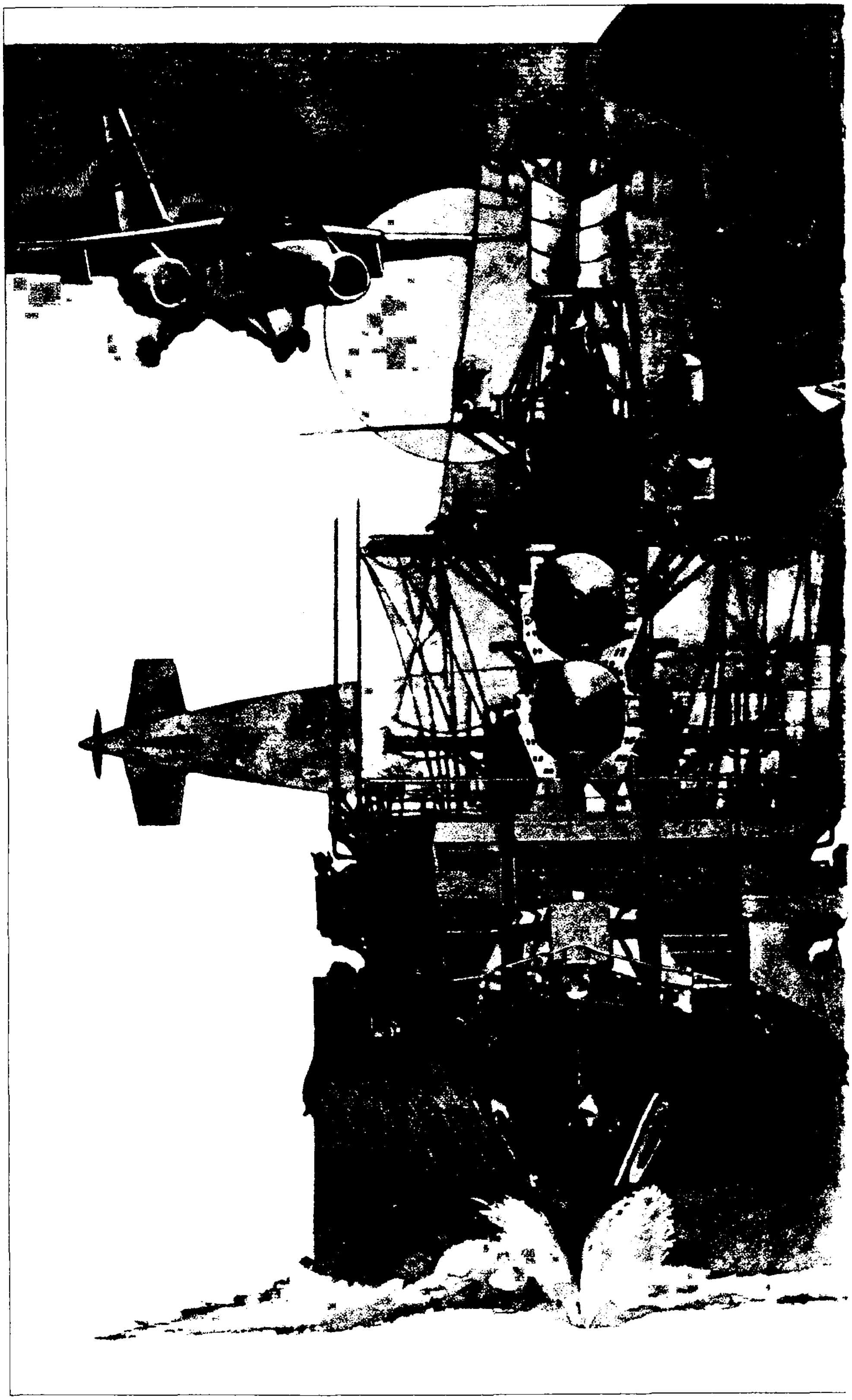
Winning the ASW Technology Race

By William D. O'Neil

Huge technical efforts are needed to provide ASW platforms with sensors good enough to detect new and stealthier generations of submarines.



Antisubmarine warfare is one of the longest running races in naval warfare—a race between the technologies of finding submarines and hiding them. With the hiders now pulling ahead, it is time for renewed ASW technology efforts. The United States can sidestep some military problems, but not ASW.

