Analysis 3 - The Market for Ship-Deployed Sonars - Archived 10/98

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The Market for Ship-Deployed Sonars

Executive Summary

The ship-deployed sonar systems market, comprising about 125 systems at an estimated value of US$450 million a year, is undergoing a number of internal changes. By and large, the sector is now in the hands of three industry powerhouses: Thomson-Marconi Sonar Systems, Lockheed Martin and Bremer Vulkan's STN-Atlas Elektronik – which has since become part of British Aerospace. Raytheon is also in the big league but its presence is skewed by dependence on a few high-valued systems and a relatively limited product range. This rapid paradigm shift is the direct result of the changes in the ASW environment, combined with the increasing necessity by companies to cut costs and economize their production.

Starting from late 1950s, the majority of the sonar market was taken by navies facing the need to counter Soviet nuclear-powered submarines. This emphasized the importance of long-range detection in blue-water conditions. The last years of this century are seeing the threat change to that of smaller non-nuclear submarines operating in a shallower, littoral or green and brown water environment. When running on batteries, these submarines are much quieter than nuclear-powered boats and they present smaller targets for active sonars. Such submarines operating in shallow water are very difficult to detect using present technology. A wholesale re-equipment of the world's major navies is economically impossible. This means that the major emphasis will be the adaptation of existing low-frequency sonars into systems capable of detecting this new threat.

The sonar market is dynamic but is facing a challenging and volatile future. The traditional hull-mounted active/passive sonar has been joined by the passive towed array (offering a longer range with fewer interference problems), which in turn is being developed into the active/passive towed array. New signals processing technology is allowing the use of lower frequencies in shallow or obstructed water, thus increasing the range of active sonars in these environments. Using these systems successfully is a major challenge.

While, for the near term, sonar will still remain the mainstay it has been for so long, sonar sensor technology is coming up against the basic limits of physics. Even with modern technology, there are limits as to how much further acoustics-based detection technology can be developed. The future lies with further research into signals processing techniques, where technology is needed to make some very significant breakthroughs.

The US Navy has been forced to re-evaluate its priorities and decide if Anti-Submarine Warfare (ASW) is still the primary concern. The service is focusing on improving air warfare and ship self-defense capabilities, regulating ASW farther down the funding list. This will have a significant impact on the potential for the ASW community to obtain funding. The Navy started to feel the impact earlier when Congress directed all branches of the government to reduce spending. In the aftermath of the canceled SQY-1 program, the Navy is going to upgrade the SQQ-89 with selected SQY-1 enhancements for backfit to its DDG-51 Flight I/II ships. These Flight IIA ships, now entering construction, will feature a partial ASW suite. They will have the SQS-53 hull sonar and helicopters but no towed array. In addition, the service is accelerating the retirement of older ships, so that by the end of the decade the US fleet will be reduced to less than 350 ships.

Because the number of companies that manufacture ASW systems is small, there will not be a major change in the market. There will be an increase in joint ventures during this decade. This has already been demonstrated by the teaming of Hughes and Thomson to win the AQS-22 Airborne Low Frequency Sonar (ALFS) contract. There have also been a limited number of acquisitions, but these have involved mostly small companies that have particular technological expertise to offer. Rather, there seems to be a developing trend of international cooperation. The joint production of Thomson and GEC is another testament to this trend.

During this decade, one area of the sonar market that will experience a sharp increase will be the Mine Countermeasure (MCM) market. The two Persian Gulf wars have highlighted the need for a good MCM systems base. While this is not strictly an ASW market, a large portion of the technology that is used to locate a submarine is also used to locate a mine, while brown water ASW techniques bear much resemblance to mine warfare. In addition, this technology can be used to develop new and improved mines.

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Introduction

The first documented use of sonar techniques was made by Leonardo da Vinci, who was able to hear the movement of a ship by listening to a tube held underwater. Since the ships in question were sailing vessels and, thus, had no machinery to generate narrow-band noise spectra, Leonardo must have been detecting the broad-band flow noise generated by the movement of the hull through the water. Almost 500 years later, this is still one of the most important noise sources for passive sonar detection. Older, undocumented accounts go back to Aristotle and Pliny the Younger, who record cases of fishermen signaling between boats by striking submerged earthenware jars, the signals being audible by listening through the bottom of the boat. If correct, these probably represent the first use by man of narrow-band underwater sound emissions.

Since the velocity of sound in a medium is directly proportional to the density of that medium, the velocity of sound in water is approximately four times that in air. From the 16th century to the end of the 19th century, a concerted effort was made to use this characteristic for a more standardized form of communication. These efforts were unsuccessful; the failure was originally attributed to the techniques being inadequate. However, as research continued, it became apparent that the behavior of sound waves underwater was far more complex than had been realized. Temperature, salinity, underwater currents and debris all affected how sound waves were propagated, making the exploitation of underwater sound transmission extremely difficult.

This logjam was broken early in the 20th century by the Submarine Signal Company (now the Submarine Signal Division of Raytheon Inc and probably still the world's leading authority in the physics of underwater sound transmission). At that time, coastal navigation hazards were marked by lighthouses. The warning signals from these were obscured by heavy fog or other conditions of bad visibility – precisely when their services were needed most. Attempts to augment the visible light warnings with signal guns, whistles, and steam sirens all proved unsatisfactory. The Submarine Signal Company evolved a system of underwater bells suspended near the hazards, coupled with a new and very sensitive "hydrophone," a metal case with a thick metal diaphragm to which was attached a carbon-button microphone. Variations in water pressure caused by underwater sound waves vibrated the diaphragm, varying the electrical resistance of the button. This generated an audible signal in a telephone receiver on the ship's bridge.

Originally, interference from the ship's powerplant required that the hydrophones be towed behind the ship in a wooden "fish." This can be seen as a very distant ancestor of the present-day towed array. Later, ship-borne noise was excluded by mounting the hydrophones in small water-filled tanks on the port and starboard sides of the ship – an arrangement reminiscent of the current flank arrays. The signals could be received at ranges of up to 15 km, with directional bearing achieved by turning the ship until the sound level from the two hydrophones was equalized. By 1912, this system was well established and most transatlantic ships were fitted with receiving apparatus. More significantly, many UK Royal Navy (UKRN) ships had been equipped with the system for navigational purposes.

The first use of this system to detect submarines was purely serendipitous. A British warship was using its equipment to navigate, when it picked up engine noises. There were no ships visible, so the crew concluded that their contact was a submarine and so reported it. From this early beginning, an entire range of passive submarine detection equipment was devised, culminating with steerable pairs of hydrophones on a Y-tube and with hydrophone arrays being used to detonate minefields. The requirement for surface ships to hunt for submarines while underway led to a revival of the towed hydrophone system and, by 1918, many British destroyers regularly towed streamlined arrays of hydrophones (called "rubber eels") on long cables. The designer of these arrays, a Mr. G.H. Nash, was awarded £3,000 by the Admiralty for his work in "turning an old and discarded idea into a successful instrument of war."

The German navy never considered the hydrophone to be much of a threat; nevertheless, the natural evolution of submarine design was reducing the noise levels of the boats. By 1918, the UKRN had realized that this trend meant that the only effective answer would be an active system based on echo-ranging. After intensive development work, a high-frequency active sonar system was devised and operators were trained to use it. This system was called "ASDIC," and for many years this was the generic name for similar systems. (One of the minor mysteries of history is just what ASDIC stood for. The usual explanation, an acronym for the designers, the Anti-Submarine Detection Investigating Committee, does not hold water, since the word was in use long before the committee was founded.)

ASDIC was not ready for use in the First World War, but was the subject of intense development and a major British military secret in the 1920s and 1930s. The major areas of endeavor were not so much the sets themselves but handling the signals once received and perfecting the mechanics of installation. The former area produced a chemical chart recorder that provided a trace of the ASDIC echoes for analysis – the first step toward the modern art of signals processing. The second field of research produced a new, streamlined sonar dome, determined the optimum practical location for the sonar, and the best materials for the construction of such domes. With the outbreak of the World War II, all the results of this work were handed over to the USN and were incorporated into the new generation of USN sonars.

From the early 1920s through the end of the World War II, active sonars had totally eclipsed the older passive systems. The development of very fast submarines, capable of 16-20 kts underwater, changed this. Passive sonar was required as an area search system, with active sets being restricted to depth, range and bearing determination just prior to an attack – essentially fire control functions. As the required ranges rose, operating frequencies had to be driven down, from the World War II high-frequency sets to medium, then to low frequency. This forced up the demands on the signals processing networks as the volume of data from the sensors rose with the area searched. The introduction of 30 kt nuclear-powered submarines accelerated this trend still further.

Effectively, the increasing underwater speed of submarines increased the volume of water that had to be searched and, thus, increased the range demands. This can be clearly seen in the generations of target/sensor/weapons that followed the World War II. The conventional but snorkel (snort)-fitted submarines were matched by the high-frequency SQS-4 generation sonars (range about 4,000 m on a good day) and ahead-throwing depth-bomb launchers such as Limbo or Weapon Alpha. The fast submarines of the Type XXI type and their successors were matched by the medium-frequency SQS-23 generation sonars (range about 10,000 m) and the ASROC and Ikara ship-launched stand-off weapons. The arrival of the nuclear-powered attack submarine pushed the range requirement out to coverage of at least the first convergence zone. This was matched by the low-frequency SQS-26 and SQS-53 generation sonars and ship-borne helicopters to deliver the ASW weapons to their targets.

This trend has now been reversed. The fall of the Soviet Union has eliminated the threat posed by its fleets of nuclear-powered submarines from the world scene. The new threat will be from smaller non-nuclear submarines that operate in the shallower, green and brown, water environment. Modern diesel-electric submarines have taken advantage of the noise-eliminating technology developed for noisy nuclear plants to produce submarines with noise signatures little or no different from ambient water conditions. A submarine of this type operating in shallow water is very difficult to detect using present technology; therefore, the major emphasis in this decade will be the development of sonar systems capable of countering this new threat.

The traditional hull-mounted active/passive sonar has been joined by the revived rubber eel, the passive towed array (offering a longer range with fewer interference problems), which in turn is being supplemented by an active towed array component that exploits new technology allowing the use of lower frequencies than the old variable-depth sonars. There are limits as to how much further acoustics-based detection technology can be developed. Acoustics technology needs to make some very significant breakthroughs in order to retain its dominance, yet there are technological limits that are as much a function of the performance of acoustics in water as of the sensors themselves. This suggests that the major advances will be made in signals processing technology rather than in the sensors themselves.

As signals processing capability has increased, sonars have been made available for other roles. Most mine warfare vessels are equipped with high-frequency imaging sonars that produce a television-like picture of a selected object on the seabed. The range of these systems is, by basic physical laws, short, and the minehunter has to approach dangerously close to the mine in order to verify its existence and dispose of it. This has resulted in much interest in various types of helicopter-towed and/or remote-controlled minehunting systems and in the design of new technologies, such as scanning blue-green lasers that can replace high-frequency sonars.

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Trends

Oceanology, Technology and Related Sciences. Sonar is the only ASW sensor effective beyond a few hundred yards. Numerous and expensive, but ultimately abortive, attempts to develop nonacoustic sensors have been made. These have not succeeded, except under very specialized conditions. As a result, the overwhelming probability is that the world's navies must continue to rely on sonar as a primary ASW detection tool.

Direct-Path Sonars. Except under very rare circumstances, there is a surface layer (or surface duct) in the sea, kept at constant temperature (hence constant sound velocity) by mixing due to weather; this surface layer acts as a waveguide. In the North Atlantic, this surface duct is about 300-600 feet deep depending on weather conditions. Within this duct, sonar acts much like radar, with signals propagating in nearly straight lines. The bottom edge of the surface duct is marked by a very rapid change in water temperature called the inversion layer.

Once below the inversion layer, the velocity of sound varies with depth, so that sound rays bend, refracted according to the same physical laws as light passing through a complex medium. One effect of this is to place severe limitations on the detection range of a surface ship against a submarine operating below the surface duct. For a hull-mounted sonar, the maximum (direct-path) range in the surface layer is about 10,000 m, and ranges are often considerably shorter. The ability of a given sonar to realize such ranges depends upon its power and frequency.

Convergence Zones. If the sonar's signals can propagate far enough and if the water is deep enough, they bend down to a region of minimum sound velocity and then refract back up. The signals focus in a convergence zone around the ship, at a range set by water conditions. This convergence zone forms an annular ring around the ship. Additional convergence zones form at multiples of this first range. The typical range to the first convergence zone in the North Atlantic, for example, is 35 nm, and additional zones are found at 70, 105, 140, etc., with each zone being about 5 nm wide. The problem is that a sonar detecting a submarine in a convergence zone cannot distinguish positions within that zone. This does not provide the basis for a firing solution, so a standoff platform must search the area within the zone thought to contain a submarine in order to re-acquire the target and refine the solution before attacking.

Bounce-path Sonars. Two other acoustic paths are tactically valuable. One is bottom (or surface) bounce. This exploits the fact that both the bottom and the surface can function as acoustic mirrors. In the late 1950s, it appeared that bottom-bounce propagation could help fill the gap between relatively short direct-path ranges and long convergence-zone ranges; maximum bottom-bounce range was about 40,000 m. Bottom bounce later lost much of its popularity because the sea bottom in much of the world turned out to be much more absorptive than had been expected.

A submerged submarine (or, in theory, a submerged variable depth sonar) can use surface-bounce propagation. US submarine sonars are spherical, enabling them to depress and elevate their beams. This design feature was included specifically to exploit surface – as well as bottom – bounce propagation. Early Russian submarines, such as the Project 671, have bow torpedo tubes and are limited to cylindrical chin sonars, unlikely to make much effective use of surface-bounce propagation. That limitation, in turn, may be related to the Russian submarine fleet's philosophy of operating at shallow depths. The later Project 671RTM submarines have bow tubes and small-diameter spherical sonars. Surface bounce propagation is somewhat limited by weather, since reflection will be much less efficient if the surface is rough in proportion to the scale of sonar wavelengths.

Size is an important factor here; the larger the sphere, the more precisely the beams can be formed and thus the more precise the contact. In addition, smaller, tighter beams can be made to exclude more background noise, easing signals processing. Very often the spherical array has a linear receiving array wrapped around it. In Seawolf and the latest Russian Project 885 class submarines, the sonar arrays actually form one-and-a-half spheres for optimum sonar operation. When the size demands of these sonars are coupled with correct hydrodynamic design, the inevitable result is going to be a large and expensive submarine.

Both bounce paths are inherently limited in range, because the sound rays must pass steeply enough through the various layers to avoid refraction and trapping, a phenomenon equivalent to that of the critical angle in optics. Actual range must depend on the bottom depth or, in the case of surface-bounce, on the depth of the source, but for surface ships under average conditions, the usual assumed maximum range is 40,000 m. That figure may be based in part on an estimate of the loss to be expected in reflection off the bottom.

