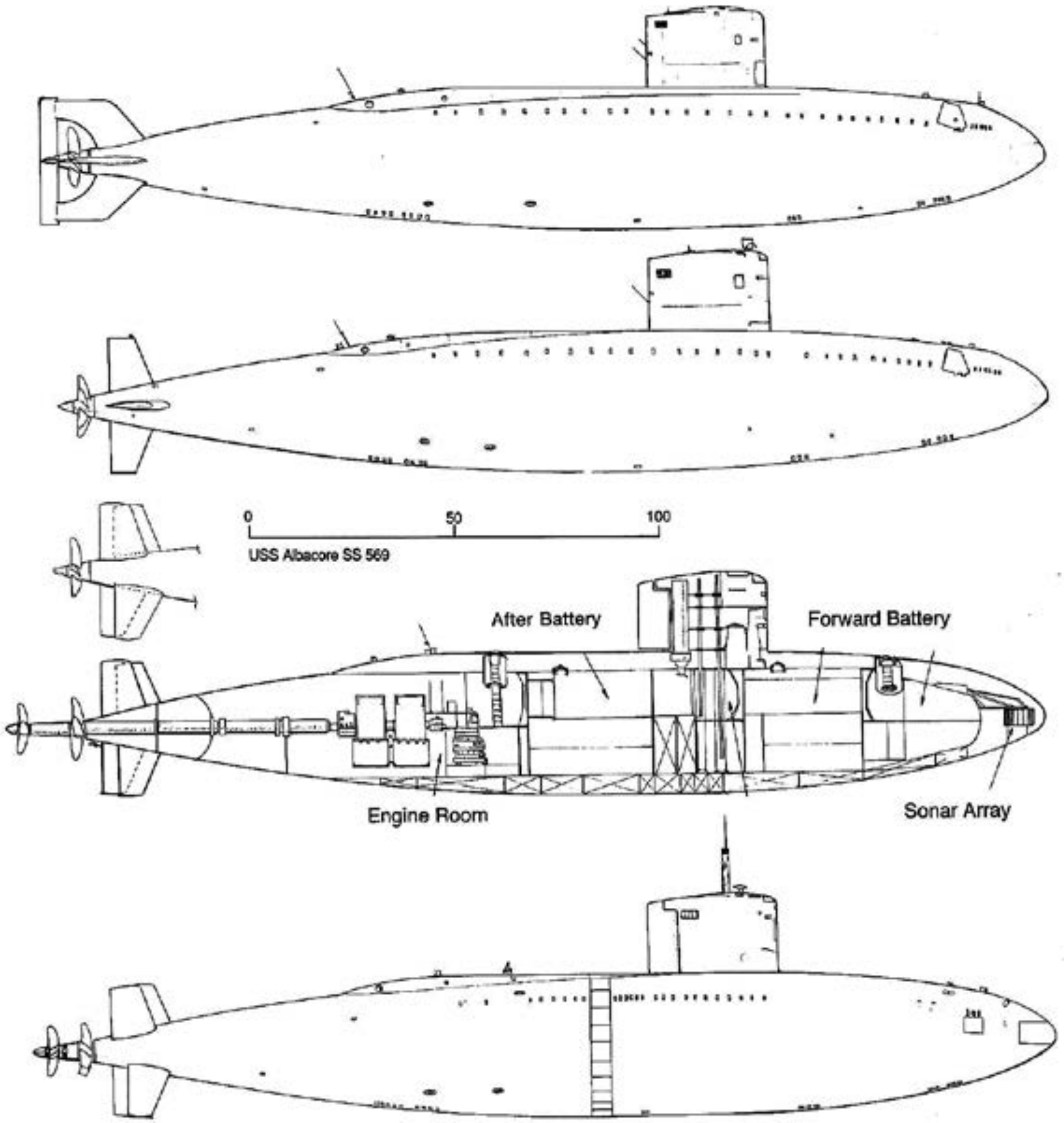
by Tom Dougherty

Albacore - Designed For Speed

With the end of WWII, the US Navy had a large number of relatively new fleet submarines. These submarines had enjoyed tremendous success in the Pacific against Japanese shipping and naval units. But the end of the war also brought the realization that the German experiments with high-speed submarines such as the Type XXI and Type XXIII, along with the possibility of novel propulsion such as closed cycle, hydrogen peroxide and nuclear power, made the new fleet submarines to some degree obsolete. This was coupled with the fear that the expansionist Soviet Union planned a major submarine building campaign with advanced designs based on captured Type XXI subs. An interim solution was the Guppy program, to streamline fleet submarines and equip them with new batteries and a snorkel, enabling short bursts of underwater speed at 16 knots. This program increased underwater speed significantly, but it also highlighted control problems at higher speeds. In a turn, the flat decks of the fleet submarines acted as planes and depth control became extremely difficult to manage. The dynamics of the submarine were more complex, and the controls and gauges were too slow in response, not adequate for the higher speeds. With even higher speeds anticipated with nuclear power, it became clear that submarine hydrodynamics needed to be better understood in the future.

The hydrodynamics and control problems were investigated at the David Taylor Model Basin, using different model hull forms towed underwater. The Series 58 hulls, based on airship designs, with a length to diameter ration of 7 were found to be ideal in minimizing resistance for underwater speed. A smoothly tapered hull with constantly changing diameter (body of revolution, as if turned on a lathe) was ideal, although a tubular mid hull with tapered ends would be easier to build and not give up too much in speed. But the control problem was still looming. What would be the best hull shape/control surface combination? At the same time, Dr. Kenneth Davidson of the Stevens Institute of Technology was advocating for a completely new set of studies to understand submarine high-speed hydrodynamics and control. The upshot was a large, detailed study report on submarine hull shapes. The case for building a full scale submarine to explore submarine hydrodynamic designs was championed by several key individuals, including John Coleman of the Committee on Undersea Warfare, Admirals Charles Styer, Andrew McKee, Edward Cochrane and Charles "Swede" Momsen. Cochrane insisted that it had to be a "ship of the Line", built by BuShips and Navy manned. In the same time period other submarine concepts were under development, most notable nuclear propulsion but also air independent propulsion (hydrogen peroxide) and the postwar *Tang*-class design. After much negotiation, the budget line for the high speed SST submarine was approved in March, 1950, substituting funds from a destroyer escort conversion. The experimental submarine would be hull number 569 and given the name *Albacore*, after a lost WWII fleet submarine. Initially designated SST (submarine target) she was later AGSS, auxiliary experimental submarine.