The oceans cover about 105 million square nautical miles. In war, perhaps only a few tens of millions of square miles would be militarily significant at any one time. But for most of the 74-year history of ASW, average effective operational search rates for an ASW ship, submarine, or aircraft have been well under 1,000 square miles per hour, making comprehensive searches impossible and giving submarines ample opportunities to hide. Success in ASW always has hinged on narrowing the areas to be searched with convoying, intelligence, and surveillance as major tools. But such means never have had enough certainty or precision to allow a missile to be dispatched to some indicated point with much assurance that it would find a hostile submarine there.

Thus, ASW forces have needed large numbers of "platforms" that seek to gain more precise information about the locations of submarines whose general presence is already known or suspected, and then to deliver weapons against them. Because detection ranges are so short, it is essential to have a great many platforms to achieve anything approaching adequate coverage. There are other factors as well—for example, ASW forces are required to cover widely separated areas—so it is misleading to suppose that increases in detection ranges can translate directly into reducing numbers of platforms needed. But it is clear that if the ranges of tactical ASW sensors are reduced significantly, then the current forces of ASW platforms will become seriously inadequate.

MAGNAVOX

Open-literature sources suggest that radiated noise levels of Soviet attack submarines have been cut by about 25 decibels (dB) since the late 1970s, which means that the actual sound pressures are about 0.3% of their original values. This can be expected to slash the range of any given passive acoustic sensor by roughly 95%. Because it takes years to replace an entire submarine fleet, we have not yet felt the real effects of Soviet quieting. But we will, soon enough.

Because passive acoustic sensors generally have been our most effective submarine detectors, a steep decline in passive acoustic ranges is a particular concern. Must we abandon passive acoustic sensors? What will take their place? Is there any way to achieve effective ASW capabilities against quiet threats?

The answer is that technology holds reasonable promise for bringing the antisubmarine side back to the point where it is neck and neck with the prosubmarine side in the race. But this is not technology in the guise of the cheap and easy maker of miracles. ASW technology will have to take major strides in scale and complexity.

It must be emphasized that the problem is that submarines are hiding too well, and we need the technology to find them better. We must not expend major resources in solving minor problems, simply because they are easier or because they lend themselves to solutions that are "fun," or pleasing to some interest. Some subsidiary problems also need significant attention, but anyone who suggests putting anything in ASW ahead of improving detection capabilities might as well be in the pay of the Soviets.

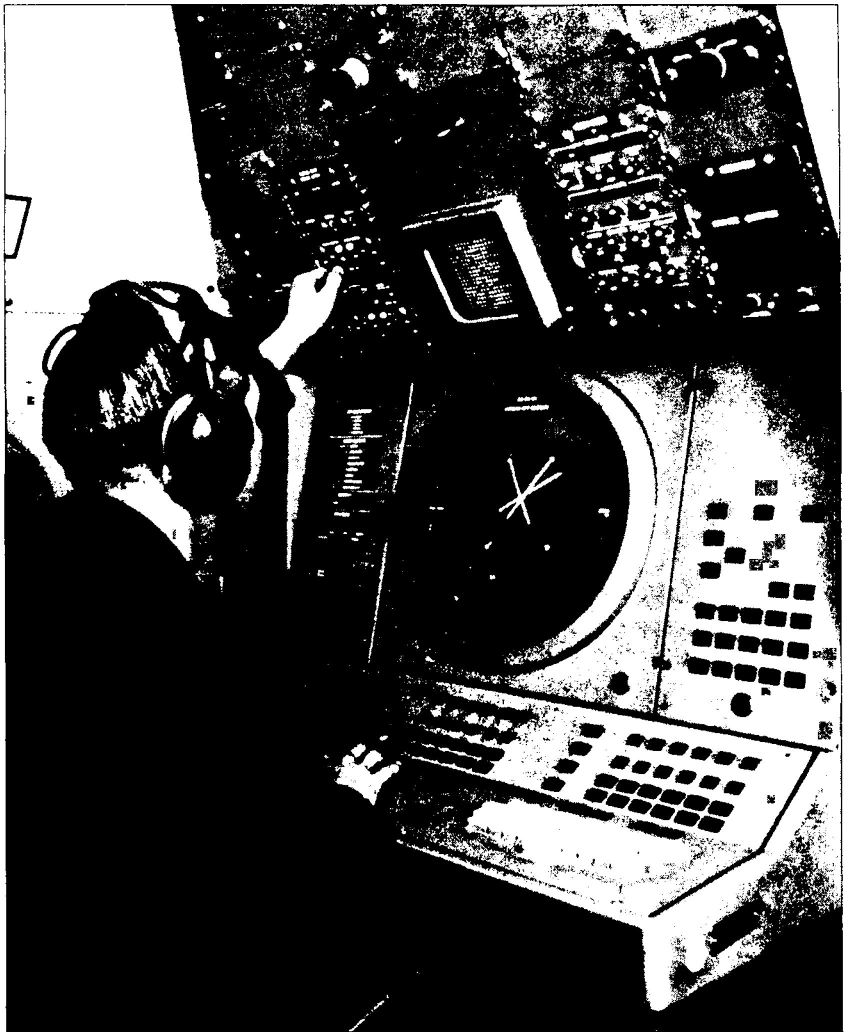
Since platforms are the most expensive factor in ASW and do figure prominently in finding submarines, it is necessary to think about platform improvements in terms of how they can improve detection. ASW platforms use many different methods to find submarines, but most fall into two classes: platform sensors or distributed sensors. A sonar mounted on or trailed by a ship or submarine is an example of a platform sensor, as is a magnetic anomaly detector (MAD) on an aircraft; there are many others. Today, the sonobuoy is virtually the only example of a distributed sensor.