The other alternate mode is the reliable acoustic path (RAP), essentially the vertical path from bottom to surface or vice versa. No matter what the acoustic layering of the sea, a signal propagated perpendicular to the layers should pass through without distortion. There should also be a small angle around the vertical in which signals can pass with little loss or distortion. If the sound source or detector is deep enough, even that small angle can subtend a very considerable distance at the surface. RAP is hardly new, as it explains the successful operation of echo sounders. However, the widespread application of RAP to sonar operation is relatively recent, because a submarine-mounted RAP sonar generally has to be quite deep in order to provide adequate coverage.

In relatively shallow water, inside the 100-fathom (600 ft) curve, convergence-zone propagation is impossible. Hull sonars suffer from multiple bottom bounces, so detecting real targets is very difficult. However, very high-frequency upward-looking RAP sonar can function effectively. A sonar source well below the surface, moreover, can send out a horizontal beam that can avoid bouncing off either bottom or surface. Horizontal transmission is probably one mode of operation of the new low-frequency helicopter dipping sonars.

Sensor/Environment Interaction. The ASW environment and the forces that operate within it can be divided into three separate, distinct and quite different sectors. For the purposes of this market overview, these sectors will be referred to as "blue water," "green water" and "brown water." While the degree of technical sophistication and apparent threat degree decrease in the order blue-green-brown, it should not be assumed that forces optimized for operations in the blue water environment will be able to cope with the apparently lesser threats presented by green and brown water. Any ASW force optimized for operations in one of these environments will have difficulty adapting to operations in the others.

The Blue Water Environment. Blue water is the traditional adjective applied to the oceanic areas of the world and to the navies that are able to maintain a significant presence on those areas. Blue water is, by definition, far from land; operations upon it require a high degree of organizational skill, fleets capable of prolonged self-sustaining deployments, and sufficient firepower to cope with any conceivable threats. The oceans are a hostile environment capable of great violence even without manmade assistance. Ships operating in the blue water environment must have great endurance and sea-keeping ability in addition to their more obvious military qualities. Such ships tend to be larger than the average due to their need for fuel tank capacity and the sea-kindly value of a large hull in foul weather.

There are few navies with a true blue water capability. Indeed, only the navies of the USA, UK, Russia, France, Japan and India fall into this category. Russian capability for sustained operations in this environment has declined sharply but could be revived. The last three countries are marginal cases. Many nations have ventured out onto blue water and claimed that status as a result, but the abiding criteria is the ability to sustain operations in that environment. Only the six countries listed can achieve that end.

It is in the blue water environment that the opposing submarine and anti-submarine forces reach the highest level of technical sophistication. During World War II, land-based and sea-based anti-submarine air power reached a degree of efficiency that effectively drove the conventional diesel-electric submarine off the high seas. When hostilities are underway, it is now reasonable to assume that any submarine that has to surface at regular intervals will be quickly detected and killed. The blue water submarine today is nuclear-powered and armed with long-range, high-speed homing torpedoes and subsurface-launched anti-ship missiles. These submarines are fast, in some cases reaching speeds up to 40 knots, and capable of diving to depths below 1,000 meters. They pay for their speed and comprehensive weaponry with size and noise.

Even the quietest nuclear-powered submarine is noisy compared to a modern diesel-electric boat. Although some diesel-electrics do operate in blue water, they are limited by their low speed and need to recharge batteries at regular intervals. The universal installation of snorts on these boats, enabling them to charge their batteries underwater, has reduced their vulnerability but not eliminated it. A point often overlooked is that a nuclear reactor can generate as much electrical power for sensors as is needed – on a diesel-electric boat, electricity used to operate the sensor system comes directly off the underwater endurance of the boat. A major factor behind the US move to discard diesel-electric power for submarines was the inability of non-nuclear power trains to generate the electrical power required for the latest sonar systems.

The nature of the threat presented by the nuclear submarine puts urgent emphasis on the need to detect, localize and engage the boat as quickly as possible and at as long a range as possible. In sonar terms, long range means low frequency. The acoustic conditions of blue water tend to favor the long-range propagation of low-frequency sound (although no one actually understands how low-frequency sound is propagated in deep water), making the blue water environment uniquely conducive to low-frequency operations. Furthermore, the self-generated noise of the nuclear-powered boats makes possible the extensive use of passive detection techniques.

The standard sensor fit, therefore, of a blue-water ASW platform is a low-frequency active/passive sonar, usually bow-mounted and operating in conjunction with a towed passive array operating at very low frequencies indeed. This combination, it is hoped, provides the platform with the ability to detect and track a target by means of its passive equipment without giving away its own position. Examples of ships mounting this fit include the US Spruance class and the British Type 23 frigates. As explained in the introduction, these are coupled with long-range standoff weapons capable of reaching out to the first, and even second, convergence zones.

The Green Water Environment. Green water is a relatively new term, an intermediate stage between the traditional blue and brown water environments. Green water, as a distinct operational environment, was born in the late 1950s and early 1960s. At that time off-shore drilling was becoming a major factor in the oil industry and the possibility of exploiting other marine resources – food, energy and raw materials – appeared to be a significant factor in future economics. Green water is defined as offshore operations in continental shelf and economic zones of influence.

Green water is, therefore, relatively close to land. Ships intended to operate in this environment do not require the long endurance of their blue water equivalents. Since the waters tend to be more sheltered, they also do not require the extreme sea-kindliness of the blue water ships. However, they are operating in a much more complex threat environment, with the possibility of facing heavy and persistent land-based air attack, submarine threats and the chance of engagement by enemy surface units. The result of the green water environment, therefore, is a smaller ship carrying a greater variety of ready-use weapons. Since actions in this environment will be short and savage, the emphasis is placed on weapons available for immediate launch rather than the number of reloads carried. Due to their smaller size and tight design, these ships have a shorter effective life than their blue water equivalents – a point often hidden by any navies retaining such ships in service for prestige reasons long after they have ceased to have real military effectiveness.

From the point of view of a sonar operator, the most significant factor about the green water environment is not the sea itself, but the seabed. Green water is relatively shallow, with the bottom being within easy reach of most submarines. The continental shelf itself is heavily contoured with many rocky outcrops and littered with wrecked ships – many the tragic relics of the two previous great anti-submarine battles. This has major implications for submarine detection capability.

In green water, the modern diesel-electric submarine apparently reigns supreme. The big nuclear-powered boats are accused of being too large and too clumsy to be brought into these shallow, restricted waters. The small, highly maneuverable and very quiet diesel-electric boat is indeed well-suited to exploiting the conditions prevailing in green water. The disadvantages of this type of boat – its limited speed, restricted underwater endurance and shorter-ranged sensors – are offset by its proximity to base and the physical limitations of the environment restricting maximum possible ranges to those comparable with the maximum real ranges of its sensors. In reality the situation is not so clear-cut and the nuclear submarine remains a weapon to be feared.

Sonar ranges in the green water environment are limited by the poor acoustic conditions of the shallow and turbulent water. While blue water is relatively isothermal, with the exception of a marked thermal layer, green water is a mixture of drifting water bodies of different temperatures, salinities and speeds. In addition, shoals of fish are more in evidence. Under these conditions, low-frequency sonars lack the precision and definition required for adequate ASW operations. Active sonars in the medium- or high-frequency bands are required to make some sort of sense out of the chaotic conditions. Passive sonars of whatever frequency are only of limited use, while towed arrays are at best of marginal value and may be a liability due to the restrictions they impose on maneuverability.

A curious problem in green water has only recently emerged. A number of exercises have been conducted between the British Type 23 frigates and the Upholder class submarines (both being the quietest in the world in their categories). As the trials proceeded, it became apparent that when both ships were running silent, their detection abilities were only capable of obtaining a firing solution at distances inside the minimum ranges of their weapons. However, when the ship and submarine were moving at higher (above silent) speeds, they could be detected outside the maximum ranges of their weapons and their opponent could use the data to evade contact (either by turning and running or by exploiting sonar shadows). This discontinuity between sensor envelopes and weapons envelopes presents interesting opportunities. One is the possibility of separating the “hunter” and the “killer” portions of the ASW role. This has the advantage that a single “hunter” (with very expensive sonars) could target spot for a larger number of ships armed with relatively inexpensive weapons.

Most of the world's larger navies fall into the green water category. This includes nearly all the NATO forces not blue water capable and a large number of South American, Asian and Middle Eastern forces. This suggests that this environment offers the major likely market for ship-mounted sonars. From this, it follows that medium-frequency sonars are likely to remain the largest overall market sector in terms of numbers of systems sold. However, these sonars tend to be much lower in cost than low-frequency systems, basically a result of the much greater level of signals processing required for low-frequency convergence zone operations. Thus, in value terms, the low-frequency sector leads.

The Brown Water Environment. Brown water is traditionally defined as the areas of sea directly off a country's coast, including its harbors, estuaries, bights, bays and other inshore features. The water here is very shallow and usually virtually opaque with mud (hence the term brown water). The term "brown water navy" is often used as a term of contempt, indicative of a force that spends most of its time in port and never sets sail out of sight of land. Although in many cases this is an accurate usage, there are a number of highly competent navies that operate in the brown water environment, for example the Swedish navy.

In purely technical terms, ASW operations in brown water are incredibly difficult. Indeed, the Swedish navy found during the 1960s that ASW operations in the brown water environment were so difficult that the problems effectively could not be resolved, and the Swedish navy abandoned any pretense of ASW capability. The combination of highly variable sonar conditions, treacherous sea bottoms and filthy water make detection of submarines exceptionally difficult. Any detection which does occur will be at exceptionally short range. On the other hand, the inshore waters are usually sheltered and relatively calm. Furthermore, ships will be operating under screens provided by land-based defenses and can, in theory, rely on them to absorb any major threats.

One redeeming merit of brown water is that it is so shallow that only the smallest submarines can operate with any degree of stealth. The big nuclear boats in these conditions would almost certainly have insufficient water to submerge. Even the diesel electrics would have their room to maneuver severely restricted. Brown water is the arena of the midget submarine, tasked with delivering swimmers for various purposes – laying mines, smuggling goods or performing a variety of nefarious activities. It should give pause for thought that nearly all the "serious" submarine hunts in the last decade have taken place in brown water against such midgets.

The extremely poor acoustic conditions of brown water and the highly confused environment severely limit the value of all sonar systems. Only high-frequency, high-definition sonars, preferably side-scanners, have any real use and these are, by definition, very short-ranged. Underwater TV cameras are of some assistance, as are such ancient techniques as drawing sweep wires. In contrast, a new technique is the use of a blue-green laser to create a holographic image of the sea and the seabed beneath it. This was used by the USN as a mine detection system during the Persian Gulf War of 1990-1991 and has potential for brown water ASW use. Intriguingly, the Russian Tupolev Tu-142 Bear-Foxtrot Mod.4 has a blue-green laser as part of the electro-optical package mounted under its nose. A number of area defense sonars have been proposed for use in brown water but have all fallen foul of the very poor acoustics. It is noticeable that the ASW techniques for brown water (such as they are) bear more resemblance to mine warfare than to normal ASW.

Towed Array Technology. During the 1980s, the extreme low-frequency towed array sonars became the dominant sensors for blue water ASW. First deployed on submarines, they quickly became a standard item of equipment on dedicated ASW frigates. However, the basic design of the systems limits their applicability to the environment developing in the 1990s. From a material point of view, a significant part of the problem lies in the weight and bulk of the sonar wet end. This places a considerable strain on the lightly built hulls of the smaller ships used for ASW operations in coastal and continental shelf waters. The large winch used for the array represents a severe structural load at the extreme end of the hull girder, one which smaller ships cannot accommodate without pushing hull stress values beyond acceptable limits.

Caution must, however, be exercised when relying on open source information concerning the problems caused by these arrays. For example, during the late 1970s, the UKRN stated that the Type 22 Batch 1 frigates were unable to be equipped with a towed array because the hull had insufficient longitudinal strength to cope with the tow loadings. In fact this was disinformation; the apparent weight problem resulted from the use on Leander class frigates of a VDS winch weighing 26 tons for the towed array. A dedicated towed array winch weighing less than six tons was available and would have solved any hull stress problem. The real reason was that the CAAIS command system installed on the Type 22 Batch 1 had insufficient computing power to process the information generated by the towed array and a separate sonar processing unit would be required. The ships simply had insufficient space in their Operations Room (the British equivalent of the CIC) to accommodate this additional processor.

This cautionary tale points out a potential problem in reorienting many navies from general purpose to ASW duties. CAAIS is a typical export integrated command system of the early 1980s and is highly centralized and inflexible. It has strictly limited processing power, while the system architecture makes changes to the platform's weapons/sensor suite difficult. Thus, modernization of ships carrying this type of system is likely to be significantly more expensive than immediately apparent. More recent command systems are modular and fully distributed, using databus technology for data transfer. These systems are far easier and cheaper to upgrade – this is, after all, why they were designed that way.

The problems with towed arrays are being overcome by the introduction of massively parallel computing in the dry end processing facilities and by the use of fiber optics to reduce the weight and bulk of the wet end. The introduction of fiber optics permits the towed arrays to handle large bandwidths and therefore to generate greatly increased amounts of data. They can provide improved coverage of flow noises, blade beat, cavitation and radiated machinery noise. The enhanced processing capability provided by massively parallel computing means that this data can be properly analyzed while carrying out beam-forming, analysis of target movement and narrow-band processing to analyze signals. The use of Fast Fourier Transform technology enables this data to be processed in real time, while these capabilities will be further enhanced by the introduction of optical data processing.

The introduction of fiber-optic-based thin-line technology led to the discovery of a new series of problems. Since flow noise is directly related to the surface area/bulk ratio, thin-line arrays generate greater levels of self noise. This can be countered by the use of new materials, such as polyvinylidene fluoride (PVDF), as line coatings to smooth out water flow and reduce self-noise. The availability of substantially greater computing power has made possible the development of active noise measurement and sound cancellation techniques. These developments made the widespread introduction of thin-line towed arrays possible.

Experience has shown that long, thin-line arrays provide the best long-range, broad-band, low-speed coverage. In contrast shorter, thick-line arrays have better performance when towed at higher speed and have significantly better narrow-band discrimination. Earlier submarine platforms had to choose between the two technologies; the latest designs carry (and can stream) both. Surface ships are likely to follow this lead.

Exploiting these advances in towed array technology led to the development of thin-line arrays aimed at deployment from fast attack craft and small corvettes for use in coastal waters. Arrays of this type have now been available for a number of years and have met with an overwhelming lack of success. Although superficially attractive, experience with these systems revealed a whole clutch of new problems. The arrays use bearing displacement or bearing shift to determine movement, while range can only be assessed by using triangulation. However, when streamed behind a platform in coastal waters, the array is subject to directional uncertainty as a result of veering between port and starboard, flexing caused by the lack of rigidity, droop caused by the array not remaining in a fixed horizontal plane, and torsion caused by the array's motion through the water resulting in twisting.

These effects can only be minimized by the platform holding a straight course at steady speed while the array is streamed. In blue water this presents few problems, but once operations move inshore the situation changes. Restricted waters compel the platform to change course at regular intervals, while the proximity of the bottom results in a continuous risk of fouling obstructions. Inshore waters are heavily traveled and streaming an array several hundred meters long under such conditions is a significant hazard to shipping. Also, under green water conditions the submarine is quite likely to have detected the surface ship and already be calculating its fire control solution. Maintaining a steady speed and course under those conditions is quite inadvisable!