The submarine design was accomplished by a team under noted submarine architect Capt. Harry Jackson. Because of the requirement that she could surface with one compartment flooded, the "body of revolution" design had some unusual features. Compartments tended to be wide but compartment length was



The four main phases of Albacore*. Ph. 1 featured the aft rudder and planes. Ph. 2 moved control surface forward of the propeller. Ph. 3 (scrap drawing) went to the "X" stern and Ph. 4 had the contra propellers with the X-stern (with different spacings).*

minimized to hold down volume. The hull was the first built with an experimental, high strength steel, HY80, which would become standard on US submarines from the late 1950's onward. Her frames were conventional 50,000 lb. yield steel, which meant a test depth of 600 feet. This number proved conservative and on at least two occasions, the sub significantly exceeded a depth of 1200 feet. Despite her modern shape, *Albacore* retained the double hull configuration of earlier fleet submarines, with main ballast tanks along the sides and bottom of the double hull. Because of her anticipated underwater speed, a unique control station modeled after aircraft controls was installed. Although there were two control stations, the design allowed a single "pilot" to control the submarine, if desired. An analog computer/servo mechanism also smoothed control responses and could act as an autopilot. The big rudder and planes control wheels found in fleet submarines would not be responsive enough at high underwater speeds. After much heated discussion, the submarine was designed unarmed; this ended a contentious battle between the designers and the Navy bureaucracy.

The short compartments meant that a very compact diesel would be needed in the small engine room. The contemporaneous *Tang*-class was being outfitted with a revolutionary lightweight, radial GM-16-338 "pancake" diesels. These featured four vertically stacked radial banks of four cylinders each, with a vertical crankshaft. The electrical generator was located directly beneath the diesel stack. The idea was to keep the *Tang* hulls short, as four of these installed diesels took up much less room than standard in-line diesels. Since *Albacore* had a very short compartment only two of these diesels were installed, one port and one starboard. They were placed in sound reduction cabinets due to their proximity to the crew. However the initial four *Tangs* almost immediately had diesel problems with major breakdowns of these units, and were eventually lengthened and the four radial diesels replaced with a more conventional in line Fairbanks-Morse design. The lightweight design led to excessive vibration and wear on bearings, resulting in metal particles being shed into the lube oil, resulting in further wear. Lube oil would leak down onto the electrical generators, causing problems here as well. The sixteen *Tang*-class GM radial diesel units were assigned to *Albacore* as spares, as there was no way to lengthen *Albacore* and preserve the hull shape. The electric propulsion motor drove a single centerline propeller, again an innovative departure from contemporary twin screw submarine design. *Albacore* had a substantial Exide Guppy II battery, but lacked a snorkel to recharge the battery while submerged. The two radial diesels proved barely adequate to recharge the batteries after a high speed run. *Albacore* featured a robust hydraulic plant, with three pumps in parallel to actuate her controls in anticipated high speed runs; mechanical steering would not suffice. Due to its experimental nature, it was equipped with a single periscope.

Phase 1

Albacore was built at Portsmouth Naval Shipyard and commissioned on December 1953. She was in what was to be called Phase I configuration. She had bow planes, an 11 foot diameter propeller and the control surfaces behind the propeller, supported by outrigger arms. Due to the location of the control surfaces, the submarine was found to be exceptionally maneuverable and easily controlled by the single pilot arrangement. Top submerged speed was 27 knots. Large, high speed changes in depth were possible, along with an exceptionally tight turning radius. These evolutions were so radical that many experienced “riders” were initially alarmed at the large angles the submarine could take at high speed. It was found that the stern installation with the outrigger arms induced drag on the submarine, and the outriggers were subjected to considerable stress during high speed maneuvers. Also, due to their extreme responsiveness, it was easy to overcontrol with the aft rudder and planes. After testing this configuration (and solving problems), *Albacore* was returned to Portsmouth NSY in December of 1955 to convert to the Phase 2 configuration.

Phase 2

Phase 2 stern conversion took from December of 1955 to March of 1956. The aft control surfaces were removed along with the outriggers and the rudder and stern planes moved forward of the propeller. This made *Albacore*’s configuration virtually identical to the *Skipjack*-class SSN design just being finalized. The extreme maneuverability of the aft control surfaces was lost, but drag was reduced and control was still very tight. In this configuration and as part of SubDevGru 2, *Albacore* exercised against ASW forces tested a number of quieting measures. Machinery was placed on rubber mounts and piping was cushioned. An experimental plastic substance, Aquaplas, was used to coat the interior of ballast tanks and flooding voids to minimize vibration and flow noise. Alas, it did not bond well to metal and peeled off in large sections. During this period the noisy bow planes were removed and a larger (14’ diameter), slower turning propeller installed. She continued ASW evaluations, including at the instrumented Tongue of the Ocean site in the British West Indies. In November of 1960, it was back to Portsmouth, NH for conversion to Phase 3.

Phase 3

In the Phase 3 overhaul (Nov. 1960-Aug 1961), the radical X-stern was added, along with a set of diving brakes. The X-stern employed four long, airfoil shaped fins, which were all moving surfaces to control the submarine. The fins were moved in response to control inputs fed through an analog computer. The upshot was to restore almost all of agile maneuvering capabilities of the Phase 1 system, with a turning circle radius of just 165 feet. In addition, they improved safety by alleviating the jammed sternplane scenario, as the opposing set could counteract any dive. Also installed on the sail in Phase 3 was a unique dorsal rudder to attempt to counteract the snap roll tendency in high speed turns. The dorsal rudder, worked by the pilot with foot pedals, was effective in ameliorating the snap roll, but caused tremendous drag, flow noise, and bending forces on the sail structure. Finally a set of ten flaps that extended out from the hull as “dive brakes” were tested as a way to arrest an uncontrolled dive at high speed. Whereas the X-stern was a great success in improving high speed maneuvers and mitigating the tendency to dive in turns; the flap dive brakes on the other hand were a total failure. In addition to noise and turbulence, the brakes caused severe control problems when deployed. After a few uses, they were basically inactivated. Not visible but important was the addition of a bow sonar (BQR-2B) and an active sonar (BQS-4). The steel bow was removed and a fiberglass bow created using the steel version as a mold. Thus *Albacore* had the first free flooding bow sonar, improving sonar sensitivity. *Albacore* had originally been built with no sonar installed. She also received an experimental towed array.

