Modern United States Submarines

By HARRISON W. SIGWORTH

OF JAPAN'S combined naval and merchant tonnage sunk during the war, United States submarines sank 70 per cent, representing nearly five million tons. Undoubtedly fine fire control devices and superior radar accounted for much of this success, but these ingenious devices would have been useless had there not been a vehicle to carry them, undetected, within shooting distance of the enemy. It was also necessary that this vehicle be capable of bringing them home despite the efforts of enemy anti-submarine vessels, planes, and shore batteries; for submarine personnel and their effective apparatus were never considered expendable.

Such a submarine was developed in our Navy in 1939. Later models incorporated changes dictated by experience in the war, but essentially these "Fleet" type submarines were the same—big (over 300 feet long), fast, quick diving, deep diving, of long range. They were produced in such numbers after 1940 that a fleet was evolved, capable of whittling incessantly at the Japs from start to finish of the war.

How these boats dive and surface, how they propel themselves, stay at sea for months, and come back, meanwhile keeping a crew safe and in a good state of morale, are items of especial interest.

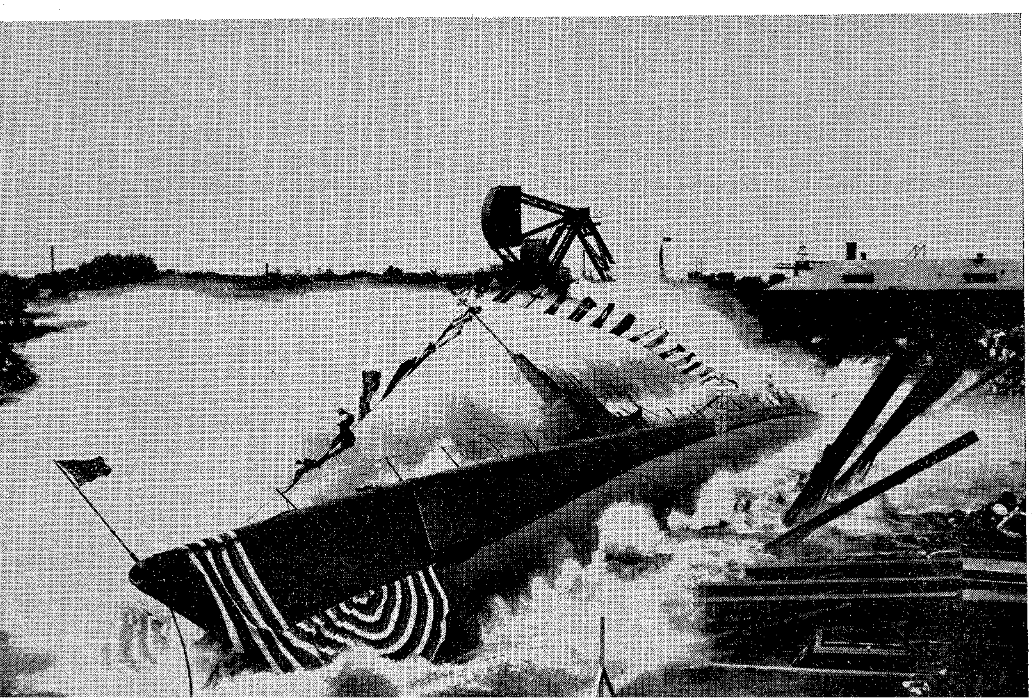
DIVING AND SURFACING

In the study of submersibles it is necessary to be acquainted with four types of buoyancy: neutral, positive, negative, and reserve. Neutral buoyancy is the state in which a submerged object displaces exactly its own weight. An object which floats has positive buoyancy. An object which sinks has negative buoyancy. Reserve buoyancy is the amount of weight a floating body must take on in order to submerge. In the case of a submarine, it equals the weight of water which must be flooded into the boat's tanks in order that it may dive with neutral buoyancy.