The detection capacity of platform sensors usually can be represented in a simple way as the product of three factors: the platform's speed, the width of the search swath swept by the sensor, and the average probability of detecting a submarine that falls within this swath. This is the search rate, and it also can be calculated for distributed sensors and platform sensors that operate in a dipped or sprint-and-drift fashion, although in a somewhat more complicated way.

Currently, ships and submarines depend exclusively on platform sensors; aircraft nonacoustic sensors also belong to this class. Obviously, the search rate can be increased by increasing the platform's speed, but this tends to involve major costs for minor gains. Fixed-wing aircraft are the only class of ASW platform for which greatly increased speeds are possible, but even in the air, speed is costly beyond a certain point. Moreover, aircraft depend mostly on deployed sensors for ASW, and in such cases, increases in platform speed do not translate directly into increases in search rate.

The speeds of spacecraft are so great that if the spacecraft could search even a relatively small swath width with a low probability of detection, it could have a large search rate. For instance, a spacecraft in a 90-minute orbit that could detect submarines lying ten nautical miles to either side of its track with a probability of 35% would have a search rate of 100,000 square nautical miles per hour! Ideas for space-based ASW sensors deserve serious consideration, therefore, even if they will be difficult to implement.

Leaving aside the possibility of submarine-detecting spacecraft (pending development of suitable sensors), none of the foreseeable platform technologies can provide significant increases in search speed per dollar. But another way to increase search rate is to increase the sensor-carrying capacity of platforms that use distributed sensors. With little increase in the P-3C's size or cost, for instance, it would be possible to provide capacity for twice its 84 sonobuoys, plus enough endurance to permit dispensing and monitoring them all in a single mission. This would increase the search rate by a factor of two or so for a small increment in life-cycle cost. This appears to be one of the major goals of the Navy's long-range air ASW-capable aircraft (LRAACA) program. It is more difficult to make such gains with shipboard aircraft, whose weight and size are severely constrained.



U S NAVY

Technology has increased the effectiveness of this P-3C tactical coordinator a hundredfold. But in time, his successors will need near-human computerized assistants, to help handle the flood of data from advanced sensors.

Many proposals for platform technology center on improving survivability through more hardening, greater stealth, improved countermeasures, or other means. Recently, specific concern has been expressed over the vulnerability of ASW aircraft, even though sober reflection on the performance of Soviet air defenses in intercepting large airliners that have wandered over Soviet territory would not lead to excessive anxiety over the safety of ASW aircraft hundreds of miles out at sea. Another aspect of aircraft vulnerability is the danger of counterattack by submarines. It is widely supposed that submarines can hear and localize aircraft noises, but the submarine would have to carry a torpedo-tube-size missile to attack any aircraft more than a mile or so from the launch point, and without real-time guidance updates, kill probability is bound to be poor against an aircraft equipped with good warning and countermeasures systems. Also, launching missiles tends to attract the sort of attention submarines normally seek to avoid, so it is questionable whether the submarine would choose to sacrifice scarce weapon space and run an increased risk of being attacked by ASW forces for a relatively small chance at kilting an ASW aircraft that might otherwise never detect, localize, or classify the sub. Aircraft, after all, are the only ASW units that are a great deal less expensive and more numerous than the submarines they hunt, have far smaller crews, and can be more easily and rapidly replaced.