With all of these changes, a quiet, high speed test bed was created to explore new ideas for future submarines and perform advanced acoustic research in collaboration with the Naval Undersea Sound Lab.

Phase 4

In December of 1962, *Albacore* once again entered the Portsmouth NSY for an extensive renovation to attain even higher speeds. This required extensive "surgery" on the submarine, lasting until March, 1965. The stern hull aft of the diesels was removed and a new single hull section installed. The 7500 SHP electric motor was replaced with a twin 15,000 SHP motors (the same SHP as a contemporary S5W nuclear propulsion system), twin contra-rotating propellers with a concentric shaft system, a silver zinc battery for additional propulsive power and an emergency blow system to conform with SubSafe.

The contra-rotating propellers were driven by an outer hollow prop shaft of 28 inches and an inner prop shaft of 15 inches. These drove the two propellers, a 10 foot diameter seven bladed forward one and an 8 foot six-bladed aft propeller. The after propeller recovered some of the swirl energy of the forward propeller, increasing efficiency. Because of their smaller diameters, the propellers did not enter the entering the disturbed sail wake and were not subject to "blade rate" noise, which is detectable at long distances by passive sonar. Initially the two propellers were spaced 10 feet apart, later shortened to 5 feet. The new silver-zinc battery had much more storage capacity than the old Exide lead batteries. But, after a high speed run, Albacore's two small radial diesel engines took an inordinate amount of time to recharge the silver-zincs. Often she did short runs and recharged from shore facilities at Portsmouth.

It was in this form that *Albacore* set the underwater speed record of 33 knots in February, 1966. The submarine also performed a number of acoustic noise tests throughout 1966-67. On January 1, 1968, it entered drydock to adjust her propeller spacing to five feet and conducted further acoustics testing the Atlantic Undersea Test and Evaluation Center. These studies contributed to the "stealth" advantage US submarines enjoyed over Soviet submarines for decades of the Cold War. In 1970, she was again modified for Project SURPASS. Three soft tanks that held 40,000 gallons of a polymer fluid were installed, along with two ejector rings around the hull, one around the bow and one replacing the mid ship dive brakes. The viscous polymer was to be ejected into the water (using a water ram scoop) to coat the hull and reduce friction. The objective was to see if a speed burst could be obtained. In preliminary tests in 1972, ejecting 1,500 gallons per minute yielded a 9 percent speed increase. But, the promising speed tests were interrupted by the breakdown of the radial diesels. And, at this point, after just 19 years, *Albacore* had gone through her two original diesel engines and all sixteen spares from the four *Tang*-class submarines. There were no more spare engines, no parts, and no tooling.

Albacore languished in the Inactive Ship Reserve in Philadelphia from June 1972 until 1985, when she was towed to Portsmouth, NH. After overhaul and preparation at Porstmouth NSY, the submarine was towed across the Piscataqua River and through a temporary canal (temporarily cutting off a railroad and a highway) and after some delays, brought to rest at the present spot. The canal was backfilled and the basin drained. She now sits high and dry, not subjected to corrosive salt water and her pioneering hull fully exposed to all who visit this historic ship. It's worth the trip.

References

USS Albacore-*Forerunner of the Future*. Robert P. Largess and James L. Mandelblatt. The Portsmouth Marine Society

US Submarines Since 1945. Norman Friedman. Naval Institute Press.

Cold War Submarines. Norman Polmar and K.J. Moore. Brassey's.

A Photo Tour of USS *Albacore*

Above: Bow shot of Albacore *as a museum ship in Albacore Park, Portsmouth New Hampshire.*

Quarter port side view. Albacore sites in a trench some 250 feet from the Piscataqua River. The canal to float her into place in 1985 has been filled and no trace remains.

Aft quarter view.

The Phase 4 X stern and contra propellers.

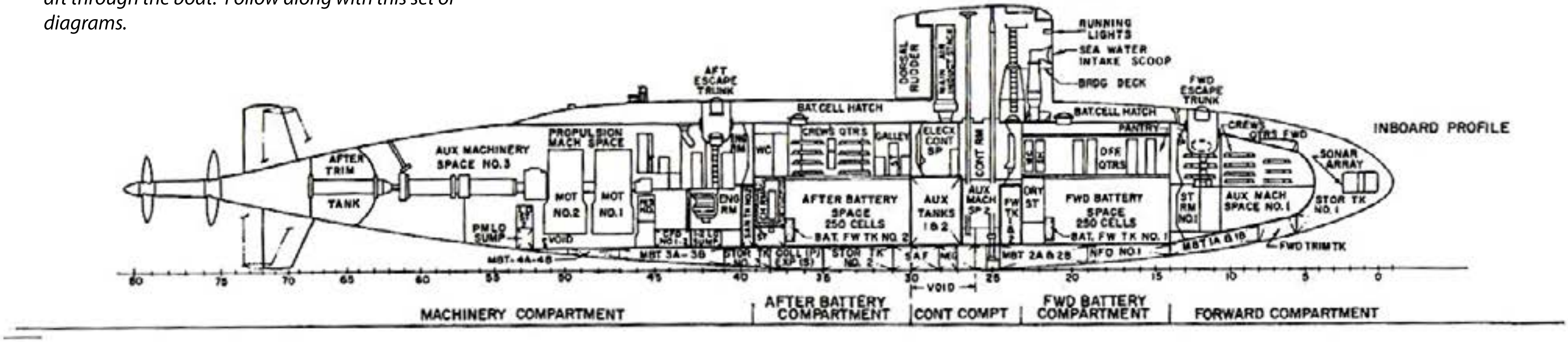
Note the different blade skews of the two contra-propellers. Also noticeable is the stagger to the X stern insertion points in the tapered hull.