The tanks which are flooded on diving are called main ballast tanks. The drawing on the next page shows one of these in cross section. For the most part they are contained by the outer and inner hulls. In the bottom of the tanks along the keel are many big holes or "flood ports." The only thing which prevents the tanks from flooding through these holes when the boat is on the surface is the small air pressure maintained inside the tank. If the air pressure is vented off through the vent valves in the top of the tanks, the tanks will quickly flood. This, in fact, is the way a submarine is dived.

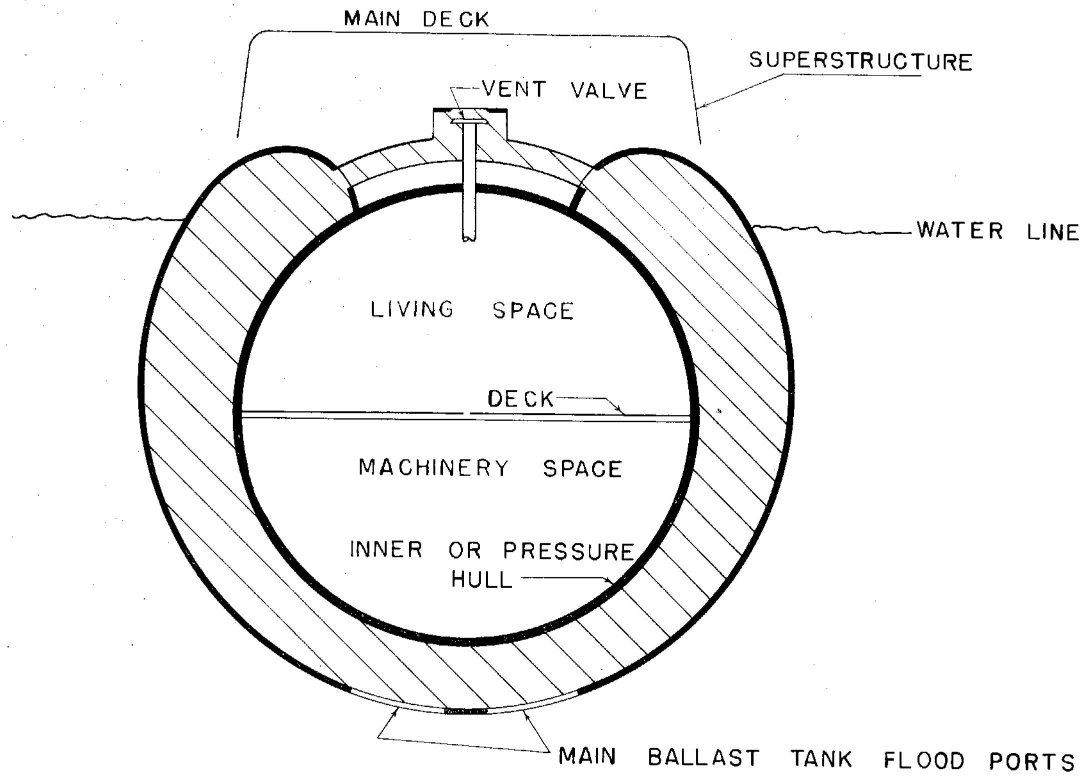
Since the flood ports are merely open holes, it can be seen that when the boat is submerged with the main ballast tanks flooded there is no differential of pressure through the outer hull. Consequently, the outer hull is of light construction. But since the pressure inside the boat is approximately atmospheric, the inner hull withstands full sea pressure. To withstand sea pressure at extreme depths the inner hull is thick and of circular cross section. Frames or braces are spaced longitudinally between the outer and inner hulls. These, being welded to the inner hull, are stressed in tension, with the result of a saving in weight and material.

All talk of diving with neutral buoyancy by flooding the main ballast tanks is predicated upon the fact that the reserve buoyancy must at all times approximate the capacity of the main ballast tanks. Changes in weight are occurring continuously while the boat is under way on the surface. Fuel is being used, water is being distilled and moved from one part of the boat to another, sanitary tanks are being emptied, and perhaps torpedoes and ammunition are being ex-



AT LEFT:

Submarine launching by the Manitowoc Shipbuilding Company, Manitowoc, Wisconsin. This was the only company to launch submarines sidewise.