Thus, the small, lightweight arrays have proved unacceptable for use in green and brown water. Solving the problems of acquiring and exploiting submarine contacts in the conditions presented by green and brown water requires different technologies. Since the large, bow-mounted low-frequency sonars commonly used in blue water ASW frigates are unsuited to the developing environments of the 1990s, the problem will be to maintain the efficiency of these ships in green water without prejudicing their ability to resume blue water operations should the need arise. This can be met by developments in the art of signals processing.

Signals Processing. Signals processing is based on the principal that the submarine's signals are regular, whereas the background noise is random. There are two fundamental approaches: the signal may be analyzed in spectral (frequency) terms, on the theory that, over time, the constant signature of the submarine will emerge, or the sonar can look instead at small volumes (cells) of ocean, choosing a particular cell that is consistently louder than its neighbors on the assumption that it contains a noise source.

Mathematically, the two approaches are Fourier Transform alternatives. Spatial processing, concentrating on a cell or on a volume defined in terms of bearing angle, is equivalent to integrating signals over a broad band of frequencies from sources within that cell or angular range. Spatial processing is, therefore, often described as broad-band. The alternative, spectral processing, is, naturally, described as narrow-band.

Narrow-band noise is produced by rotating devices such as machinery and propellers or, for a diesel, the regular firing of the engine. In practice, each line of noise is accompanied by harmonics, weaker repetitions of the sound at progressively higher frequencies. A signals processor may concentrate on a harmonic, even though it is weaker, because it occurs in a quieter part of the background noise spectrum. Moreover, because listening arrays are limited in size, they will have better gain, that is better directional discrimination, at higher frequencies. With improved discrimination, less background noise is mixed with the signal of interest. Broad-band noise is much less well defined. Examples include the flow noise over the submarine's hull and the gurgling of piping inside the submarine. Broad-band noise is also known by the technical term “pompholugopaphlasmasin” representing the symphony of individual noises that make up the overall signature.

The appropriate choice for analysis depends on several factors. The fainter the submarine's sounds (that is, the better it is silenced), the longer the period of integration required to separate a regular acoustic signature from the surrounding noise. If the signature is not really constant, integration time is limited, eventually to the point below that required to overcome noise. In that case, broad-band (spatial) processing may be a much better choice.

Many systems combine the two types of analysis, by forming beams using spatial processing and then breaking down the signal in each beam by narrow-band processing. The greater the computing power of the system as a whole, the more easily it can conduct this two-step analysis. Provided sufficient processing power is available, the user must cope with an enormous amount of data; this demands some semi-automated means to indicate the presence of a real signal in a narrow frequency band of one of many beams.

Conversely, a computer-based combat system can trace an enormous number of targets simultaneously. In most cases there will be relatively few real targets, but analysis of the motion of the others will often allow them to be disregarded. This is also true of decoys, and it explains the need for a modern torpedo, such as Spearfish, to track numerous targets simultaneously.

To deal with quieter and more distant targets, arrays have grown in complexity and area. When the Los Angeles class submarines were designed, the number of separate hydrophones (in several arrays) quadrupled in comparison with earlier classes. Since all the array data is digital, it can all be processed together, a single system forming beams out of all the array data. This type of processing can be very powerful. It can form nulls to cancel out self-noise and jamming, and can also produce a very high data rate, as much as an order of magnitude greater than in previous systems. This output is essential in order to cope with quieter targets in a more complex and varied oceanographic environment.

Both types of processing can be quite sophisticated, and both represent alternatives to active operation. After World War II, when submarines (particularly those snorting) were relatively noisy, passive operation entailed essentially no integration and a sonobuoy (or, for that matter, a homing torpedo) had only to seek a noise noticeably louder than its surroundings.

That operation was very simple broad-band processing, but its utility ended in the early 1950s, as submariners learned not to snort for protracted periods. The question then was whether passive ASW was still practical. The solution turned out to be low-frequency narrow-band processing and integration, which the USN codenamed LOFAR (LOw-Frequency Analysis and Recording).

LOFAR was the basis for Western passive acoustics from the mid-1950s on, and for many years it was a closely guarded secret (or so Western intelligence sources believed). The success of LOFAR depended, in part, upon knowledge of the detailed acoustic signatures of potential enemy submarines because signal processing could be much more effective if specific features of a target submarine's acoustics were known. During the 1970s Soviet recording devices began to turn up in areas where NATO submarines operated, such as Norway and Puget Sound. Such devices are useful only in a LOFAR-acoustics context. In 1988 the US DoD provided confirmation by publishing a photograph of a Soviet equivalent of a US LOFAR sonobuoy. Subsequently (at the UDT exhibition in 1994) the Russian Gidropribor Design Bureau displayed LOFARgrams obtained by the sonar suite on a Project 627A (November) class submarine. This suggests that LOFAR technology became known to the Russians roughly in parallel with its Western development. It would be intriguing to find out whether the two developments were connected or independent.

Many modern passive sonars use Waterfall displays, in which the vertical ordinate is time. The horizontal scale is either frequency or bearing. In either case, the data flows down from the top of the display, which shows the short-term history of what the sensor receives. The beaming version, therefore, shows relative target motion. Signals that are constant in frequency stand out in a frequency waterfall, usually called a LOFARgram, or just "gram." The observer integrates the data visually to separate the stable signals (which appear as more or less continuous vertical lines) from the surrounding noise. The LOFARgram is, in effect, a spectrogram. Some systems record relative intensities at different frequencies at time intervals and then integrate over time to form a true spectrogram that is usable, for example, for automatic or semiautomatic target recognition.

The question is whether these techniques of passive signal processing have much of a future. There are three possibilities for modifying them to suit the changing environments now being experienced. One is that improvements in LOFAR technology – for example, adding more spatial discrimination, tightening discrimination between nearby frequencies, or increasing integration time – can solve the problem. The United States' new LOFAR array sonobuoys and continued investment in towed passive arrays typify this approach. If this approach succeeds, much of the current generation of sensors and signals processing technology will remain viable.

Another possibility is that low-frequency narrow-band passive sonar will lose its capability, so that passive operation will be reduced to medium-frequency flow noises. In that case, it will pay to abandon expensive signal processing in favor of mass producing relatively simple (broad-band) sensors of flow noise and strewing them about the estimated position of a submarine. This approach is the basis of the new low-cost sonobuoy. An intermediate possibility would be to distinguish regular features of broad-band noise and, thus, to retain longer-range operation at a cost in processing complexity.

The third alternative is to abandon passive operation in favor of very low-frequency, very long-range, active operation. In that case the existing low-frequency systems would be retained, but they would function as the receivers in bistatic sonars, receiving echoes from the pings of relatively simple noise sources.

New Technologies. The pressures of adapting existing ASW technology to counter the changing environment while remaining within ever-tightening fiscal constraints have forced the development of new processing techniques. One of these is adaptive sensing in which the equipment estimates the relative intensities and frequency spectra of the signal and noise. The signals processing equipment then automatically harmonizes the sonar array's listening beam with the frequencies to which it is tuned in order to get the best signal-to-noise ratio possible. Further work is ongoing to integrate information from a variety of sources, including passive and active sonars, nonacoustic sensors, and satellite images of the ocean surface, into a central processing station to be distributed to tactical forces.

There is an increasing emphasis on the development of automatic systems for classifying submarine noises, freeing the sonar operator to analyze the relative positions and maneuvers of the detected submarines. The US Navy is sponsoring innovative concepts for processing acoustic data to achieve a technological quantum leap in the detection, classification, and localization of hostile submarines. This effort also covers correlating and/or fusing acoustic data and that from other sources to achieve a more efficient detection and classification process.

These investigations form part of a wide range of ongoing programs aimed at improving processing capabilities. ARPA is funding a program called AADS (Automated Acoustic Decision System) that is aimed at helping sonar operators cope with the large amounts of data generated by acoustic sensors by telling them the significance of the data, as well as suggesting possible courses of action. Expert system technology as well as parallel processing are expected to figure prominently in the developed product. Other ARPA work includes the incorporation of a supercomputer capability as a way of compensating for lagging hydrophone technology. The result will be that operators of next-generation passive towed arrays will be able to cope with at least an order of magnitude increase in data, as well as to provide a more accurate identification of the objects being tracked.

Mine Countermeasures Sonars. Typical Procedures. The typical sequential operational procedure for mine countermeasures consists of the following elements: search, detection, classification, identification, and neutralization. Sonars come into play for the search, detection, classification and identification portions of the operation. In many operations, separate detection and classification sonars are used.

While transiting the survey route, the MCM vessel begins a search with sonar, using the detection capability to spot any mine-like objects, then classifying these objects as to their true nature with the classification capability of the sonar system. If the object is still suspicious, the MCM vessel will then deploy either divers or a remotely operated vehicle with the capability of making a final identification using acoustic, magnetic, or optical sensors. The mine can then be neutralized by dropping demolition charges to blow it up or by cutting its cable to enable the MCM vessel to detonate it, usually with rifle or machine gun fire. Sweeps that cut the cable can also be used by the MCM vessel itself.

Detection consists of the ability to detect all mine-sized or mine-like objects in a given area whether on the bottom or floating below the surface. The detection sonar's capabilities must include the ability to detect the mine even against background clutter in the form of noise and surface and/or bottom reverberation. The detection sonar's capability parameters are defined by its acoustic discrimination capability, as well as the ability to reduce the surface area of the resolution cell (beamwidth and pulse length of the signal are reduced to overcome a background reverberation). This is especially a problem in shallow water.

Mines are now often covered with anechoic materials that deaden their acoustic response, the detection sonar must be able to reduce its frequency as a countermeasure. Other counter-detection techniques include shaping the mine casing do that it does not look mine-like or can easily meld into the sea bed. The Swedish Bofors mines use this approach. An extreme example is the construction of fiberglass or other types of case for a mine that resembles an innocuous item of garbage (for example a dumped refrigerator or television set. All these developments require ever-finer imaging capabilities at the detection stage.

The classification process involves taking the object parameters and comparing them against known mine parameters. Mines can be classified at both long and medium ranges. Long range classification is particularly valuable in cases of objects floating beneath the surface, because of the greater area of destruction that can result as opposed to bottom-lying mines. This type of classification relies on phase and amplitude monopulse analysis or very narrow horizontal preformed beams, with the latter being most efficient.

Medium-range classification deals with seabed-moored mines, which, with a destructive force that seldom reaches in excess of 100 meters (328 feet), allow for closer approaches. The best method in this type of classification is the examination of the size and shape of the mine's shadow as it is projected on the seabed when the mine is illuminated by the sonar. This method calls for excellent capabilities in the areas of spatial resolution and range resolution (which determine the quality of the image and thus the ability to analyze it) and the ability to filter out the mean contrast of the shadow from background clutter such as that given off by the seabed.

Two principal types of minehunting sonars used are the hull-mounted and the variable depth. The hull-mounted type is designed to operate in waters less than 100 meters deep and the variable depth system to operate in waters more than 100 meters deep. Powerful processors are an integral part of any minehunting system, as are very accurate navigation gear and a data library that includes the parameters of all known mines, their particular characteristics, and extensive oceanographic data.

Mine Developments. MCM sonar development is constantly having to deal with an evolving threat as mine technology assumes new or more effective guises.

The mines are also becoming more dangerous to the MCM vessels. The hulls traditionally are made of nonmagnetic materials such as glass-fiber reinforced plastic (GRP). The systems installed also have suppressed signatures, for example, antimagnetic engines. Finally, the ships are equipped with a degaussing system to compensate for the residual magnetic signature. Yet, the mines themselves are becoming more sophisticated. Intelligent mines are already available, and "brilliant" mines capable of completely autonomous mobile action are on the verge of operational service. The MCM craft itself is in as much danger now as unsuspecting targets. The advent of mines that bury themselves presents further dangers, since they cannot be detected reliably by present MCM technology. Parametric sonar techniques (using side scan sonars and other types of sonars to examine an object from various angles and for various characteristics) may be the solution, and work is now proceeding in this area.

Mines are also being developed with the specific intention of killing mine countermeasures vessels. Once narrow-band processing was a viable part of mine warfare technology, it became possible to design a mine fuze that would be activated by the emissions of a mine location or mine classification sonar. The first generation of these weapons worked using the mine classification sonar and simply exploded when the sonar emissions released a given level. This could be countered by artificially increasing the level of sonar emissions to give the appearance that the MCMV was approaching when, in fact, it was standing off at a safe distance. Later versions are designed to sense a Doppler component in the sonar emissions and use this to determine whether the apparent approach was genuine.

A further development of this technique is the Russian PMK-1 (NATO codename Cluster Gulf). This is a 533 mm 1,850 kg weapon which can be laid to depths of 200-400 m. The PMK-1 fires a high-speed (150 kt) unguided underwater "rocket" at the target. The exact nature of the projectile is unknown since the Russian word "Raketny" is applied to a number of reaction engines and has also been used to describe torpedoes powered by SCEPS propulsion systems. A version of the PMK-1 is the 820 kg MSHM (NATO codename Cluster Guard). Although originally thought to be a shallow water anti-submarine mine, this is now known to have a very different function.

The key sensor of the MSHM is a directional passive sonar array, wrapped around the outside of the mine casing. This is optimized to pick up and localize the high-frequency emissions from a mine detection sonar. It uses these to provide a firing solution for the same 150 knot underwater projectile used in the PMK-1. Such a projectile would require only 20-30 seconds to reach a minehunter at normal standoff ranges. This is insufficient for any meaningful evasive action by the target, while the striking velocity of the projectile should mean that it would penetrate deeply into the relatively flimsy hull of a minehunter before the warhead detonated. It is improbable that such a strike would be survivable. Both the PMK-1 and the MSHM (the designation MSHM actually stands for MSH-Killer referring to an ultimately canceled US MCMV program) were advertised at the 1993 Abu Dhabi armaments fair and are available to anybody who can pay for them.

These developments suggest that conventional mine warfare techniques, which depend on the MCMV actually entering the mined area and checking out each contact individually, are fundamentally flawed. It is likely to be supplanted by methodologies based on remote-controlled and expendable platforms.

MCM Sonar Future Requirements. In order for MCM sonars to cope with the constantly evolving mine threat and its advancing technology, a sonar must evolve that can reduce the time a ship spends in a minefield. For example, the ability to execute detection and classification in a single pass is crucial. The less time spent over the suspect object the better. Actually, spending any time over the object's area is inadvisable. Thus, ways of scanning the area without the need to come overhead are going to be emphasized. This is already seen in the use of side-scanning sonars, but these types of sonars are limited by their resolution/coverage rate characteristics.

A better avenue of approach would emphasize the advances being made in unmanned underwater vehicle (UUV) development. It may be possible to have a sonar-equipped, remotely controlled UUV moving in front of the MCM vessel itself, using a real-time data link to connect the sonar to processing onboard the MCM vessel. However, the present state of sonar technology (and more importantly datalink technology) does not present the capabilities that would put a sonar analogous to that fielded by the MCM vessel itself onboard the UUV. For example, several UUVs may be needed. Also, a tethered UUV would be required because of the real-time imperative, but this would result in constraints on the UUV's operational speeds, because it is tied to the mother ship.