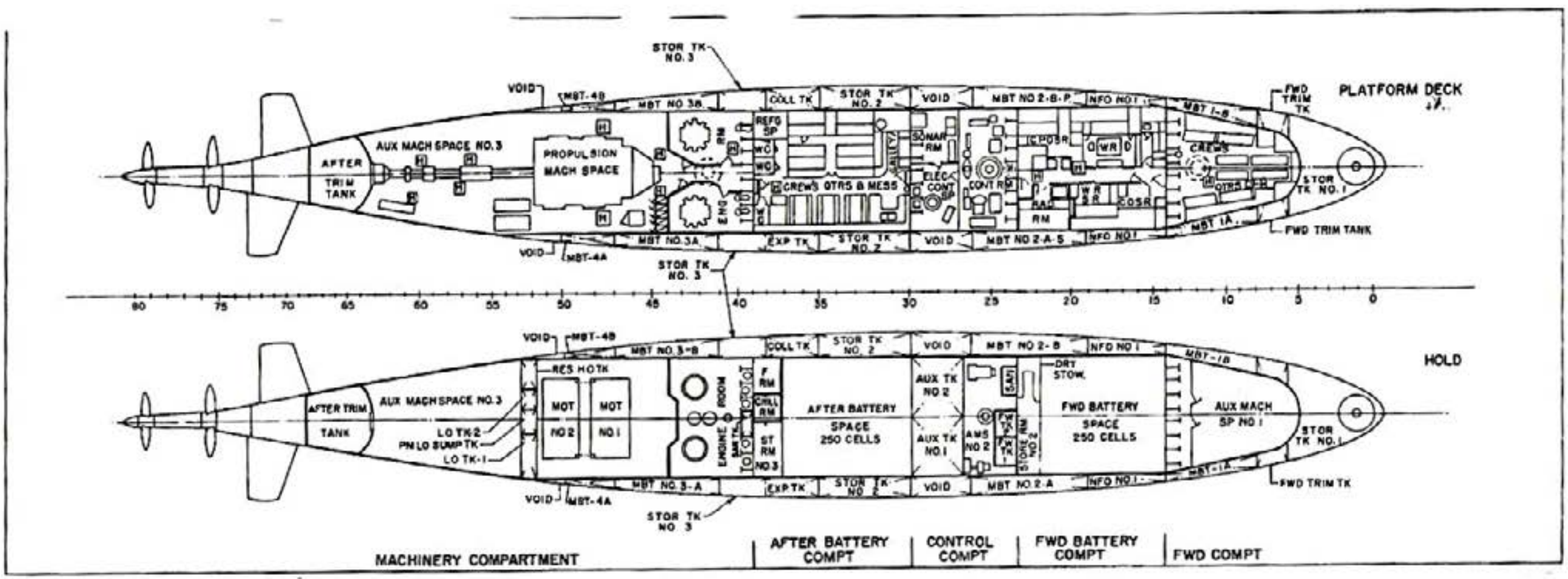
Stern view of Albacore showing the contra propellers, the X stern and her tapered hull. The small turtleback structure is for the diesel exhaust housing.

The sail with the unique trailing edge rudder to counteract snap roll. The single periscope is raised.

The tapered bow shape. The entrance was cut into the hull for visitors.

Albacore's interior layout. The next series of photos will begin at the bow (crew space) and proceed aft through the boat. Follow along with this set of diagrams.



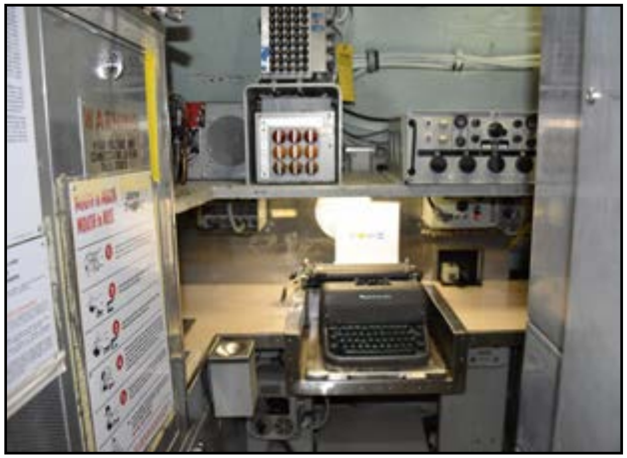


Top Left: Starboard crew bunks in the bow. We are above Auxiliary Machine Space 1 of the bow.

Left: Port side set of bunks separated by a longitudinal bulkhead from the starboard set. Some of the bunks have close by overhead valves. Watch your head.

Right: Watertight door between forward crew compartment and "officers' country".

Top Right: Officer wardroom and mess.. Located on the portside. (WR on diagram).



Upper left: Officers' quarters on the starboard side of the passageway.

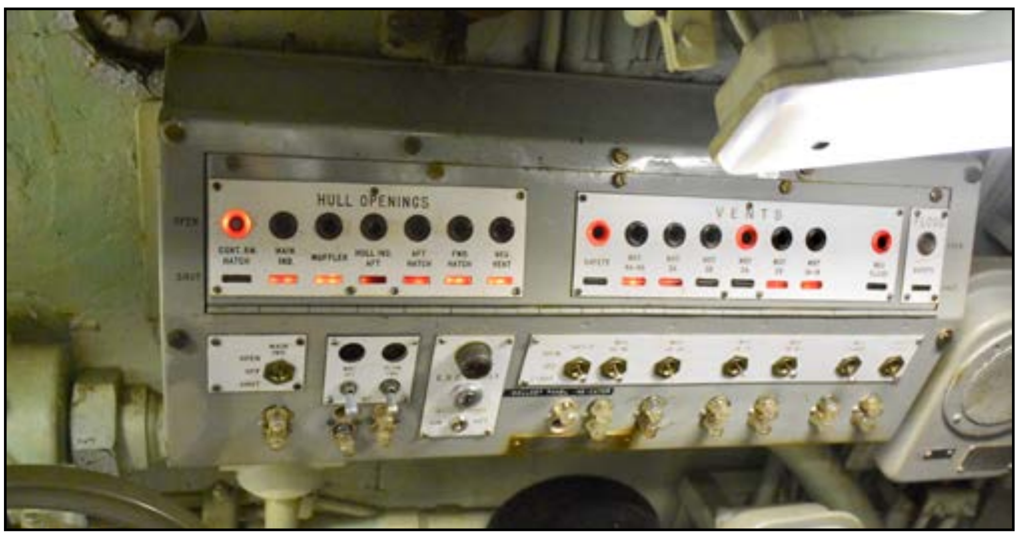
Center: Commanding officers state room, complete with folding wash basin & mirror (COSR on diagram).