AT RIGHT:

A typical cross-section of the double hull construction, with main ballast tank flood ports and vent in evidence.

pended. All these weight changes must be compensated for before the boat dives in order to keep the reserve buoyancy approximately equal to the capacity of the main ballast tanks. It is a policy to "compensate" the boat every few hours when under way or after each big change of weight, so that if the boat should dive at any minute, she would have a satisfactory trim.

To surface the boat, using the main ballast tanks, the vent valves are closed and high pressure air is injected at the top of the tanks, forcing water out through the flood ports. Compressed air for this purpose is stored in steel cylinders at several thousand pounds pressure. Enough water is blown out to surface the boat with the main deck awash, but the tanks are not blown dry, because it is highly uneconomical to compress air to such a high pressure and then throttle large volumes down to about 7 or 8 pounds per square inch. For this reason a high capacity, low pressure, Roots type blower is used to blow the tanks dry. The blower is not started until the hatch to the bridge is opened and can take its supply from the atmosphere.

When the boat is at sea, rigged for diving, only the hull valves necessary to the function of propulsion and ventilation are open. At the sounding of the diving alarm, first the hydraulically operated main ballast vents are opened. The boat starts to dive. Second, the engines are shut down and the exhaust valves closed. Propulsion is shifted to the battery. Third, the main air induction valve just aft of the conning tower is closed hydraulically. Fourth, when all personnel are below, the upper conning tower hatch is closed. The pressure hull is then watertight and the boat well on its way down.

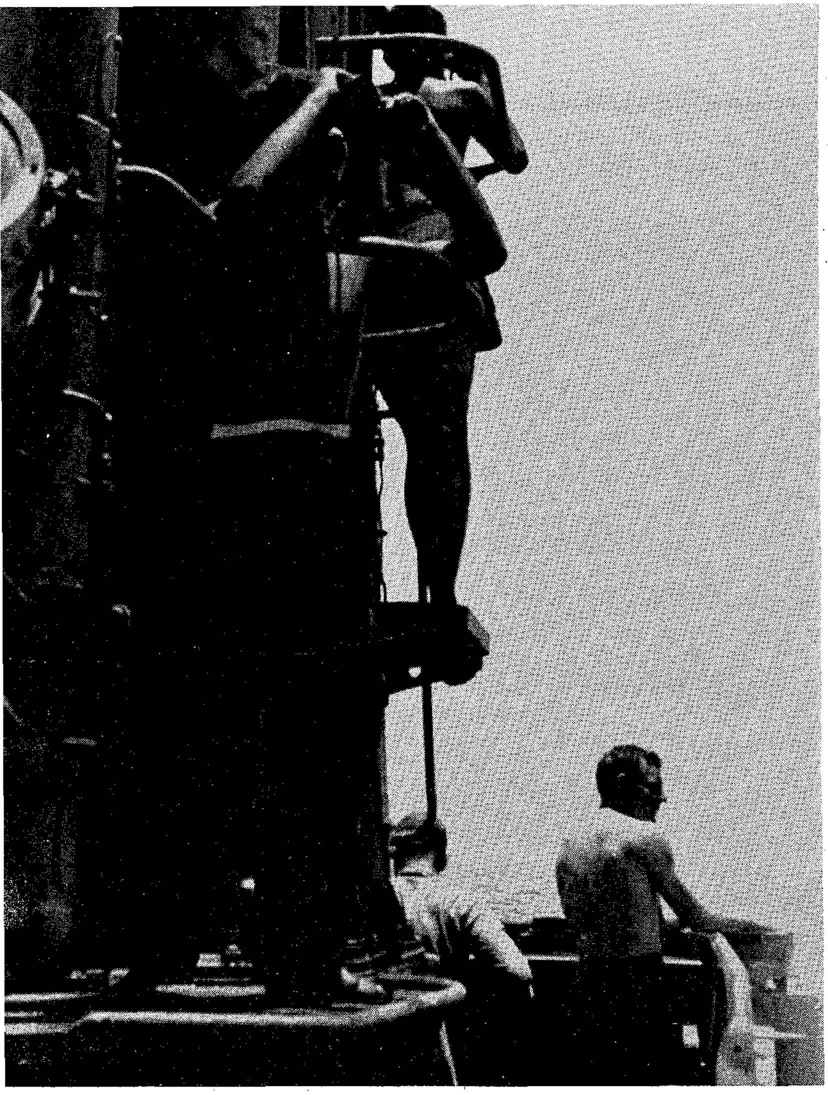
Although an exact figure on diving time is a guarded secret, it is less than a minute. From personal experience on the **Loggerhead** it can be said that the interval from the sounding of the diving alarm to water coming over the bridge is not long. Unless the officer-of-the-deck gets down the hatch on the heels of the lookouts, he is likely to find the hatch closed and himself swimming.