Thus, in the shorter term, the refinement of existing techniques will be a more viable alternative. This includes developing multifrequency sonars that are capable of adapting to changing requirements. The ability to penetrate into the seabed via parametric sonar techniques must be developed, since mines that bury themselves are among the hardest to detect at present. The French are presently working on a parametric buried-mine towed array sonar that also involves the British and Dutch. Processing capabilities must be significantly enhanced, especially in enhancing computer-aided detection and classification. Integration of all systems concerned with MCM is proceeding apace, yet there is still a great amount of room for improvement.

Military/Political and Economic Factors. Outside the US, the military/political environment is changing very rapidly. ASW budgets are being pressured on one side by overall constraints on defense expenditure, and on the other side submarine operation is proliferating and representing a more discernible threat in regional conflicts. As a result, the current situation is highly variable and shows very marked regional differences. It is, however, possible to pick out these regional trends and likely factors that will influence the overall level of expenditures on ASW.

United States. The US Navy strategy announced in September 1992, titled "...From the Sea," shifted focus from blue water, oceanic operations on the sea to joint operations from the sea. This resulted in a switch of concentration to littoral (green water) warfare and maneuvering from the sea (power projection). In effect, the reformation of policy does not change the major USN concentration on its traditional roles of sea control and power projection. Deterrence, previously a strategic term, now also applies to conventional war, and the USN regards forward deployment as key to deterrence. ASW strategists put the issue this way: "Credible regional deterrence depends on assured sea control, which in turn is dependent on ASW clearing the area."

In the current restricted financial environment, highest priority is being placed on readiness and force structure, thus taking funds away from modernization. The acquisition of next-generation programs – buoys, weapons, processors – will be at reduced quantities and at a jump in cost. Because ASW is a support role and not "primary warfare," the budget trends are ominous. These reductions will not be accommodated by making vertical cuts to take platforms out of ASW, for example, putting all MPA squadrons into the reserves. Instead, horizontal cuts will reduce platform capabilities from those previously envisaged; for example, the DDG-51 Flight IIA will not have a towed array but will retain helicopters.

With a shift of focus to regional ASW, the USN has downgraded its previous ASW requirements that stressed blue water capabilities against Soviet attack and ballistic missile submarines. Rather than holding strategic submarines at risk, the USN only wants the "ability" to hold strategic subs at risk, meaning that ASW forces (SSNs and MPAs) do not have to be there all the time. USN ASW forces will be required to retain the ability to counter any potential open ocean submarine capability, notably CIS, Chinese and Indian. USN ASW operators claim that the CIS has stopped deploying its submarines. Recently, one source stated that, "In five years, the CIS may not retain a blue water capability." UKRN sources strongly contest both claims and indicate that Russian SSBN and modern SSN operations are continuing, although most older boats have been laid up. The remaining crews from these boats are being concentrated into new construction hulls; as a result the operational technique of those submarines has shown a marked improvement.

These factors suggest that attention will be paid to modifying and enhancing existing equipment originally designed for the blue water environment rather than designing an entirely new generation of systems optimized for green water. Fortunately, the latest generation of low-frequency, bow-mounted sonars, the SQS-53C (or 53-Charlie as it is more commonly known) uses digital beam-forming and can thus be made suitable for green water deployment. Although streaming towed arrays in green water is a serious gamble, the equipment can be made substantially more effective by including an active component with the array.

Western Europe. Overall military budgets in Western Europe are set to decline throughout the forecast period. The demise of the USSR and the implosion of Russian armed forces have removed the obvious threat facing the NATO countries and made popular demands for a "peace dividend" irresistible. The fact that the availability of substantial funds saved from military budgets for such a dividend is illusory has little to do with this. European countries historically have elaborate social security and public welfare systems that involve massive open-ended commitments. For example, had no changes in Britain's National Health Service been made, by the end of the century, NHS expenditures would have exceeded the British GNP. Thus, any savings that could have been made on defense expenditures were swallowed up without a trace.

These defense expenditure reductions have affected, and continue to affect, all three armed services. Navies tend to be affected early in such processes due to the high perceived capital costs of new warships. However, in the longer term, the European navies are likely to have the importance of their roles enhanced in public eyes as a result of operations connected with aid distribution, mine clearing, etc. If, as most European analysts accept, the Persian Gulf War of 1990-1991 is just the first of a long series of such engagements (with operations in the former Yugoslavia being the second), then naval forces will return to their primary role of power projection. After all, ships remain the only way substantial quantities of heavy military equipment can be moved from one continent to another. If, as in the former Yugoslavia, there are inadequate facilities for operating aircraft, air support for such operations will have to be carrier-based.

Finally, ships carrying aid and relief supplies will have to be protected – not too long ago, an Italian aircraft carrying humanitarian relief supplies was deliberately shot down by the people for whom the relief supplies were destined. The motivation, apparently, was to blame and discredit their enemies and thus incite UN military intervention.

We therefore expect that in the medium and long term, naval budgets will not be as severely affected as those of the other two armed forces. However, ASW funding is likely to be disproportionately reduced. Most European navies have ASW capabilities ranging from the world leader (Britain's Royal Navy) to limited-but-competent-within-those-limits (France). These existing capabilities are regarded as being adequate for the moment and expenditures will be limited to enhancing the green water capabilities of forces previously operating largely in blue water. However, the area AAW capability of European navies ranges from the dismal to the dreadful. It is noticeable that the current warship building plans (the Anglo-French-Italian Project Horizon, the Dutch-German F-124 program and the Turkish MEKO Track IIB frigates) are all AAW optimized. Only Project Horizon (following determined insistence by the British) will have a significant ASW capability – it is also the largest at 6,200 tons light.

Such ASW expenditure as does occur is likely to be helicopter-related, centered around three programs, the Anglo-Italian EH-101, the NH-90 and the US-Italian ASH-60 Leonardo. The perception is that helicopters offer the most flexible and cost-effective means of providing ASW capability within the environments foreseen. Although the future of the NH-90 helicopter remains highly questionable, any cancellation of this program is likely to be offset by other acquisitions. This obviously has major effects on funding for hull-mounted and surface-deployed sonars.

One effect of this environment is the rapid decrease in the number of front-line sonar types being deployed. Twenty years ago the UK Royal Navy deployed five front-line primary surface ship hull sonars and three primary submarine equivalents. In ten years time, there will be only a single surface ship system, developed and deployed jointly by the UK, Italy and France. Although submarine and surface ship sonars remain distinct, commonality between the two is growing. This is particularly marked in the dry end of the system where signals processing commonality and the use of standard operator workstations are blurring the distinction between ship and submarine deployment. It is possible that within a few years, ship and submarine sonar systems will be identical except for the transducer array and some elements of signals processing – indeed progress to this goal is well in hand.

Eastern Europe. The probability is that the countries of Eastern Europe will be so busy rebuilding their shattered economies that major arms expenditure of any type will be out of the question. The best that can be predicted is a limited upgrade of existing assets, enhanced performance by using more advanced Western sensors, and a reduction of reliance on spares and support no longer easily available from Russia. Poland, the Czech Republic, Slovakia and Hungary are all following this route already with their air forces (the first to feel the results of spares shortages); naval units are likely to follow in the medium term. In the long term this may well evolve into supplying such upgraded forces on the open market. However, few of these countries have a major maritime presence and only Poland maintains a significant navy.

Middle East. The strategic implications of the possession by Saddam Hussein of a small number of diesel-electric submarines would have been profound and could have materially affected the conduct of the Persian Gulf War of 1990-1991. This has not escaped the surrounding nations; indeed Iran hurriedly acquired ex-Russian Kilo class submarines on much the same logic. The Iraqi invasion of Kuwait and the subsequent fighting have instigated a significant increase in military expenditure throughout the region. This is an across-the-board exercise, affecting land, sea and air forces. It is matched by an appreciation of just how much more effective were the professional, highly trained soldiers of the Western forces and of the overwhelming value of true military professionalism.

The Persian Gulf War of 1990-1991 has had several other, less obvious influences. For one thing, it was an imposing demonstration of sea power, both as a means of delivering huge supplies of military equipment and of striking at targets deep in hostile territory. For another, it showed Gulf Coalition partners, who have previously purchased mainly fast attack craft, what real warships looked like, what they were capable of, and just how helpless were their FAC-Ms against such ships. It is intriguing to note that over the last year the naval acquisitions by all of the Gulf states are much more impressive, multipurpose vessels than the previous units.

Overall, ASW proliferation throughout the Middle East is likely to be a feature of the 1990s. Capability in this area will, however, have to be built from scratch. This will involve the provision of ASW-related systems, equipment and training on an all-inclusive basis, a suggestion that the contracts resulting from this trend will best be met by a consortia of contractors.

The Far East. When the Chinese initiated negotiations to acquire the "aircraft carrier" RFK Varyag from the Russians, they fired the starting gun in a Far Eastern arms race of profound political and economic significance. Eventually, the purchase attempt proved abortive when the Chinese discovered that the Project 1143.5 design is not an aircraft carrier but a fleet flagship that happens to carry some aircraft. This does not change the basic Chinese drive to expand the power projection capability of their fleet. The most likely response to the emergence of the Chinese blue water fleet will be the strengthening of the submarine forces in the area. Since it will take 10-15 years before Chinese Naval Aviation reaches an operational level of competence and about the same time for the submarine fleets to reach similar levels, we are looking at the start of the slowest-motion arms race in history. That does not make it any the less dangerous.

As previously mentioned, the logical consequence of creating a seagoing aviation capability is the creation of a powerful surface fleet to protect the carriers. It also suggests that the Chinese navy will have to invest heavily in the acquisition of capable area defense AAW weapons and in ASW capability. None of its indigenous efforts in these areas have seen much success. If previous efforts are anything to judge by, this equipment will have to be imported. The evidence currently available is that extensive contacts exist with France to this end.

Nations throughout Southeast Asia are viewing the emergence of the Chinese navy with great alarm. Causing even more alarm is the perception that Japan will be "compelled" to drop any pretense of maintaining "self defense" forces and acquire their own air-capable ships and naval aviation. Sources in Southeast Asia are quite blunt about regarding this prospect as even more frightening than the growth of Chinese power perception capability – they have, after all, bitter memories of Japanese occupying troops during World War II.

The Japanese, already significant players in the ASW arena, are likely to enhance their ASW capabilities as part of a significant overall naval program. As part of this effort, it is probable that efforts will be made to design weapons and sensors internally rather than relying on versions of (largely) US-supplied systems. An initial pointer to this is that the Kongo class Aegis destroyers have an integrated command system, OYQ-9, laid over the US-supplied Aegis, SQQ-89 and SLQ-32 systems.

Other factors leading to tension in the area lie in the Korean peninsula. This situation is even more tense than widely appreciated and, according to local security experts, could blow at any time. The critical factor may well have been the recent death of the existing North Korean leadership. The new "great leader," Kim Jong-Il, seeing the sands of time running out, could launch an attack on the South to cement his inheritance of the leadership before the accelerating economic differential makes such an offensive quite impossible.

Thus, the probability exists that the medium- and long-term prospects in Southeast Asia will see ASW expenditures rising as part of an accelerating arms race. Indeed, a pessimistic view may suggest that while the main focus of superpower rivalry during the last half of the 20th century was in Europe, that of the first half of the 21st may be in the Pacific Basin.

ASW Proliferation. The above regional review, which highlights the degree of submarine proliferation as a real and significant planning imperative for the next decade (and beyond), will act as an equal and significant driver toward the development of ASW capability. This is likely to take two forms: the reorientation of the existing ASW capability deployed by the major world navies (most notably the USA and Great Britain) and the establishment of an effective ASW presence within smaller navies where none previously existed.

When considering the likely proliferation of submarine threats and the related ASW efforts, it is very difficult to avoid the conclusion that the emphasis placed on blue water ASW during the 1970s and 1980s is now redundant and that the remainder of the 1990s will see attention switch to combating the diesel-electric submarine in green water. This represents a major re-ordering of priorities for the larger world navies.

It is rarely appreciated just how limited is the spread of real ASW expertise. At present, this is largely concentrated in the hands of the British and the US Navy, with the Japanese also having a significant presence. These all use the same basic ASW technology, bow-mounted low-frequency passive sonars and ultra-low-frequency towed arrays for detection at first and second convergence zone ranges. These contacts are then exploited by helicopters. They act either as weapons delivery platforms steered to their targets by the mother ship (the Anglo-French Lynx, US SH-2G and SH-60B) and relaying the data obtained by their sensors back to the mother ship for processing, or as autonomous search units with their own onboard processing and data coordination capability (Anglo-Italian Merlin HAS.1, Westland Sea King or US SH-60F). After prolonged experimentation, the British came to the conclusion that only the second approach was viable and has largely reassigned the Lynx helicopters to ASuW operations.

This existing expertise was built around an entirely accurate assessment that, at the time of its evolution, the major threat to be faced was the massive Soviet submarine fleet launching an offensive against the North Atlantic sea lines of communications (SLOCS). Indeed the entire operational rationale of the UKRN since 1968 has been orientated to that threat. Until recently, of over 1,000 analysts working in the UKRN Department of Naval Intelligence (DNI), only three were assigned to studying non-Russian data.

The result has been that, while the UKRN is one of the world's leading ASW forces and very proficient in this art, its capabilities are largely restricted to the blue water environment. The much vaunted Type 23 ASW frigates are among the quietest in the world and, according to some estimates, the only surface combatants confirmed as having third convergence zone capability. Their towed arrays, large bow-mounted passive low-frequency sonars and autonomous Sea King and Merlin HAS.1 helicopters, are all blue water tools, unsuited to operations in green or brown water. Some degree of green water capability is provided by the Type 162 bottom mapping sonar and the ability to drop Mark 11 depth charges from helicopters, but these will only provide the basis from which a more effective capability will be developed. The UKRN will require a major change in orientation to match the demands of the 1990s.

The US Navy is in a more fortunate position in this respect. As an economy measure, the FFG-7 class frigates were equipped with the medium-frequency SQS-56 sonar, which fortuitously proved to be quite satisfactory when used in the green water environment. It substantially outperforms the low-frequency SQS-53 and Type 2050 sonars under these circumstances. The Japanese navy also has some green water capability as a result of the operational requirement to conduct ASW operations in the Sea of Japan and Inland Sea areas. The orientation of both navies remains, however, focused on ASW operations in the blue water environment, and current investment plans are likely to require reconsideration.

The smaller NATO navies do, however, offer a reserve of expertise in green water ASW. The Italians have long faced a most difficult series of sonar conditions in the Mediterranean and have trained to operate under these complex geographic and hydrographic conditions. The Dutch have specialized in operations in the North Sea, another complex and difficult environment, while Spain has made great strides in recent years toward developing significant ASW capability in both blue and green water.

Finally the Swedish navy has, after a long delay and several false starts, begun to develop real brown water ASW capability, a capability matched only by the Russians and the South Korean navy. The South Koreans are the only navy in recent years to have achieved real successes in killing submarines in brown water. Similar moves are going on in the other Nordic countries, including Finland, whose geographical position next to Russia already dictates some of the operating realities of that navy. Finland has long been involved in underwater monitoring, albeit with less notoriety than Sweden, but both countries recognize their operating theaters as being fundamentally littoral and consequently are investing appropriately in their sonar and underwater surveillance capabilities.