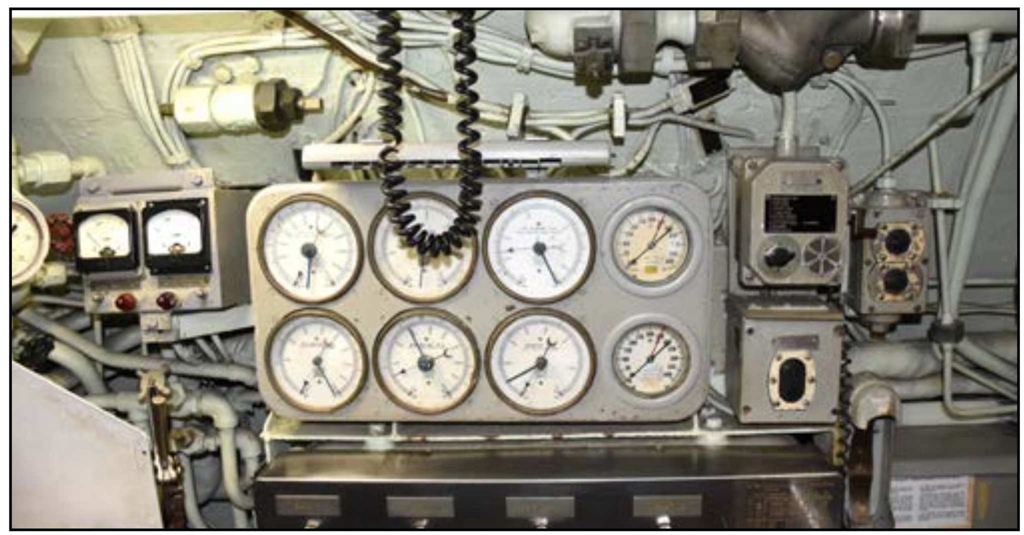
Upper Right: Forward battery status panel in the passageway.

Left: Radioroom (RM) on the starboard side.

Left to Right: Yeoman's office. Ship's paperwork all went through here; An essential piece of equipment which must be properly operated. Just read the instructions on the back wall….

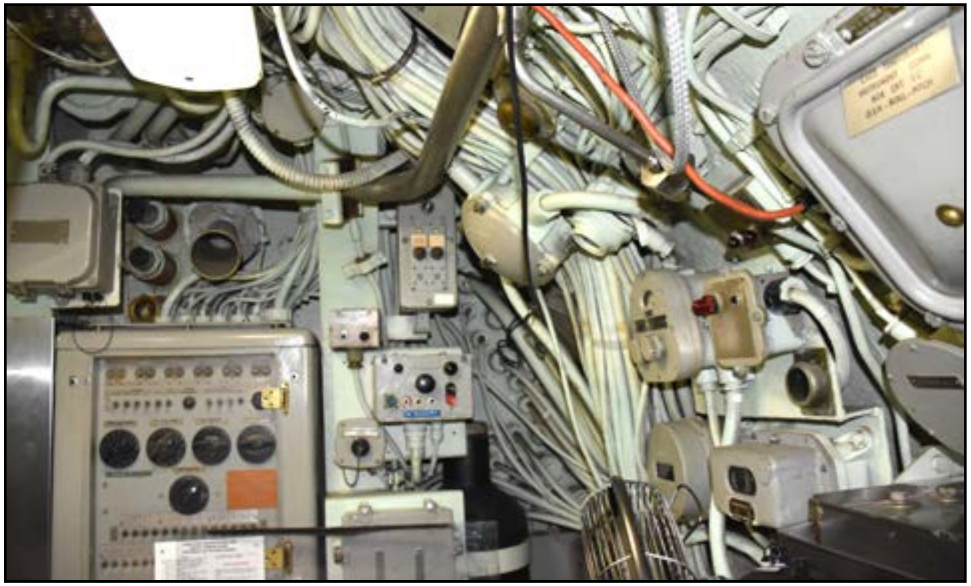
Left to Right: View of Albacore's unique "pilot" station. The seat is facing forward. The closest control wheel can be employed for single pilot mode. Alternatively, the load can be split between two pilots using the secondary control wheel. The large black gauge, reading 000 is the digital depth gauge. Other instruments indicate heading, speed and angles (Cont Rm on the diagram); Another view of the piloting station. The starboard wheel moves forward and backward when in single pilot control mode. The larger black panel between the two wheels is the mode selection switch. These are the much improved Ph. 4 instrument suite.





Left to Right: Just to the left and overhead of the pilot station are the all important hull openings and vents panel. Even at this point, the WWII red and green lights have been replaced by circle and bar symbols with all red lights. During WWII, red night vision goggles made it difficult to see the green lights; On the port side hull next to the pilot station are the trim tank indicators.