SUBMERGED OPERATION

The achievement of neutral buoyancy is a practical impossibility. It can be approached by pumping water out of the trimming tanks or flooding in; but true neutral buoyancy in which the boat will stay anywhere it is placed below the surface without sinking or broaching is impossible. Depth can be maintained within a foot for hours at a time, however, by propelling the boat through the water and using the diving planes. These are horizontal, tiltable, planing surfaces placed at the bow and stern to control depth and angle of the boat.

When a boat is badly out of trim from damage and taking on water, depth can still be controlled with the planes; but high speed must be used to increase the planing effect. The **Loggerhead** once dived 25,000 pounds heavy in the after end of the boat with the after trimming tank dry. By using a 15 degree up angle and full speed, depth was maintained. In this case advantage was taken of the planing effect of the whole hull by allowing such a large up angle.

There are three variable ballast tanks or trimming tanks: one forward at the bow; one at the center of gravity, called the auxiliary tank; and one aft. These tanks and a pump are interconnected so that trim fore and aft as well as overall can be adjusted. There is no stability fore and aft, submerged, like that from side to side. Thus trim fore and aft must be reckoned with. The tanks are of large enough capacity to compensate for the difference between displacement at the start and at the end of the patrol when a boat has lost stores and torpedoes. It is noteworthy that these boats can be made to operate in fresh water, which necessitates a ballast change of 100,000 pounds.



Lookouts and Officer of the Deck on the Loggerhead keep a sharp watch in a war zone, ready to dive at any instant.

PROPULSION

Fleet submarines have a so-called Diesel-electric drive. On the surface four 1600 horsepower, constant speed, non-reversible, Diesel engines each drive a direct current generator. Two direct current motors are connected to each of two propeller shafts. If one considers the fact that energy for propulsion submerged must be supplied by batteries, this type of drive is seen to be the simplest and most flexible. On diving, the motors can quickly be switched from generators to batteries. On the surface, any combination of generators may be used for propulsion or charging batteries.

Maximum speed, submerged, is 10 knots. On the surface it is about 20 knots. But many factors contribute to varying this latter figure—to name a few, the state of the seas, the draft of the boat, the condition of the bottom (whether clean or not). The best speed ever made by the **Loggerhead** was raised 2 knots one night after an attack on a convoy in a Japanese harbor, when she was chased by four escort vessels in water too shallow for diving.

Generally the engineering plant of the **Loggerhead** performed amazing feats of endurance. Eighteen thousand miles were steamed during one patrol. At one time a run of 2,000 miles was made from the Java Sea to Subic Bay, the Philippines, at full speed virtually all of the way.

SAFETY DEVICES

The development of the United States submarine is largely a story of safety precautions. Every time a boat has an accident or is inadvertently sunk, detailed observations are made and improvements result to avert the danger in a later instance.