The value of reducing the vulnerability of ASW units depends in large part on how great their vulnerability is in the first place. It is obviously important that the attrition of ASW forces be at a slower rate than that which they inflict on the submarines, and ASW crews should never be exposed to needless risk. But it makes no sense to reduce the risks to one class of ASW platform at the cost of increasing the losses to others—or to deprive the troops ashore of reinforcement and resupply because fear of risks to ASW forces prevents them from meeting the threat.

If platform technology cannot improve ASW search rates significantly, we are forced to refocus on sensor and systems technologies. There are three broad categories: passive acoustic, active acoustic, and nonacoustic (known to acousticians as "un-sound" sensors). There has been speculation that passive acoustic sensors will pass from the scene altogether, and be supplanted by active sonars. Fortunately, the future of passive sonar does not appear quite so dark as that.

The details of the prospects for passive sonars (and other sensors) are too technical and too sensitive than is appropriate for this discussion. Very broadly, however, substantially better performance can be obtained at the price of vastly greater complexity in terms of numbers of hydrophones, amounts of electronics, and volume of computations, as well as better exploitation of the acoustic environment. To develop these vastly complex systems at all will take major efforts; to package them in a feasible size and at a practical cost for ASW use will take more. Altogether, the prospect is for scientific and engineering efforts on a scale hitherto associated with programs such as ballistic missiles, major space systems, or even the Strategic Defense Initiative.

At best, it may be impractical for passive sonars to regain all of the range lost to quieting. One partial solution may be the greater use of distributed sensors, widely scattered to ensure that the target comes within detection range.

Given the difficulty of increasing passive sonar performance, active sonars probably will have greater prominence. Certainly this would be desirable since it would limit U. S. vulnerability to sudden unanticipated gains in quieting by the Soviets. But we must remember also that active-sonar stealth may be possible as well.

Long-range active sonars must rival advanced passive sonars in size and complexity. Because sound travels better in the lower-frequency range, the active sources must be large and, of course, high power is also essential for long range. At the same time, these systems will need receiving arrays with many hydrophones and very powerful processing; indeed, it is possible that advanced passive sonars will also serve as the receiving half of long-range active sonars. Performance will depend on the environment, and particularly its reverberation and transmission loss, but long ranges probably can be achieved in many environments. Distributed systems may also show advantages in the case of active sonars.

As the name suggests, the category of nonacoustic sensors covers a multitude of possibilities, including detection of directly reflected energy from the submarine's hull, submarine intrinsic radiation, submarine discharges, hydrodynamic wake phenomena, magnetic anomalies, and submarine-stimulated bioluminescence. None of these possibilities yet offers a clear prospect for sensors with useful ranges, but several may ultimately become exploitable. Even after the necessary scientific foundations have been laid, however, it is clear that any of the nonacoustic detection schemes so far considered would involve extraordinarily complex sensor systems.

Sensor fusion, artificial intelligence, expert systems, neural nets, and like techniques have drawn keen interest of late. Engineers tend to group all under the heading of post-processing, and this rather colorless terminology has the value of emphasizing the basic physical fact that the input to the post-processor is the output from one or more signal processors: if there is no signal to start with then, there will be no signal-processing output (other than noise), so the post-processor will have no input and, hence, no output. But where sensors can be found to provide signals in the first place, advanced methods of post-processing show much promise for revealing the real target amidst a welter of noise and confusion.

More broadly, some of these techniques may hold the key to one of the real bottlenecks of future ASW: operator overload. At the dawn of ASW, one operator monitored the output of a single hydrophone. Today a single operator must handle the outputs of hundreds of phones or comparable sensor elements. Tomorrow it will be tens of thousands. Only with a great deal of help from semiintelligent "operator assistant" machines will such a task be possible. "Tactical assistants" will be necessary as well, to help decide how best to choose among the millions of possible ways of using advanced sensors, and to correlate and organize the flood of diverse data.

There are a number of subsidiary ASW issues also needing attention—including weapon effects, command and control, communications connectivity, and environmental support—but space does not permit them to be considered here. The crucial point is that we need sensors far more powerful than any we have developed so far to have an effective ASW posture against the submarines the Soviets are building today and will build tomorrow. To develop them and their essential supporting and coordinating systems will demand focused, well-managed scientific and engineering programs on a very large scale. We have no choice but to accept and surmount these challenges if we are to maintain a credible deterrent to general conventional war.

William D. O'Neil is the Director of Strategic Planning for Lockheed Corporation. From 1977 to 1984, he served as Assistant Deputy Under Secretary of Defense (Naval Warfare and Mobility), with responsibility for most Navy development and acquisition programs. He is a captain in the U. S. Naval Reserve.