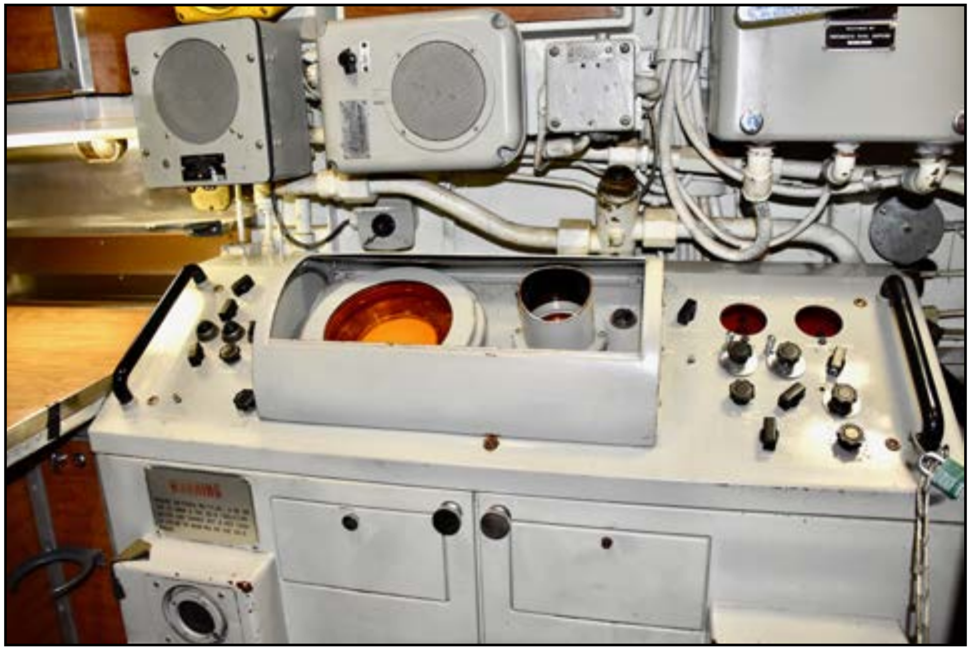
Left to Right: Directly behind the pilots are the high pressure air bank gauges. HP air was used to empty ballast tanks. This late installation allowed push button control of the HP air manifold; On the starboard side of the control room is the chart area and sounding gear.



Left to Right: Sounding sonar set on aft wall of chart area. Older style of pen and ink plotter; Starboard side overhead. It wouldn't be a submarine without a profusion of overhead cables.

Control room center is where the single periscope is housed (central round circle in Cont Rm).

Ladder from control room up to the top of the sail.



Top Left: Moving back toward the stern one compartment brings us to the sonar/radar room on the port side. Side by side sonar consoles face aft.

Top Right: On the left is the BQR-2B, a cylindrical passive array in the bow. The red wheel would manually sample the directions, indicated above the wheel. A bearing time plotter is above the control panel. On the rightt is the BQS-4 active sonar set.

Left: Also installed in this compartment, facing forward, was the ship's radar equipment. Identical to the radar unit installed in Guppy III subs (see March 2019 SCR *on* Clamagore*), there was not space in the control room for this vital unit employed in surface navigation.*

Opposite the sonar room, the ship's Sperry gyrocompass and associated electronics are installed.

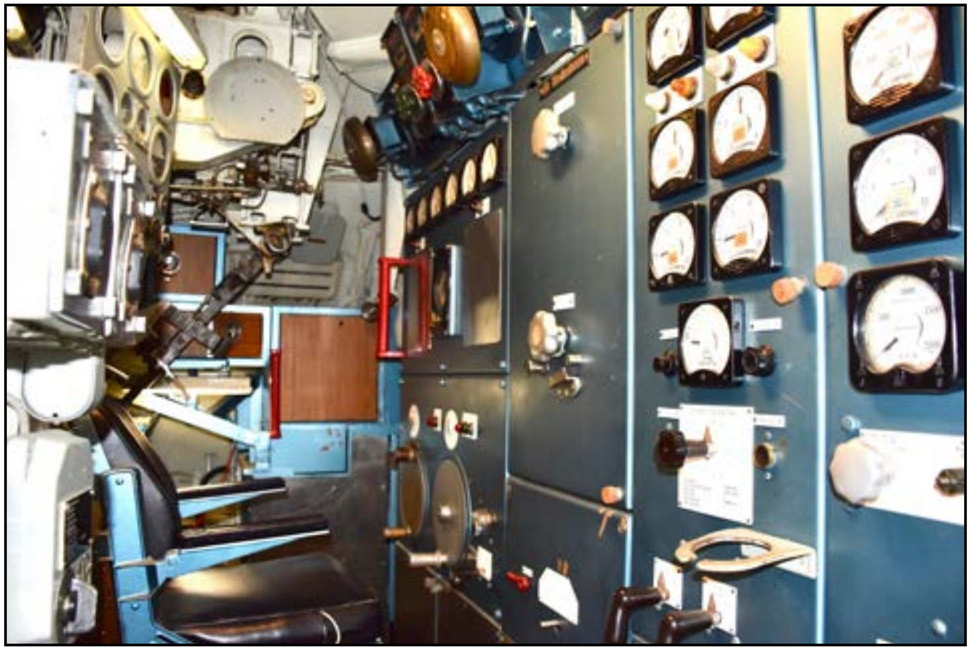
Heading further aft on the port side we find the ship's long & narrow galley. A large grill on the left side.

Left: Opposite the galley is the small crew mess area. This is more compact than on fleet submarines. Directly below is the aft battery compartment.

Right: On the other side of the hull from the galley is the second crew bunk area. Normally a separate compartment on fleet submarines (Crew s Qtrs & Mess on drawing).

Entering the engineering/propulsion spaces, facing aft. One sees the large equipment cabinet and the elevated maneuvering area immediately behind it. Notice that the equipment cabinet has a padded bench top.