The **Squalus** sank on trial runs off Portsmouth, New Hampshire, in 1939 because she dived with the large air induction valve open, allowing a stream of water 36 inches in diameter to flood into the boat. The **Squalus** was later raised, but difficulty was encountered in closing the main induction valve while the **Squalus** lay on the bottom. Now each submarine is fitted with quick closing valves inboard of the main induction, as well as having a special wrench stowed topside for divers to use in closing the valve, should it ever be necessary.

Each compartment is fitted with pipes running from the topside for blowing out water. Each main ballast tank can also be blown by means of fittings on the main deck. Marker buoys which may be released by a sunken boat provide telephone communications with the surface.

During his training every submariner is required to make an ascent from a depth of 100 ft., using the oxygen-charged Momsen Lung. These "lungs" are effective in aiding escape to depths of 300 ft. So at least a fighting chance is provided the crew of a boat in peacetime, if they are fortunate enough to find themselves sunk in shallow water.

Hydrogen generated when the batteries are being charged has always been a menace. Five per cent in air will make an explosion sufficient to kill everyone in a battery compartment. Consequently, by forced ventilation through the top of each battery cell, the concentration is maintained below three per cent, even when charging is going on.

More than any other ship, a submarine is in danger from collision. On the surface the reserve buoyancy is only 20 per cent of the displacement, while in the case of most surface craft, it is normally 100 per cent. A submarine's pressure hull is virtually below the surface at all times. Only the conning tower and superstructure emerge on surfacing; thus the puncturing of the pressure hull means almost certain disaster. The only cure for this danger is prevention. The submarine service is outstanding for giving every officer, including the youngest, ample opportunity to handle the ship in all operations, surfaced and submerged. By this policy the safety of the boat is never jeopardized by inexperienced ship handlers.

There are submarines which have made 5000 dives without a serious accident. They develop a diving procedure which is full of precautions yet runs like clockwork. Of the 46 boats which failed to return from patrol during the war, some had been bombed, some torpedoed, but undoubtedly some had fatal accidents. That is inevitable in a machine which dives as a matter of routine.

LIVING CONDITIONS

It has been said that the storage battery, the Diesel engine and the tin can made submarine warfare possible. But it would be best to add that air conditioning and fresh frozen foods are what made the submarine livable. No surface craft can pretend to boast the atmospheric comfort enjoyed in a submarine. Whether the boat is surfaced or submerged, the controlled ventilation, combined with small room volume, allows excellent air conditioning. In patrols four degrees in latitude from the equator submarine crews are no less comfortable than at 40 degrees from the equator. On the **Loggerhead,** fresh meat twice a day was the rule. Special ice cream machines ran continuously, turning out ice cream for every meal, if desired. Fancy dishes such as shrimp and lobster were carried. Bread, cakes, and pies were baked regularly, for food was recognized as a major morale factor. The average patrol run was 60 days; and after he has looked at the same 79 faces and the same eight rooms and the same ocean for months, meals become important in a man's life.

Quarters were cramped. Forty men sleep in a compartment 18 ft. by 30 ft. with semicircular overhead. Stowage of food, personal effects, and spare parts is an ever-present problem. On more than one boat passage ways were paved with stores in boxes of uniform height. It is generally known that torpedoes are bunkmates with many a submariner, but so are valves piping, chain fall and motor-generator sets.

Cleanliness is important; much effort is expended to keep the boats clean. The new boats have a beautiful interior which may be likened to a fine new Pullman car, despite the predominance of piping and valves in the motif. Nor was nine million dollars spent for machinery only. Broadcast radios, record players, and record libraries come with the boat.

An interesting oddity is that mice or rats are unknown on an operating submarine. Perhaps the reason is the Diesel odor, or maybe the body odor (six days between showers), or the old theory of rats leaving a sinking ship. In any event, they, along with bacteria in general, pay little attention to submarines. Cases of colds, influenza, catarrhal fever clear up after a few days at sea and never reappear.*

*Another biological curiosity is the recognized predominance of girls born to the wives of submariners. In one year, to the families of one submarine squadron 20 children were born. Of these, 18 were girls.