An unusual factor, then, is the capability of the Russian navy. Under the Soviet doctrine, ASW was divided into two separate functions. The first, referred to as ASW, is descended from Russian navy guardship (SKR) traditions. This takes place in green and even brown water and Russian technology and tactics have evolved specifically to meet the challenges presented. These tactics are highly innovative and quite unlike anything used elsewhere.

The second thread of Russian operations are the Pro-Submarine Warfare (PSW) forces, descended from another traditional Russian fleet component, the Breakout Forces. The PSW forces are assigned an offensive role aimed at protecting the breakout of Soviet cruise and ballistic missile submarines through choke points by engaging NATO submarines and ASW groups. The PSW forces also have the role of protecting Russian SSBNs in their bastions. Detailed consideration of the Russian PSW and ASW tactics is essential – firstly because the solutions they have reached are of value in the reorientation to green and brown water operations, and secondly, because re-equipping these ships and aircraft with Western sensors after their sale to other parties will represent a substantial market sector.

Throughout the rest of the world, ASW has been in low esteem. Few navies train with any degree of enthusiasm for ASW operations, and the ASW community has little political or planning impact. Although most frigates and corvettes delivered to Third World navies over the last decade have helicopter hangars or landing pads, the assigned helicopters are tasked with general maritime surveillance rather than ASW. Other ASW-oriented shipboard weapons and sensors are notable for their absence. The sonars are usually the cheapest obtainable and thrown into the package by the systems integrator as an afterthought. The ships may carry ASW torpedo tubes but rarely have a full outfit of torpedoes – or, indeed, any serviceable torpedoes at all. Many such navies have never fired a live torpedo. Such ASW training as is undertaken is more concerned with self-defense against an attacking submarine than offensive sub hunting. The situation is made worse by ASW exercises being canned and predetermined, aimed more at making an impression rather than demonstrating any real operational capability.

This situation is not as irrational as may at first appear. The navies in question are, first and foremost, political tools tasked with showing the flag, policing national waters and Economic Exclusion Zones (EEZ), and providing a deterrent to those who may dispute the precise boundaries of any EEZ. This role profile requires an impressive display of above-decks weapons (known to warship design teams as a "fierce face"), combined with relatively low operating costs. These characteristics tend to result in short-term conscript crews and diesel engines; neither conducive to the development of a cadre of personnel skilled in the ASW arts. The perceived threats are equivalent general-purpose frigates in neighboring countries that are designed to the same requirements and share the same characteristics.

All this will have to change as submarines proliferate and the degree of green water ASW operations increases throughout the 1990s. All of these changes will take place in an era of declining defense budgets and of severe competition from other demands on government expenditure. The acquisition of new platforms to fulfill these roles is, therefore, most unlikely. The most probable course of events will be the upgrading of existing assets to enhance ASW performance, plus the procurement of surplus, second-hand ASW-orientated platforms from existing users.

A highly favored route may well be to equip the existing maritime surveillance helicopters assigned to general purpose frigates for a specific ASW role. This will be particularly attractive if such modifications can be palletized so that the helicopters in question can be adapted from one role to the other with minimum down-time. This would also mean that the quantities of ASW equipment purchased can be limited and transferred from helo to helo as required. Additionally, navies will have to build up centers of expertise in ASW – reading sonar returns is an art, not a science, and one only acquired by long practice. Put together, this is all suggestive of technology packaging that includes equipment supply, support and a long-term commitment to training.

ASW Training and Simulation. The fact that few nations train for ASW operations with any degree of dedication has been indicated earlier. The problem also is that many of the navies needing to acquire ASW expertise have severe funding shortfalls that restrict available sea-time. Thus, a combination of lack of motivation and the need to divert what sea training time is available to roles perceived as being of higher importance, conspire to restrict ASW training. Some idea of the problem this causes is indicated by the fact that the Royal Thai Navy uses a version of the recreational computer wargame "Harpoon" (produced by 360 Corporation) as a serious training aid.

This implies that the provision of training simulator equipment may well be a growth sector, particularly if it can be supplied on a commercial basis (for example in a dockside container) so that the cost can be shared between a number of countries. This approach is already used for electronic warfare training where a number of civilian companies (including Flight International, FRS, and FRA) all own aircraft fitted with EW equipment that is then leased for varying periods to armed forces requiring such facilities.

* * *

Competitive Environment

Low-Frequency Sonars. Examination of the market for low-frequency sonars reveals that the total forecast for the decade is almost completely committed. Given that low-frequency sonars equip blue water escorts for major navies and that these are the subject of long-term procurement plans, this is hardly surprising. Although there are a substantial number of construction programs in hand, the sonar suppliers for these programs are either already specified or will be undertaken by a consortium of suppliers from the members of a multinational program. The Netherlands navy will either go for a French sonar built by Signaal as a result of the ownership of Signaal by Thomson-CSF or for the British Type 2050 as a result of the long-standing cooperation between the British and Netherlands navies. The Royal Thai Navy is very likely to purchase the German DSQS-23 low-frequency adaptation of the medium-frequency DSQS-21 as a result of their highly favorable experiences with the latter sonar. In effect, the low-frequency sonar market is locked up and will remain so for the forecast period.

Medium-Frequency Sonars. The medium-frequency sonar market is more open and flexible than the low-frequency sector. Almost a quarter of the total market remains uncommitted to any system. However, there are severe problems. Firstly, the overwhelming majority of the ships likely to be purchased during the forecast period are general-purpose frigates. The MEKO design, especially the MEKO-140 and MEKO-200, dominates this sector much to the exclusion of all others. Worse, few navies purchasing these ships have any serious ASW intentions and the ASW capabilities of their ships are simply going though the motions. Sonar is not a significant factor in the procurement decisions.

The pattern often is that a medium-frequency sonar and two triple lightweight torpedo tubes are included in the naval electronics package, almost as an afterthought. This strongly favors the DE-1160/67 and Thomson-Sintra TSM-26 families that are already well integrated with the MEKO design. Many of the procurements will specify off-the-shelf equipment. If it is assumed that Thomson-CSF and Raytheon continue to hold their market share and achieve five of these orders each, the real available market drops to 10 systems worth US$40 million. There will be little competition for these; about the only option now left is STN-Atlas Electronik with the DSQS-21/23.

This leaves open the possibility that newcomers may enter the field. Such a decision would be exceptionally courageous. Given the costs of developing a medium-frequency sonar or the costs inherent in upgrading an existing system to the levels required to compete with the above products, it must be strongly questioned whether such an effort would be cost-effective. In our opinion it is most unlikely that any new entry to the market would be able to achieve more than two to three sales. If the option of upgrading an existing sonar is taken, the possibility of providing dry-end upgrades to existing installations of the base system arises.

However, few general-purpose frigate operators are willing to spend large sums on sonar upgrades, provided the existing system remains apparently capable. The main priorities are improving AAW capability and installing SSM batteries. These can be seen and have impact.

High-Frequency Sonars. The high-frequency ASW search sonar is a niche market which Simrad has cornered. There are no other participants and, due to the small total size of the market, none are likely to emerge. This survey only covers surveillance sonars and does not cover high-frequency sonars used as fire control for depth-bomb mortars and rocket launchers. These are rapidly fading from sight.

Passive Towed Array Sonars. The market for towed arrays is dominated by the blue water navies. This is not surprising, since towed arrays are designed for long-range surveillance covering the first and second convergence zones. Of the blue water navies, the UK has a very heavy commitment to its Type 2031 and Type 2057 systems, while the Japanese adoption of SQR-19 has placed that system in an undoubtedly dominant position. As the Spanish navy has moved out from green to blue water, it has also adopted the SQR-19 system. It can, therefore, be assumed that SQR-19 will represent the standard towed passive array for the 1990s and that a substantial proportion of the uncommitted market will, if permitted, adopt it.

In fact, of the navies with a towed array requirement, only India is unlikely to get SQR-19. Indian policy in this respect is unknown and unpredictable. The Indian navy may opt for a French, British or Russian system.

This leaves the possibility of towed arrays spreading to the green water fleets and to general-purpose frigates. In fact, for the type of close-in knife-fighting against diesel-electric submarines that characterizes green water ASW, a towed array is a menace to the ship that deploys it. It restricts the ability of the platform to maneuver and is a navigation hazard. It is likely to snare or snag. It isn't even very effective against a near-silent submarine in turbulent water characterized by violent temperature gradients. When it is also remembered that most general-purpose navies have little ASW commitment, the possibility of towed arrays spreading far into that sector can be negated.

Active Towed Array Sonars. The active towed array market is split between two separate systems, the Variable Depth Sonar, or VDS, and the Active Towed Array. The market in general for individual VDS units is severely limited and appears to have virtually died out. The future for VDS units is as part of an integrated system. Blue water navies have never been happy with VDS – the UKRN program to install VDS on a number of Leander frigates was aborted when it was found that the space and topweight could be more profitably used elsewhere.

The only navies left with any significant faith in VDS systems are the Italians and French. A few systems have been deployed by the Japanese for use in the Sea of Japan. VDS was a casualty of the drive to passive sonars and to the increased efficiency of passive towed sonar arrays. Many ASW craft once fitted with VDS now deploy a towed array from the VDS winch. It still retains some value in the Mediterranean (hence the French and Italian interest) where difficult acoustic conditions and ultra-quiet diesel-electric submarines put added value on the use of active sonar.

A new development has been the arrival of the active towed array, effectively the addition of an active signals generating component to a towed array. These systems suffered serious problems in producing displays capable of properly displaying the data gained during their early stages of development. British Aerospace, one of the leaders in active towed array technology, was eventually compelled to develop a system jointly with Thomson-CSF when its own display technology proved inadequate to cope with the required workload. Only after a very protracted developmental period have active towed array systems left the laboratory and been accepted for active service. The launch customer for these systems was Taiwan.

Fully Integrated Systems. A rapidly emerging development is the integration of several members of the above groups into a single sensor complex feeding the sonar data to a single signals processing system. The use of a single such signals processor, albeit an exceptionally large and powerful one, distinguishes such systems from integrated ASW combat systems such as SQQ-89. The standard configuration now emerging appears to be a low-frequency bow sonar, a towed array and an active component for that towed array, feeding a very advanced central signals processing system. Due to the range of systems involved, the probability is that such complexes will be designed by consortia with the prime contractor being the signals processing/systems integration company rather than one of the sensor producers.

Teaming and Joint Ventures. This trend to ever-more complex and expensive systems suggests that there will be an increase in joint ventures during this decade. This has already been demonstrated by the teaming of Hughes and Thomson to win the Airborne Low Frequency Sonar (ALFS) contract. There have also been a limited number of acquisitions, but these have involved mostly small companies that have particular technological expertise to offer. Rather, there seems to be a trend of international cooperation developing. The high costs associated with keeping on the leading edge of sonar technology makes this both inevitable and desirable. The longer term, however, presents some clouds. As acoustic detection technology per se appears to be reaching its limits, there is a real potential that emphasis will be placed on other aspects of the detection process.

Again, it may well be that signals processing becomes the domain of separate companies and that contracts will be awarded to a signals processor which will then select the sensors best suited to the requirements of its particular processing technology. The fact that the US Navy is seeking such alternatives means that there will be a lot of weight behind such new technologies, and there will be a snowball effect that could realistically lead to a sonar producer becoming only one of many suppliers participating in the design of ASW systems. Sonar manufacturers have to keep well aware of such possibilities, and in fact may have to decide whether sonar is a viable technology area in which to remain, unless they can make the required investment in highly advanced signals processing computers.

National Focus. There is considerable duplication of effort in the area of sonar development because of indigenous development imperatives. From one aspect, this situation is very counterproductive, since the same path may have been explored many times and, thus, much time wasted. Yet, because of the traditional secrecy that has surrounded ASW efforts (especially in regards to towed array development) even among NATO allies, the net duplication is not surprising. Another aspect is the development of capabilities in certain areas where a system already exists and is available on the open market. Because of the sentiment against buying anything made outside a given nation, developmental funds are unnecessarily spent on technology that could have perhaps been bought off-the-shelf. While the present environment of constricted military budgets is finally forcing some changes in this policy, national programs are still being started. A recent example is the announcement that two Spanish companies, both owned by the government, were starting up a new entity that will see Spain developing its own sonars.

Yet, this situation is not as it appears at first sight. There is a very good reason why so much effort is placed on the development of national sonar programs – indeed if a nation is to be serious about developing an operational ASW capability, the initiation of their own sonar development program is probably inevitable.

As an increasing number of nations acquire submarines and this increase drives ASW proliferation, the need to possess an intimate understanding of the seabed will increase. For example, the positions of wrecks and other seabed obstructions will have to be plotted so that they can be eliminated as MAD contacts. This also implies that their magnetic signatures will have to be known so that the wreck cannot be used as cover by an intruder. Patterns of currents, salinity differences, temperature gradients and fish movement patterns all require study. Offensively, if hostile waters are to be penetrated, similar information must also be available so that the efficiency of defensive efforts can be minimized. It will be noted that an intense Soviet hydrographic mapping exercise took place prior to the deployment of Yankee SSBNs in the North Atlantic and that a similar exercise preceded the deployment of Delta boats to the South Atlantic.

Very few nations have this capability at present. Acquiring it would require substantial expenditures on oceanographic equipment and the establishment of centers where the data could be processed. On its own, such expenditure could not be justified; however, the data gained would also be essential for the proper exploitation of fish stocks and raw material/energy resources from the sea. Since such resources are regarded as being of increasing importance (and in themselves are a potential cause of hostilities), it is probable that a steady increase in this sector will occur. This implies a corresponding growth in the market for the related equipment (for example, echo sounders for measuring water depth).

The key point is that all this data is essential for signals processing to work efficiently. Buying sonars from outside means handing over such information to third parties who may not always be friendly or who may represent a weak link by which vital ASW data can be acquired by an enemy (much as the Soviet Union acquired US ASW technology from the British in the 1950s and early 1960s and from the French in the 1970s).

Company Competition. Companies presently involved in sonar development and production tend to be well-established in the field, with significant experience gained over time. The technological needs of sonar development are such that a certain level of expertise is required in order to even begin developing a sonar system. For instance, a thorough knowledge of underwater acoustics can be considered the bedrock of any sonar development program. As a result of the special requirements associated with sonars, the corporate players tend to be small in number and are frequently closely associated with national governments that set the requirements.

The high costs of developing sonars from scratch has meant that governmental support is often crucial, although there is a certain extent of independent development, especially in using existing expertise to develop a new system. Also, because the most sophisticated threat usually involved NATO versus the former Soviet Union, the developmental parameters were set by the respective navies.

The sonar marketplace is certainly competitive, yet there are limits on this competition, especially, as mentioned previously, due to indigenous production requirements. For those smaller naval powers in search of sonars, the product range available to them is surprisingly broad and the competition keen. Yet, once outside the major naval powers, the quantities being ordered tend to be relatively small (an order for a half-dozen sonars would be considered significant), and even these orders may only be for certain components. For example, the Canadians ordered only the "wet end" of the SQR-19 for their new Halifax class, the installation using an indigenous processor.