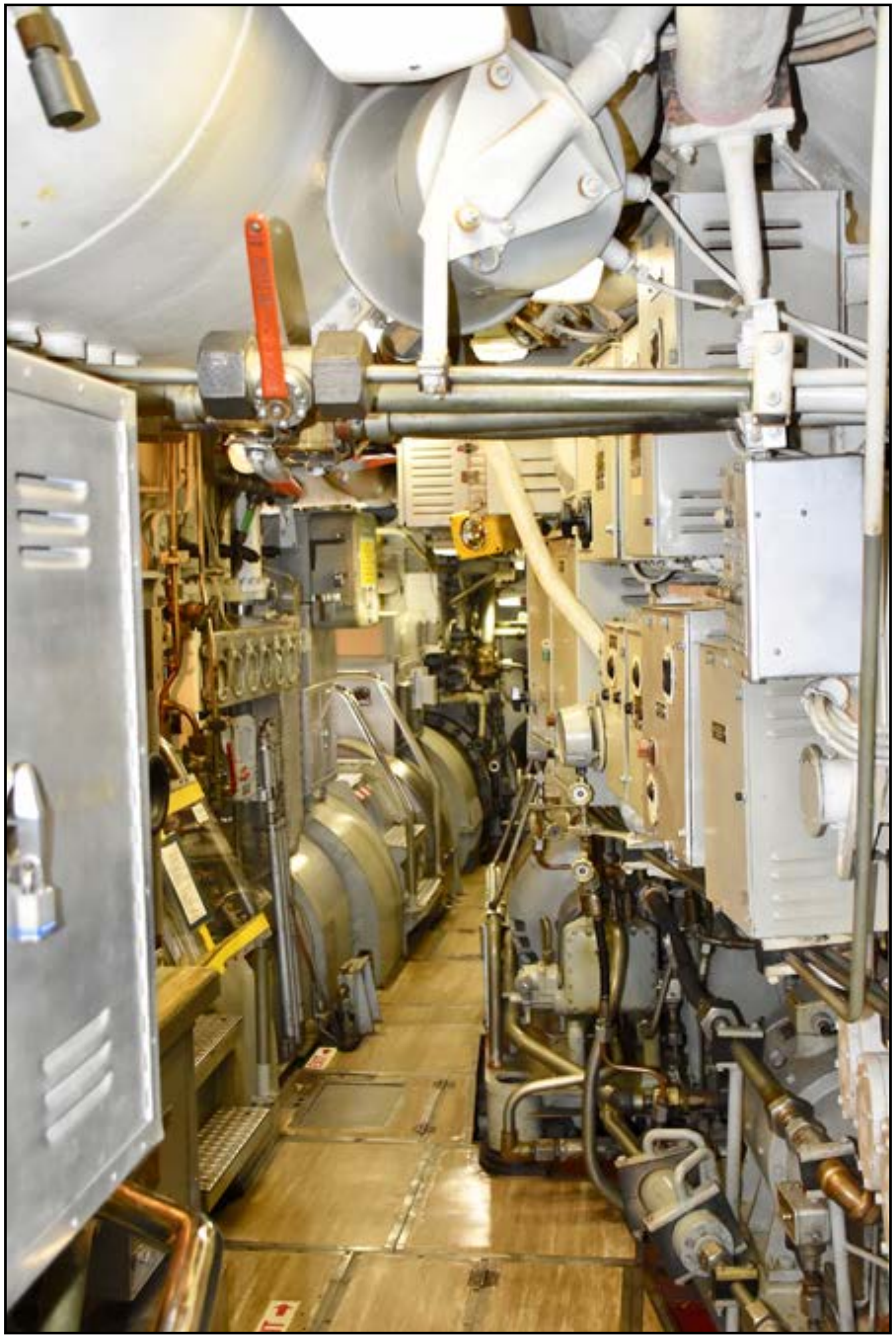
Flanking this area on either side are the two cubicles for the GM 16-338 radial diesel engines. One of the cubicle doors is open, and the air intake and exhaust manifolds are visible.

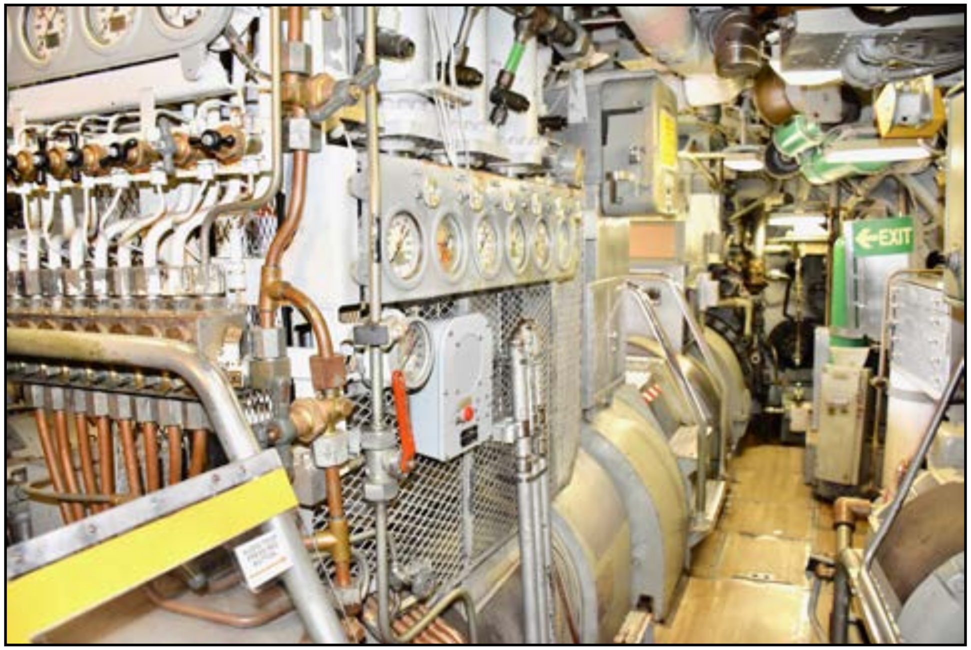


Clockwise from left: The very tight spaces in the engine cubicles made frequent repairs extra difficult. White braces hold the engine in place; Maneuvering room cubicle. Elevated and facing aft, this has the switchboards to control the electric motors and battery charging by the diesel generators; Looking forward, one sees a set of gauges in the overhead for the two diesels. These are monitored by a crewman facing forward and sitting on the equipment cabinet bench top. Passageway from the crew mess is on the left, starboard diesel on the right.

Top: Some of the diesel gauges as seen from the benchtop position. The two diesel compartments are below and to the left and right of these gauges.