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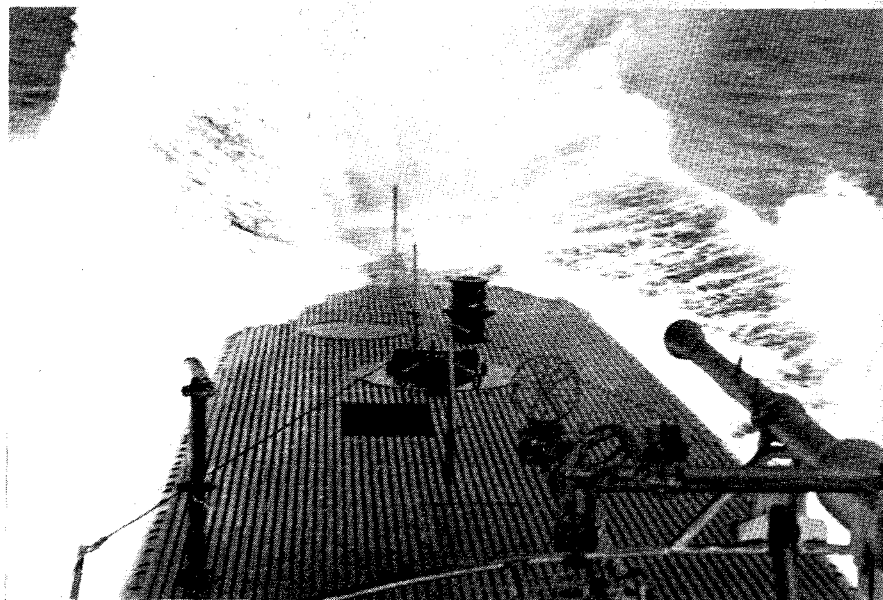