The market is further limited by size constraints. There are few navies outside the major powers that field warships larger than frigates. Many smaller countries are building their fleets around large patrol or missile boats. These trends mean that future sonar design will have to emphasize downsizing in order to fit capable sonars onboard the smaller ships. Many of the sonars now available are more suitable for use on larger surface warships and submarines.

What, then, will be the characteristics shown by a successful sonar manufacturer in the future? Such ingredients as price, service, and quality are certainly factors. However, since requirements often tend to be very specific, the ability to meet or even exceed the requirements at a competitive price could be the dominant characteristic. More so than in many other defense industry subsegments, the sonar market is focused on the end use, whether it is the size of the platform, the end mission (MCM or surveillance), or the type of waters that will be operated in (shallow or ocean). Because of the specialized nature of the technology involved, service is also definitely a factor. Quality is essential, since there are likely to be minimal parameters that have to be met, including long mean-time-between-failures. For example, repairing a hull-mounted sonar is quite a feat, especially if the ship has to be drydocked first to even get at the sonar.

The successful sonar producer in the next decade will most definitely be very flexible. The market is too diverse to expect customers to buy products completely as is. Rather, tailoring the product is going to be the hallmark of a successful sonar producer. Another discriminating characteristic is having state-of-the-art, leading-edge technology. Recent years have been very dynamic ones for sonar development, and this will continue to be the case well into the decade. As submarines get quieter, sonars will have to be made more powerful and with better discrimination capabilities. These Research and Development (R&D) programs will often have to be financed at least in part by the companies themselves since defense budgets are in decline. This will mean that the successful company will need relatively deep pockets.

The likelihood of new companies entering the field is very slim because of the very specialized knowledge that is a basic requirement. If a new company enters the field, it will likely do so in the form of an acquisition of an existing sonar manufacturer or a cooperative agreement. In fact, the declining number of sonar systems in the inventories of naval powers has lead to a drastic decline in the number of players. This survey shows that the world market has now distilled to three major power-houses and a few bit players.

There is now an increasing focus on a search for non-acoustic ASW techniques, basically as a way of finding alternatives to sonar so that there is not such a high reliance on sonar. Also, since passive sonar is seeing a relative decline in capability, other passive sensor systems such as lasers and magnetic anomaly detectors are being explored. What this means is that companies that have relied on sonar technology to establish their product line may be faced with a real decline in demand should successful alternatives be found.

The MCM niche has a very low level of competition. In fact, it seems that one company, Thomson-CSF, is the big player, at least in regards to having the broadest array of sonar products and being on the leading edge of technology. The latter is pointed out by the company's provision of the classification sonar portion of the USN's SQQ-32 advanced MCM sonar program, as well as cooperating with the United Kingdom and the Netherlands in developing a parametric sonar for the detection of buried seabed mines. Thomson-CSF’s sonar operations now include those of GEC-Marconi as a result of the formation of Thomson-Marconi Sonar Systems. Although technically a joint venture, the shareholding in this group gives Thomson-CSF a wafer-thin but controlling majority. Other participants include STN-Atlas Electronik.

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Market Statistics

This analysis is an overview of the market for military surface sonar systems currently in production, planned, or anticipated over the coming decade. Surface Sonar in the context of this analysis is confined to those arrays that are either installed on a surface vessel or submarine. Both US and non-US systems are included, and most units are in production. It is impossible to know what new programs may be developed in response to requirements that may emerge in the future. Our long-term projections will address emerging systems when they begin to affect this market.

Methodology. The purpose of this analysis is to correlate the individual 10-year forecasts of the systems involved and other systems manufactured by the identified prime contractors. Each individual report is based on detailed research, involving data obtained from various government agencies, industry sources, United States and foreign publications and individual contacts in the defense industry. This broad base of information is used to develop an overall picture of each system. The market analysis uses a computer-based approach to combine data from the individual reports and to perform several statistical analyses. Using this method, we have produced several graphic presentations of projected unit and value production by system and by calendar year through the year 2005. We have also shown the companies that are the leaders in this active market area. The companies are ranked by value of production, highest to lowest.

Definition of Prime Contractor. Unlike other types of military hardware that tend to have a single clearly identifiable prime contractor, electronic systems present a more complex identity problem. The fact is that in most cases major components of the systems are procured separately from different manufacturers by the military agencies and are brought together only during the systems integration phase of development. Other cases are clear-cut, with a single designated prime contractor and a series of subcontractors.

The true prime contractor has been identified as clearly as possible, or if this was not possible, the major producers of the system components involved. Particular notice was taken of contract information and of the commonly accepted identification of the primes in the various press releases and media. In previous editions of this survey, a number of entries have shown two or more companies as primes for a program. This has now been eliminated and the workload represented by those programs split pro rata between the contractors in question.

Pricing of Systems. Precise pricing of sonar systems presents some significant difficulties. Unit prices in government contracts often vary, depending upon quantities ordered, adjustments for inflation, discounts and additional services that may be included in contracts. Foreign military sales may also affect domestic prices. However, an effective market analysis requires the best possible estimates of unit prices.

Sources for unit prices vary. In some cases, the prime contractor provided an average or typical unit cost. When price quotes were not provided by the manufacturer (which is often the case), estimates are based on contract awards, funding and number of units ordered. There are some pitfalls to this approach. Often, RDT&E costs do not appear in the unit cost, especially if development was government funded. In other cases, government funding documents had been sanitized, removing a significant tool for approximating costs. In these cases, a pure estimate of the unit cost was made based on the type of system, its complexity, prices of comparable systems and a general understanding of the sonar marketplace. While the price information may not be exact, unit cost estimates are in the proper order of magnitude.

Initial Observations. It bears repeating that ship-deployed sonars represent high-value items in the electronics marketplace. Our 10-year forecast period shows the production of 858 systems worldwide (a significant increase on the total of 713 last year) with a total value of US$5.56 billion (a sharp fall from US$6.07 billion in our 1995 overview). Based on these figures, the average cost of a system is US$6.5 million, steeply down from US$8.5 million last year, a continuation of a long-standing decline. This figure has to be treated with caution since the high per system costs of the SQS-53C (US$34 million) and SURTASS (US$18 million) distort the overall picture. The downward shift does indicate the growing importance of the non-US market where the less expensive medium-frequency sonar is dominant.

Unit production has leveled off and the market will see a slight downward trend during the latter part of the decade. The main US system that will be in production during this period is the SQS-53C, which is the mainstay for new-production combat ships such as the DDG-51 class. The analysis deals with known, active (or about to become active) systems, and thus does not factor in those systems which, as yet, exist only on the drawing board. These will be a major factor toward the far term and will counteract the downward trend in existing systems. A particular but unavoidable underestimate is the allowance made for NEC. The sheer scale of Japanese naval development will greatly increase the real market share of this group; as yet insufficient data is available to suggest by how much.

Overall, the market can be divided into two groups; the “Big Three” (Thomson-Marconi, Lockheed Martin and STN-Atlas Elektronik) who account for well over 60 percent of the market and about a dozen smaller companies who divide the rest between them. For some years, their has been speculation that the big gorillas were going to devour the smaller players. In the surface sonar sector, this seems to have happened. Even though two of the smaller competitors have respectable value shares (Northrop Grumman, US$646 million, 11.61 percent and Raytheon, US$465.5 million 8.21 percent) this is on the basis of small numbers of expensive systems. The basic strength of the “big three”, represented by large value and numerical shares, is absent

Thomson-Marconi Sonar Systems – 34.69% – US$1,170.8 Million – 284 Units

The newly formed Thomson-Marconi Sonar Systems is undoubtedly the dominant force in the world sonar market. The group combines the sonar activities of Thomson-Sintra, the monopoly supplier of ASW equipment to the French navy, GEC-Marconi Sonar Systems and Ferranti International. In short, with the exception of STN Atlas-Elektronik, the new group incorporates every significant sonar systems producer in Europe. Shareholding in the group is 50.1 percent Thomson-CSF, 49.9 percent GEC plc. The new group is, therefore, effectively a Thomson-CSF subsidiary, a point which has already raised some concern.

This consolidation took place in a series of phases, the last of which was the GEC purchase of the Ferranti International interest in the Ferranti-Thomson Sonar Systems joint venture. The new organization covers a broad spectrum of ASW activity, including hull mounted medium and low-frequency sonars, towed arrays, VDS fish, integrated systems, dipping sonars for helicopters and a very wide range of mine countermeasures equipment.

For the UK Royal Navy (UKRN), the new group is designing the Type 2076 sonar, intended to be retrofitted to the Swiftsure and Trafalgar class SSNs, replacing the 2020 set and a number of previously unintegrated arrays. Numbers will depend on the future size of the SSN fleet. Type 2054 is a large integrated suite for the Vanguard class Trident SSBNs currently coming into service. The current major surface warship sonar is the bow-mounted Type 2050, fitted in the latest frigates. It uses the same array as the hull-mounted, the Type 2016 low-to-medium frequency set, fitted in earlier frigates, destroyers and aircraft carriers. The company is heavily involved in the development of submarine towed arrays, starting with the Anglo-Dutch Type 2026 and continuing through Types 2046 and 2057. It also supplies the standard surface ship towed array, Type 2031Z.

Future prospects depend on the RN's future frigate and submarine building programs. The size of the SSN modernization program is under review, but at least three more and possibly five Type 23 frigates will be built. Beyond that is the 12-ship Future Frigate program. The Thomson-Marconi group now provides the framework by which the sonar contracts can be awarded without worries as to workshare disputes

The French navy's ASW problems are in one sense similar to those of the UKRN: to escort surface warships and merchant ships in blue water operations, to safeguard its strategic submarines (SSBNs) exiting to their patrol areas, and to work with allies in time of war. Yet, in another sense the French problems are different. France is only partially linked to NATO, so that its submarines and surface warships participate in NATO exercises only as "observers." Another difference is that a large part of France's naval responsibilities lie in the Mediterranean, a comparatively shallow sea with sonar conditions quite different from the Atlantic and Western approaches.

This preoccupation explains the reasons behind the standard large-ship sonar installations of the 1970s. The DUBV-23 direct-path hull-mounted sonar was combined with the DUBV-43 variable-depth set. It is still used, in conjunction with the Malafon standoff ASW missile and the Lynx WG.13 torpedo- and sonar-equipped light helicopter. The ships so fitted, the corvette FS Aconit and the destroyers of the Duquesne and Tourville classes, are scheduled to receive a major modernization in the 1990s, with new ASW systems. This will install the Systeme de Lutte Anti-Sousmarine (SLASM), which uses a very low-frequency towed fish for transmitting and a separate dual receiving array. SLASM is in final development.

DSUV-61 and DSUV-62 are sonar systems designed for nuclear submarines, the former a hull-mounted set for SSBNs, the latter a towed array for SSNs. DSBV-61 is the new towed sonar array for surface ships, approved for production in 1985. It was also selected for the Anaconda sonar system adopted for the Royal Netherlands navy's new Karel Doorman class frigates, integrated with the Mangouste acoustic processor and the SEWACO VII combat system. DSUV-22 is the passive bow sonar in the Rubis class SSNs and the Agosta class SSKs, also known as Eledone in its export version. It was jointly funded by the British and the Dutch, who adopted their own variants as Type 2040 for the Upholder class and Octopus for the Walrus class, respectively.

The company also produces a complete range of ASW products for the export market. The most successful export system is the Spherion bow sonar. This has been procured by Australia, India, Malaysia and Norway. It combines adequate performance for most naval requirements with a tolerable price.

More specialized sonar systems include the Salmon lightweight towed array, which was bought by the Royal Swedish Navy to help solve its unique "brown water" ASW problems.

Scylla is an advanced version of Eledone, adopted by the Royal Australian Navy for its new Collins class. A variant of Eledone is reported to have been sold to the People's Republic of China for the PLA navy's latest "Ming" type SSKs.

Lockheed Martin 14.82 % – US$500.0 Million – 184 Units

Lockheed Martin has now incorporated Loral into its structure, adding major systems integration and badly needed command systems expertise to its portfolio. The company participates in the largest US sonar programs, the hull-mounted SQS-53C and the towed array SQR-19. These form the core of the surface ASW combat system for the CG-47 class cruisers and DDG-51 class destroyers. Lockheed Martin has wrested the prime for the SQQ-89 contractorship away from Northrop Grumman. Sensing that its future prospects must be reoriented to its core engine and commercial lines, the General Electric Company (US) sold its GE Aerospace defense businesses to Martin Marietta Corp in a transaction valued at US$3.05 billion. The deal was completed in the spring of 1993 and was followed by the merger of Lockheed and Martin.

Martin Marietta had already been a smaller player in the US ASW market, primarily as a supplier of the SQR-19 towed array for GE's SQQ-89 program.

Future competition between Lockheed Martin and Westinghouse will most likely focus on the new Flight IIA ships that are expected to reach the construction phase in the late part of the decade. A new, lower-cost version of the AEGIS destroyer, Flight IIA (DDG-78 and later) will not be equipped with the complete SQQ-89(V) system, but only the SQS-53 bow array. The desire to reduce the overall costs of ship construction and the reduction in the blue water ASW threat are the drivers behind Flight IIA as an alternative to a costlier Flight III DDG-51 originally planned for the late 1990s. The USN will stretch out procurement and extend the construction phase out to about 2005.

Separate from the SQQ-89 program, Lockheed Martin is completing current orders for its SQR-19 towed array. The SQR-19 was selected for fitting to the four new Kongo class AEGIS destroyers that the Japanese have under construction. The lead ship, HIJMS Kongo, is now in full operational service. The Canadians are also buying the SQR-19 for their new Halifax class frigates. The SQR-19 will operate with the Computing Devices SQR-501 receiver and signal processor in a system called CANTASS (Canadian Towed Array Sonar System).

Bremer Vulkan GmbH – 18.99% – US$641.0 Million – 112 Units

The sonar arm of Bremer Vulkan, STN-Atlas Electronik, has a virtual monopoly on the supply of sonars to the German navy and is also aggressive in export markets around the world. Although its future status is unclear following the bankruptcy of its parent company, STN-Atlas Elektronik is the third and final significant company in this market sector. This is primarily as a result of its success in winning the contract to supply sonars for the South Korean KDX program and recent orders for Klasse 212 submarines for Germany and Italy.

Because the reconstituted Bundesmarine was given responsibility by NATO for defending the Western Baltic and the Baltic Approaches, it was from the start a "green water" navy. Although political fears about German rearmament caused a severe limit on size to be placed on the first submarines, this suited both the designers, Ingenieurkontor Lubeck (IKL), and the operating philosophy of the German navy. There has since been a steady growth in size with each new class of submarine, but IKL-designed submarines are kept as small as possible. STN Atlas Electronik has accordingly specialized in compact sonar systems with good shallow water performance.