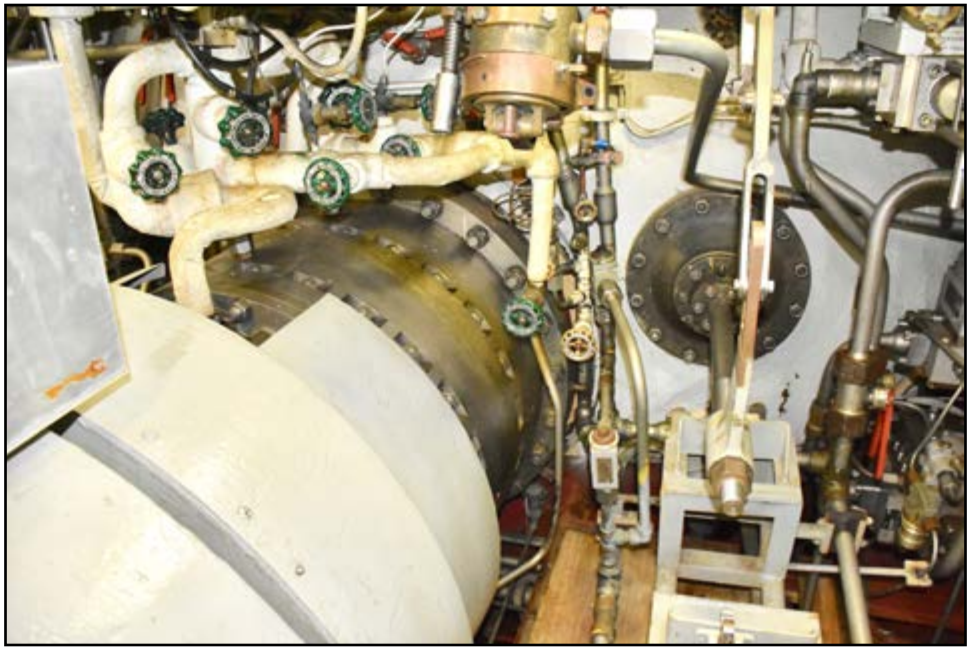
Right: A view down the corridor running aft along the portside from the maneuvering area. This is the "Propulsion Mach Space". The 7500 HP each, twin main electric motors are the dominant gray cylinders at left.





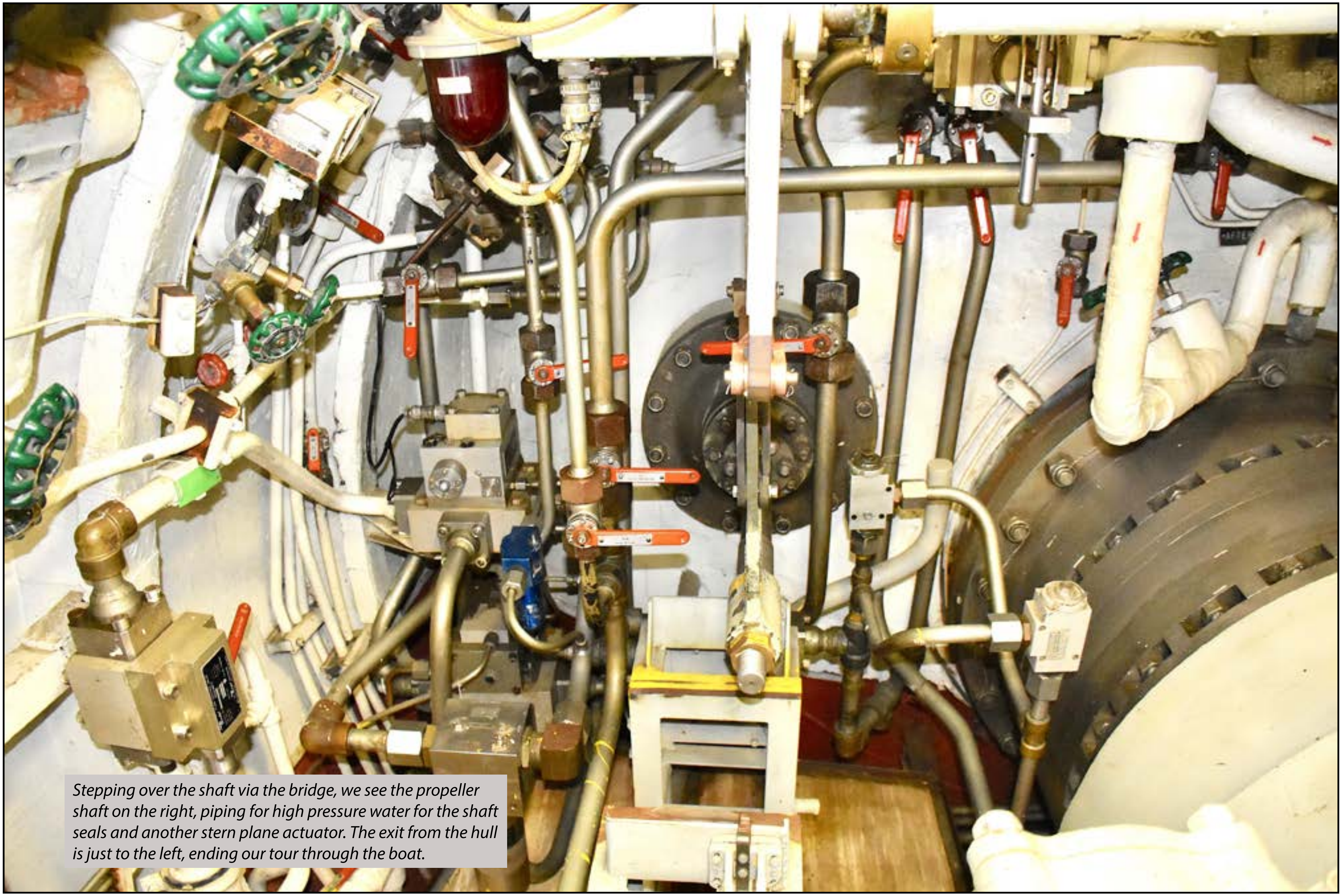
Left: Proceeding down the corridor, we see the propulsion gearing system for the contra-props in the cylinders to the left . A handrail accompanies a step bridge over the propulsion shaft at photo center (Aux Mach Space #3).

Right: Moving further aft, the massive hydraulic accumulator system with piping and gauges is on the left. The concentric prop shafts are below it and the step bridge over the shaft is more clearly visible just aft.



Left: Standing in the rear of the auxiliary machinery compartment #3 facing forward toward the propulsion machinery spaces.

Right: Turning around , we see the large propeller shaft which houses a shaft within a shaft, turning in opposite directions for the two contra-props. It exits the space through the shaft seal. Just to the right is an actuator arm for the X-stern planes.



Stepping over the shaft via the bridge, we see the propeller shaft on the right, piping for high pressure water for the shaft seals and another stern plane actuator. The exit from the hull is just to the left, ending our tour through the boat.