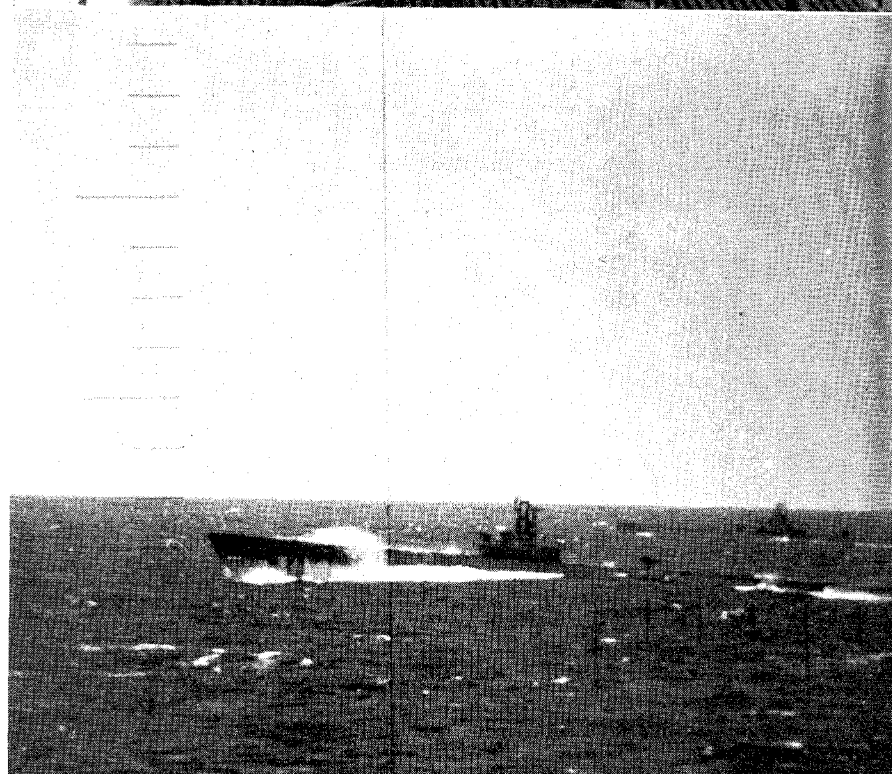
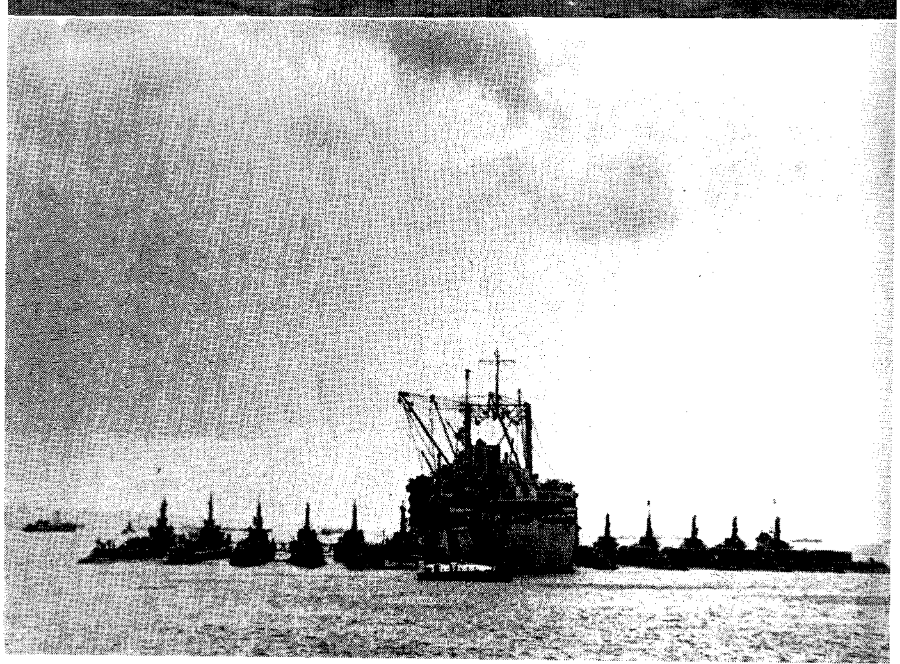