The company produces a full range of sonar systems for submarines, including the CSU 3-4, an active/passive set used by Canadian submarines (CSU = Compact Sonar for U-boats); CSU-83 fitted in Brazilian, Norwegian and Swedish SSKs; and its German navy equivalent DBQS-21. As compared with earlier systems, CSU-83 includes an integrated towed array and a flank array, allowing it to act as the primary sensor for the SLW 83 fire control and command system (marketed for export as ISUS). Under a collaborative agreement the system was also sold to the Royal Norwegian Navy for its new Ula class SSKs, built by TNSW in Emden.

The most recent submarine system is DBQS-23, an integrated suite for the German navy's next submarine program, the Klasse 212. Its commercial designation is CSU-90. The Klasse 212 program was delayed by the same political disillusionment with defense expenditure that has had such disruptive effects on other navies' programs. The first four boats were finally ordered in June 1994 with funding provided in the 1995 budget, with another three to follow at some future point as yet unsettled. Another five are also "proposed but not projected," a state of affairs that leaves both builders

(TNSW and HDW) and the systems manufacturers even more confused than before. The cost of the program has also risen steeply, at a time when the German defense budget is under severe pressure. However, two boats are to be built for Italy.

Towed array technology parallels developments in the USN, the RN and other navies. TAS-83 is the clip-on towed sonar array associated with the CSU-83 system, with two alternative "wet ends." TASS 3-2 is a surface ship towed array, intended to be fitted to Bremen and Brandenburg class frigates in 1997.

The company has been very successful in the surface field as well. Over 60 DSQS-21 sonar systems have been sold, in some cases replacing older sets. Export customers include Argentina, Brazil, Colombia, Malaysia, Nigeria, Taiwan and Thailand. The DSQS-21 has been credited with very good results in the difficult shallow waters of the Gulf of Thailand. It is installed in the German navy's Lütjens class DDGs and Bremen class frigates. The latest set, DSQS-23B is being fitted in the new Brandenburg class frigates and the projected Type 124 air defense ships.

* * *

Table 1
The Market for Ship-Deployed Sonars
Unit Production by Program

Program	Application (Operator)	Unit Cost (MM)	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total 97-06
Corporation - ALLIEDSIGNAL AEROSPACE CO													
SQR-19	SURFACE SHIPS (US NAVY)	9.100	3	3	1	0	0	0	0	0	0	0	7
SQR-19	SURFACE SHIPS (JMSDF)	9.100	0	0	0	0	0	0	0	0	0	0	0
SQR-19	SURFACE SHIPS (CANADA)	9.100	0	0	0	0	0	0	0	0	0	0	0
HELRAS	EH-101 (ITALY)	2.000	0	1	2	2	2	1	0	0	0	0	8
HELRAS	ASW HELO (VARIOUS)	2.000	0	0	1	1	1	0	0	1	1	1	6
ALLIEDSIGNAL AEROSPACE CO			3	4	4	3	3	1	0	1	1	1	21
Corporation - AUSTRALIAN DEFENSE RESEARCH CENTER													
KARIWARA	FF/SSK (AUSTRALIA)	10.000	1	1	1	1	1	0	0	0	0	0	5
AUSTRALIAN DEFENSE RESEARCH CENTER			1	1	1	1	1	0	0	0	0	0	5
Corporation - BREMER VULKAN GMBH													
ASO-90	FF (SOUTH KOREA)	4.000	2	2	2	2	2	1	0	0	0	0	11
CSU-83	TYPE 209-1400 (BRAZIL)	6.000	0	1	1	1	0	0	0	0	0	0	3
CSU-83	TYPE 209-1200 (GREECE)	6.000	1	0	0	0	0	0	0	0	0	0	1
CSU-83	TYPE 209-1400 (SOUTH KOREA)	5.000	1	1	1	1	1	1	1	0	0	0	7
CSU-83	TYPE 209-1200 (TURKEY)	6.000	2	0	0	2	0	0	0	0	0	0	4
CSU-90	TYPE 212 (GERMANY)	8.000	0	1	1	1	1	0	0	0	0	0	4
CSU-90	A-19 (SWEDEN)	8.000	1	1	0	0	0	0	0	0	0	0	2
CSU-90	SSK (UNSPECIFIED)	8.000	2	4	4	4	4	6	6	6	4	4	44
DSQS-11	MCMV (VARIOUS)	3.000	4	2	0	2	3	3	0	2	0	2	18
DSQS-21C	FFL (MALAYSIA)	4.000	0	2	0	0	0	0	0	0	0	0	2
DSQS-21C	FF/FFL (THAILAND)	4.000	0	0	0	0	0	0	0	0	0	0	0
DSQS-23	L-MF HULL SONAR (GERMANY)	4.000	0	1	2	1	0	0	0	0	0	0	4
DSQS-11	MCMV (GERMANY)	3.000	6	6	0	0	0	0	0	0	0	0	12
BREMER VULKAN GMBH			19	21	11	14	11	11	7	8	4	6	112
Corporation - BRITISH AEROSPACE													
ATAS	ASW (TAIWAN)	1.000	1	2	0	0	0	0	0	0	0	0	3
ATAS	ASW (PAKISTAN)	1.000	0	1	0	1	0	0	0	0	0	0	2
ATAS	ASW (UAE)	1.000	0	0	1	1	0	0	0	0	0	0	2
BRITISH AEROSPACE			1	3	1	2	0	0	0	0	0	0	7
Corporation - CERIDIAN CORP													
SQS-510	FRIGATES (VARIOUS)	3.000	2	3	2	2	2	1	0	0	0	0	12
CERIDIAN CORP			2	3	2	2	2	1	0	0	0	0	12
Corporation - COMPUTING DEVICES INTERNATIONAL													
SQR-501 CANTASS	LANDBASED TEST/TRAINING SITE (RCN)	5.500	1	0	0	0	0	0	0	0	0	0	1
UYS-501	EXPORT (NAVY)	0.750	1	1	1	0	0	0	0	0	0	0	3
COMPUTING DEVICES INTERNATIONAL			2	1	1	0	0	0	0	0	0	0	4

Corporation - CONTRACTOR TO BE SELECTED													
TYPE 2087	TYPE 23 FF (UK)	15.000	0	0	0	1	0	3	3	3	3	0	13
TYPE 2087	CNGF DD (FRANCE)	15.000	0	0	0	0	0	0	0	0	1	0	1
TYPE 2087	CNGF DD (ITALY)	15.000	0	0	0	0	0	0	0	0	1	0	1
TYPE 2087	CNGF DD (UK)	15.000	0	0	0	0	0	0	0	0	1	1	2
CONTRACTOR TO BE SELECTED			0	0	0	1	0	3	3	3	6	1	17
Corporation - HUGHES AIRCRAFT CO													
SURTASS	SURFACE SHIPS (US NAVY)	18.000	0	0	1	0	0	0	0	0	0	0	1
HUGHES AIRCRAFT CO			0	0	1	0	0	0	0	0	0	0	1

(TABLE 1 - continued)

Program	Application (Operator)	Unit Cost (MM)	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total 97-06
Corporation - LOCKHEED MARTIN CORP													
SQS-53C	DDG 51 (USN)	3.100	2	1	2	1	2	0	0	0	0	0	8
SQS-53C	CG 47 MODS (USN)	3.100	1	2	1	2	1	2	0	0	0	0	9
BQQ-5E(V) UPGRADE	SSN 688 LOS ANGELES CLASS (USN)	9.500	0	0	2	4	4	4	4	4	4	4	30
BQQ-5E(V)4	SSBN 726 OHIO CLASS (USN)	9.500	3	4	2	0	0	0	0	0	0	0	9
UYS-1(V)	VARIOUS SHIPS AND SUBMARINES (US NAVY AND OTHERS)	0.600	40	40	6	6	6	6	6	6	6	6	128
LOCKHEED MARTIN CORP			46	47	13	13	13	12	10	10	10	10	184
Corporation - NEC CORP													
OQS 102 (SQS-53)	KONGO CLASS (JAPAN)	34.000	0	0	0	0	0	0	0	0	0	0	0
NEC CORP			0	0	0	0	0	0	0	0	0	0	0
Corporation - NORTHROP GRUMMAN CORP													
SQS-53C	DDG 51 (USN)	3.100	1	2	1	2	1	0	0	0	0	0	7
SQS-53C	CG 47 MODS (USN)	3.100	2	1	2	1	2	1	0	0	0	0	9
NORTHROP GRUMMAN CORP			3	3	3	3	3	1	0	0	0	0	16
Corporation - RACAL ELECTRONICS PLC													
SMUTS	WEAPONS RESEARCH (VARIOUS)	1.000	1	1	0	1	0	1	0	0	0	0	4
RACAL ELECTRONICS PLC			1	1	0	1	0	1	0	0	0	0	4
Corporation - RAYTHEON CO													
SQQ-32	MCM 1 CLASS (US NAVY)	12.500	4	0	0	0	0	0	0	0	0	0	4
SQQ-32	MHC 51 CLASS (US NAVY)	12.500	0	0	0	0	0	0	0	0	0	0	0
SQQ-32	VARIOUS MCM (EXPORT)	12.500	0	0	1	1	2	1	0	0	0	1	6
SQQ-32	SPANISH NAVY MCM (SPANISH NAVY)	12.500	1	0	0	0	0	0	0	0	0	0	1
SQS-56/DE-1160/DE-116 4	SURFACE SHIPS (VARIOUS)	7.500	2	2	2	2	2	2	1	1	1	1	16
RAYTHEON CO			7	2	3	3	4	3	1	1	1	2	27
Corporation - THOMSON-CSF													
FERRANTI MODULAR SONAR	FF (SOUTH KOREA)	5.000	0	0	0	0	0	0	0	0	0	0	0
FERRANTI MODULAR SONAR	DD/FF/FFL (UNSPECIFIED)	5.000	1	1	1	1	1	1	0	0	0	0	6
DSUV-62	AGOSTA SSK (PAKISTAN)	10.000	2	2	1	0	0	0	0	0	0	0	5
DSUV-62	SCORPENE SSK (VARIOUS)	10.000	0	0	1	1	2	2	2	2	0	0	10
DSUV-62	SCORPENE SSK (SPAIN)	10.000	0	0	0	1	1	1	1	0	0	0	4
DSUV-62	AGOSTA SSK (SPAIN)	10.000	1	0	0	0	0	0	0	0	0	0	1
DUBV-23/43	LUHU CLASS/DDG (CHINA)	4.000	0	0	0	0	0	1	0	0	0	0	1
DUBV-23/43	LUDA III CLASS/DDG (CHINA)	4.000	0	0	0	0	0	0	0	1	0	1	2
DUBV-23/43	JIANGWEI CLASS/FFG (CHINA)	4.000	0	1	0	0	0	0	0	0	0	0	1
DUUX-5 FENELON	SSK (VARIOUS)	2.000	3	1	0	0	0	0	0	0	0	0	4
DUUX-5 FENELON	SSK/SSN/SSBN (CHINA)	2.000	3	3	3	2	2	2	2	2	2	2	23
DUUX-5 FENELON	SSK (SPAIN)	2.000	0	0	0	0	0	0	0	0	0	0	0
DUUX-5 FENELON	SSK (ARGENTINA)	2.000	0	0	0	0	0	0	0	0	0	0	0
DUUX-5 FENELON	SSK (PAKISTAN)	2.000	0	1	1	1	0	0	0	0	0	0	3
HS-12	ZHI-9/SH-5 (CHINA)	0.200	10	10	10	10	8	8	8	8	6	6	84
TOWFISH	MCMV (NORWAY)	12.500	1	1	1	1	0	0	0	0	0	0	4
TSM-2022	MCMV (EGYPT)	12.500	0	0	0	0	0	0	0	0	0	0	0
TSM-2022	MCMV (MALAYSIA)	12.500	0	0	0	0	0	0	0	0	0	0	0
TSM-2022	MCMV (SINGAPORE)	12.500	1	2	1	0	0	0	0	0	0	0	4
TSM-2233 ELEDONE	SSK (SPAIN)	15.000	0	0	0	1	1	1	1	0	0	0	4
TSM-2233 ELEDONE	SSK (SAUDI ARABIA)	15.000	0	0	1	1	1	1	0	0	0	0	4
TSM-2233 ELEDONE	SSK (FRANCE)	15.000	1	0	0	0	0	0	0	0	0	0	1
TSM-2233 ELEDONE	SSK (PAKISTAN)	15.000	0	1	1	1	0	0	0	0	0	0	3
TSM-2633 SPHERION	FF (AUSTRALIAN NAVY)	4.000	0	1	1	1	1	2	0	0	0	0	6
TSM-2633 SPHERION	FF (INDIA)	4.000	1	0	1	1	1	1	0	0	0	0	5
TSM-2633 SPHERION	FFL (MALAYSIA)	4.000	0	0	0	0	0	0	0	0	0	0	0
TSM-2633 SPHERION	FF (NEW ZEALAND)	4.000	1	1	0	0	1	1	0	0	0	0	4
TSM-2633 SPHERION	FF/FFL (VARIOUS)	4.000	2	4	5	5	4	4	5	5	5	5	44
TSM-2633 SPHERION	FF (TAIWAN)	4.000	1	1	1	0	0	0	0	0	0	0	3

(TABLE 1 - continued)

Program	Application (Operator)	Unit Cost (MM)	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total 97-06
Corporation - Thomson CSF (continued)													
TSM-2640 SALMON	FFL/FAC (VARIOUS)	4.000	1	2	3	3	3	3	3	2	0	0	20
TYPE 2019	SSBN/SSN/SSK (UK)	1.000	0	0	0	0	0	0	0	0	0	0	0
TYPE 2054	VANGUARD SSBN (UK)	30.000	0	1	1	0	0	0	0	0	0	0	2
TYPE 2093	MCMV (KOREAN NAVY)	5.000	0	1	0	1	0	1	0	1	0	1	5
TYPE 2093	MCMV (UKRN)	5.000	5	4	2	3	2	0	0	0	0	0	16
TYPE 2093	MCMV (VARIOUS)	5.000	0	1	1	1	1	1	1	1	1	1	9
TYPE 2093	MCMV (AUSTRALIAN NAVY)	5.000	1	1	1	1	1	1	0	0	0	0	6
THOMSON-CSF			35	40	37	36	30	31	23	22	14	16	284
Corporation - ULTRA ELECTRONICS													
TYPE 2031(Z)	DD/FF (UK)	6.000	3	3	0	0	0	0	0	0	0	0	6
ULTRA ELECTRONICS			3	3	0	0	0	0	0	0	0	0	6
Printout Total -			123	129	77	79	67	64	44	45	36	36	700

(TABLE 1 - end)