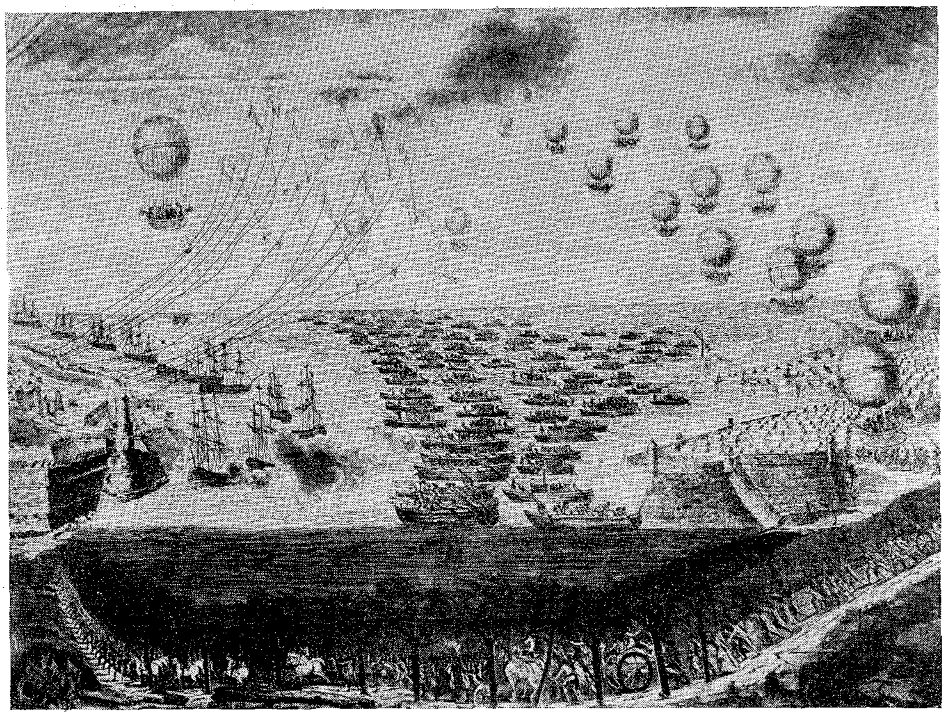




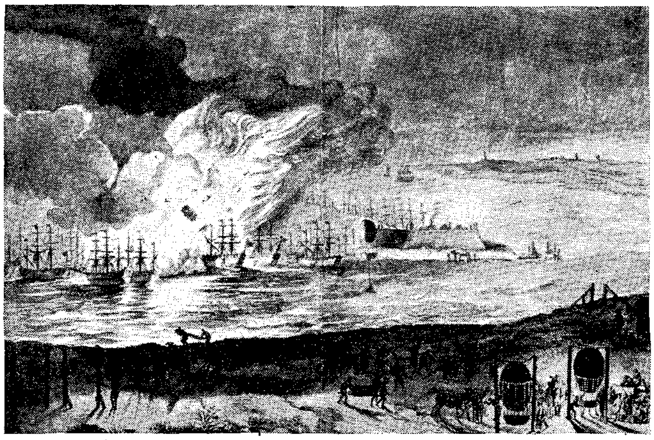
AT RIGHT:

UPPER: U. S. S. Loggerhead (SS374) taking green water over the bow in the Indian Ocean. CENTER: A modern submarine surfacing. Taken through the Loggerhead's periscope. LOWER: Submarines alongside tender in Subic Bay, Philippines.

Plate 2. A Napoleonic project for attacking England. *(Circa 1803)*



the possibilities envisioned by LANA and achieved by modern war planes were also considered very seriously nearly 150 years ago is clear from the three prints here reproduced.



The bombing and strafing of troop concentrations by airplanes has now become standard practice. Plate 1 is a reproduction of a German caricature of about 1804 showing two armies, one of which is put to flight by the artillery of two aircraft.

During the Napoleonic Wars several schemes for attacking England from the air were proposed. Plate 2 shows the French forces attacking in balloons, in barges and through a channel tunnel. Actually from May 1803 until August 1805, NAPOLEON had an army of approximately 130,000 men encamped at Boulogne while more than 2000 flat-bottomed boats and barges, designed to land men and equipment on the beaches at Dover, were constructed and assembled. The project was abandoned only shortly before the Battle of Trafalgar.

Plate 3 is an early (**circa** 1803) suggestion of a bombing attack from the air on the British Fleet.

Plate 3. (left) A Napoleonic project for destroying the British fleet. *(Circa 1803)*

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But the finest part of submarining during the war was the two-weeks rest periods after each run. For two weeks a man lived ashore in a hotel while the repair crews took over the boat. He got caught up on the sleep, fresh milk, oranges, eggs, and horseback riding that he had missed at sea. Or if he spent a refit in Australia, he could lose sleep and have a fine enough time to require two months of sea duty for recuperation. The important thing was the complete change in living routine, environment, and the lifting of all responsibility.

Fifty-two United States submarines were lost during the war—less than the number lost by any Axis nation or by Great Britain. The Germans lost 700. The Japanese lost over 100 out of an original 140. The damage to the enemy by the submarine force of this country in proportion to losses was tremendous, any way one looks at it. In terms of tonnage, the Japanese paid 100,000 of theirs for every 1500 of ours. In terms of lives lost, every American accounted for about 70 Japanese. At war's end there were 240 submarines in the United States Navy. There can be no doubt of the effectiveness of this weapon, considering the small size of the submarine force in terms of what it did.

The future of the submarine looks even brighter. Faster submerged speeds, faster, smaller and longer range torpedoes, and its innate ability to hide from radar may well leave the submarine the only truly **naval** weapon of the future. In any event, the modern American submarine has proved itself a fine foundation on which to build a future submarine navy.