Table 2
The Market for Ship-Deployed Sonars
Value of Production by Program

Program	Application (Operator)	Unit Cost (MM)	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	TOTAL 97-06
Corporation - ALLIEDSIGNAL AEROSPACE CO													
SQR-19	SURFACE SHIPS (US NAVY)	9.10	27.30	27.30	9.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	63.70
SQR-19	SURFACE SHIPS (JMSDF)	9.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SQR-19	SURFACE SHIPS (CANADA)	9.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HELRAS	EH-101 (ITALY)	2.00	0.00	2.00	4.00	4.00	4.00	2.00	0.00	0.00	0.00	0.00	16.00
HELRAS	ASW HELO (VARIOUS)	2.00	0.00	0.00	2.00	2.00	2.00	0.00	0.00	2.00	2.00	2.00	12.00
ALLIEDSIGNAL AEROSPACE CO			27.30	29.30	15.10	6.00	6.00	2.00	0.00	2.00	2.00	2.00	91.70
Corporation - AUSTRALIAN DEFENSE RESEARCH CENTER													
KARIWARA	FF/SSK (AUSTRALIA)	10.00	10.00	10.00	10.00	10.00	10.00	0.00	0.00	0.00	0.00	0.00	50.00
AUSTRALIAN DEFENSE RESEARCH CENTER			10.00	10.00	10.00	10.00	10.00	0.00	0.00	0.00	0.00	0.00	50.00
Corporation - BREMER VULKAN GMBH													
ASO-90	FF (SOUTH KOREA)	4.00	8.00	8.00	8.00	8.00	8.00	4.00	0.00	0.00	0.00	0.00	44.00
CSU-83	TYPE 209-1400 (BRAZIL)	6.00	0.00	6.00	6.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	18.00
CSU-83	TYPE 209-1200 (GREECE)	6.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00
CSU-83	TYPE 209-1400 (SOUTH KOREA)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	0.00	0.00	0.00	35.00
CSU-83	TYPE 209-1200 (TURKEY)	6.00	12.00	0.00	0.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00	24.00
CSU-90	TYPE 212 (GERMANY)	8.00	0.00	8.00	8.00	8.00	8.00	0.00	0.00	0.00	0.00	0.00	32.00
CSU-90	A-19 (SWEDEN)	8.00	8.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00
CSU-90	SSK (UNSPECIFIED)	8.00	16.00	32.00	32.00	32.00	32.00	48.00	48.00	48.00	32.00	32.00	352.00
DSQS-11	MCMV (VARIOUS)	3.00	12.00	6.00	0.00	6.00	9.00	9.00	0.00	6.00	0.00	6.00	54.00
DSQS-21C	FFL (MALAYSIA)	4.00	0.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00
DSQS-21C	FF/FFL (THAILAND)	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DSQS-23	L-MF HULL SONAR (GERMANY)	4.00	0.00	4.00	8.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00
DSQS-11	MCMV (GERMANY)	3.00	18.00	18.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
BREMER VULKAN GMBH			85.00	103.00	67.00	81.00	62.00	66.00	53.00	54.00	32.00	38.00	641.00
Corporation - BRITISH AEROSPACE													
ATAS	ASW (TAIWAN)	1.00	1.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00
ATAS	ASW (PAKISTAN)	1.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00
ATAS	ASW (UAE)	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00
BRITISH AEROSPACE			1.00	3.00	1.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00
Corporation - CERIDIAN CORP													
SQS-510	FRIGATES (VARIOUS)	3.00	6.00	9.00	6.00	6.00	6.00	3.00	0.00	0.00	0.00	0.00	36.00
CERIDIAN CORP			6.00	9.00	6.00	6.00	6.00	3.00	0.00	0.00	0.00	0.00	36.00
Corporation - COMPUTING DEVICES INTERNATIONAL													
SQR-501 CANTASS	LANDBASED TEST/TRAINING SITE (RCN)	5.50	5.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.50
UYS-501	EXPORT (NAVY)	0.75	0.75	0.75	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.25
COMPUTING DEVICES INTERNATIONAL			6.25	0.75	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.75
Corporation - CONTRACTOR TO BE SELECTED													
TYPE 2087	TYPE 23 FF (UK)	15.00	0.00	0.00	0.00	15.00	0.00	45.00	45.00	45.00	45.00	0.00	195.00
TYPE 2087	CNGF DD (FRANCE)	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00	0.00	15.00
TYPE 2087	CNGF DD (ITALY)	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00	0.00	15.00
TYPE 2087	CNGF DD (UK)	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00	15.00	30.00
CONTRACTOR TO BE SELECTED			0.00	0.00	0.00	15.00	0.00	45.00	45.00	45.00	90.00	15.00	255.00
Corporation - HUGHES AIRCRAFT CO													
SURTASS	SURFACE SHIPS (US NAVY)	18.00	0.00	0.00	18.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.00
HUGHES AIRCRAFT CO			0.00	0.00	18.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.00

(TABLE 2 - continued)

Program	Application (Operator)	Unit Cost (MM)	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	TOTAL 97-06
Corporation - LOCKHEED MARTIN CORP													
SQS-53C	DDG 51 (USN)	3.10	6.20	3.10	6.20	3.10	6.20	0.00	0.00	0.00	0.00	0.00	24.80
SQS-53C	CG 47 MODS (USN)	3.10	3.10	6.20	3.10	6.20	3.10	6.20	0.00	0.00	0.00	0.00	27.90
BQQ-5E(V) UPGRADE	SSN 688 LOS ANGELES CLASS (USN)	9.50	0.00	0.00	19.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00	285.00
BQQ-5E(V)4	SSBN 726 OHIO CLASS (USN)	9.50	28.50	38.00	19.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	85.50

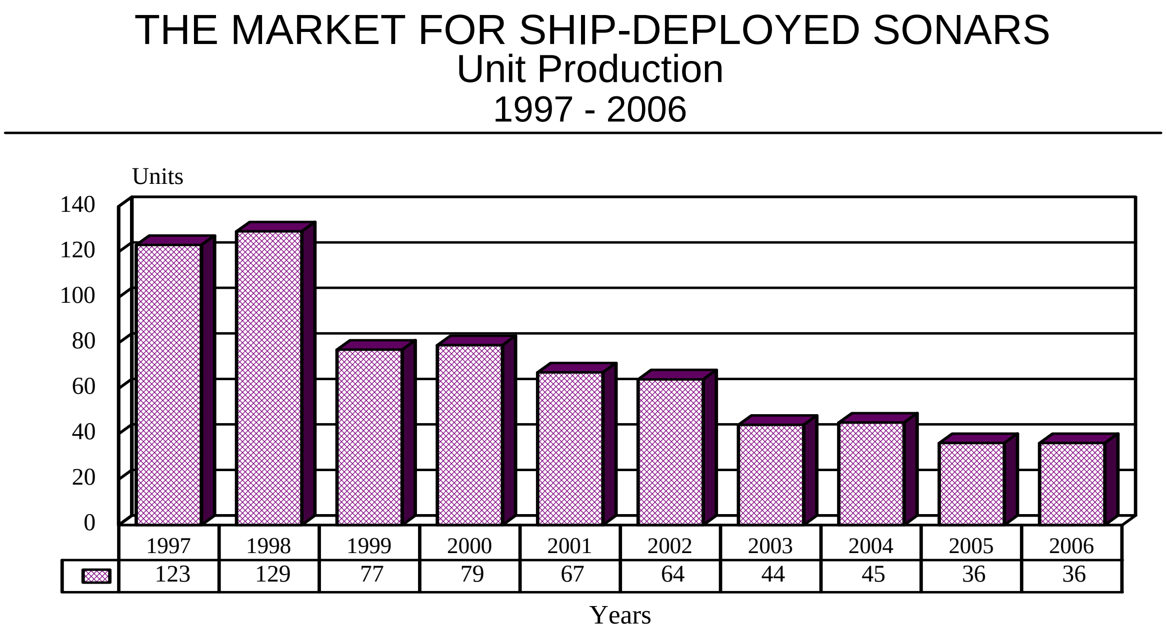
UYS-1(V)	VARIOUS SHIPS AND SUBMARINES (US NAVY AND OTHERS)	0.60	24.00	24.00	3.60	3.60	3.60	3.60	3.60	3.60	3.60	76.80
LOCKHEED MARTIN CORP			61.80	71.30	50.90	50.90	50.90	47.80	41.60	41.60	41.60	500.00
Corporation - MULTI-CONTRACTORS												
SURFACE ASW	RDT&E (US NAVY)	0.00	3.90	6.00	7.40	9.20	9.30	9.40	9.80	10.00	11.00	87.00
MULTI-CONTRACTORS			3.90	6.00	7.40	9.20	9.30	9.40	9.80	10.00	11.00	87.00
Corporation - NEC CORP												
OQS 102 (SQS-53)	KONGO CLASS (JAPAN)	34.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NEC CORP			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corporation - NORTHROP GRUMMAN CORP												
SQS-53C	DDG 51 (USN)	3.10	3.10	6.20	3.10	6.20	3.10	0.00	0.00	0.00	0.00	21.70
SQS-53C	CG 47 MODS (USN)	3.10	6.20	3.10	6.20	3.10	6.20	3.10	0.00	0.00	0.00	27.90
WLY-1	ACOUSTIC COUNTERMEASURES (US NAVY)	0.00	7.90	9.50	13.50	16.50	16.00	16.50	16.50	16.00	14.00	142.40
NORTHROP GRUMMAN CORP			17.20	18.80	22.80	25.80	25.30	19.60	16.50	16.00	14.00	192.00
Corporation - RACAL ELECTRONICS PLC												
SMUTS	WEAPONS RESEARCH (VARIOUS)	1.00	1.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	4.00
RACAL ELECTRONICS PLC			1.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	4.00
Corporation - RAYTHEON CO												
FSS	VOICE & DATA COMMUNICATIONS CENTER	0.00	4.00	3.00	3.00	3.00	2.00	2.00	2.00	2.00	0.00	21.00
SQQ-32	MCM 1 CLASS (US NAVY)	12.50	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00
SQQ-32	MHC 51 CLASS (US NAVY)	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SQQ-32	VARIOUS MCM (EXPORT)	12.50	0.00	0.00	12.50	12.50	25.00	12.50	0.00	0.00	12.50	75.00
SQQ-32	SPANISH NAVY MCM (SPANISH NAVY)	12.50	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.50
SQS-56/DE-1160/DE-1164	SURFACE SHIPS (VARIOUS)	7.50	15.00	15.00	15.00	15.00	15.00	15.00	7.50	7.50	7.50	120.00
RAYTHEON CO			81.50	18.00	30.50	30.50	42.00	29.50	9.50	9.50	20.00	278.50
Corporation - THOMSON-CSF												
FERRANTI MODULAR SONAR	FF (SOUTH KOREA)	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FERRANTI MODULAR SONAR	DD/FF/FFL (UNSPECIFIED)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	0.00	0.00	0.00	30.00
DSUV-62	AGOSTA SSK (PAKISTAN)	10.00	20.00	20.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00
DSUV-62	SCORPENE SSK (VARIOUS)	10.00	0.00	0.00	10.00	10.00	20.00	20.00	20.00	20.00	0.00	100.00
DSUV-62	SCORPENE SSK (SPAIN)	10.00	0.00	0.00	0.00	10.00	10.00	10.00	10.00	0.00	0.00	40.00
DSUV-62	AGOSTA SSK (SPAIN)	10.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00
DUBV-23/43	LUHU CLASS/DDG (CHINA)	4.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	4.00
DUBV-23/43	LUDA III CLASS/DDG (CHINA)	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	4.00	8.00
DUBV-23/43	JIANGWEI CLASS/FFG (CHINA)	4.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00
DUUX-5 FENELON	SSK (VARIOUS)	2.00	6.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00
DUUX-5 FENELON	SSK/SSN/SSBN (CHINA)	2.00	6.00	6.00	6.00	4.00	4.00	4.00	4.00	4.00	4.00	46.00
DUUX-5 FENELON	SSK (SPAIN)	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DUUX-5 FENELON	SSK (ARGENTINA)	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DUUX-5 FENELON	SSK (PAKISTAN)	2.00	0.00	2.00	2.00	2.00	0.00	0.00	0.00	0.00	0.00	6.00
HS-12	ZHI-9/SH-5 (CHINA)	0.20	2.00	2.00	2.00	2.00	1.60	1.60	1.60	1.60	1.20	16.80
TOWFISH	MCMV (NORWAY)	12.50	12.50	12.50	12.50	12.50	0.00	0.00	0.00	0.00	0.00	50.00
TSM-2022	MCMV (EGYPT)	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

(TABLE 2 - continued)

Program	Application (Operator)	Unit Cost (MM)	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	TOTAL 97-06
Corporation - Thomson CSF (continued)													
TSM-2022	MCMV (MALAYSIA)	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TSM-2022	MCMV (SINGAPORE)	12.50	12.50	25.00	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00
TSM-2233 ELEDONE	SSK (SPAIN)	15.00	0.00	0.00	0.00	15.00	15.00	15.00	15.00	0.00	0.00	0.00	60.00
TSM-2233 ELEDONE	SSK (SAUDI ARABIA)	15.00	0.00	0.00	15.00	15.00	15.00	15.00	0.00	0.00	0.00	0.00	60.00
TSM-2233 ELEDONE	SSK (FRANCE)	15.00	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00
TSM-2233 ELEDONE	SSK (PAKISTAN)	15.00	0.00	15.00	15.00	15.00	0.00	0.00	0.00	0.00	0.00	0.00	45.00
TSM-2633 SPHERION	FF (AUSTRALIAN NAVY)	4.00	0.00	4.00	4.00	4.00	4.00	8.00	0.00	0.00	0.00	0.00	24.00
TSM-2633 SPHERION	FF (INDIA)	4.00	4.00	0.00	4.00	4.00	4.00	4.00	0.00	0.00	0.00	0.00	20.00
TSM-2633 SPHERION	FFL (MALAYSIA)	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TSM-2633 SPHERION	FF (NEW ZEALAND)	4.00	4.00	4.00	0.00	0.00	4.00	4.00	0.00	0.00	0.00	0.00	16.00
TSM-2633 SPHERION	FF/FFL (VARIOUS)	4.00	8.00	16.00	20.00	20.00	16.00	16.00	20.00	20.00	20.00	20.00	176.00
TSM-2633 SPHERION	FF (TAIWAN)	4.00	4.00	4.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.00
TSM-2640 SALMON	FFL/FAC (VARIOUS)	4.00	4.00	8.00	12.00	12.00	12.00	12.00	12.00	8.00	0.00	0.00	80.00
TYPE 2019	SSBN/SSN/SSK (UK)	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TYPE 2054	VANGUARD SSBN (UK)	30.00	0.00	30.00	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	60.00
TYPE 2093	MCMV (KOREAN NAVY)	5.00	0.00	5.00	0.00	5.00	0.00	5.00	0.00	5.00	0.00	5.00	25.00
TYPE 2093	MCMV (UKRN)	5.00	25.00	20.00	10.00	15.00	10.00	0.00	0.00	0.00	0.00	0.00	80.00
TYPE 2093	MCMV (VARIOUS)	5.00	0.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	45.00
TYPE 2093	MCMV (AUSTRALIAN NAVY)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	0.00	0.00	0.00	0.00	30.00
THOMSON-CSF			143.00	194.50	184.00	160.50	130.60	133.60	87.60	67.60	30.20	39.20	1170.80
Corporation - ULTRA ELECTRONICS													
TYPE 2031(Z)	DD/FF (UK)	6.00	18.00	18.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
ULTRA ELECTRONICS			18.00	18.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
Printout Total -			461.95	482.65	413.45	397.90	342.10	356.90	263.00	245.70	230.30	180.80	3374.75

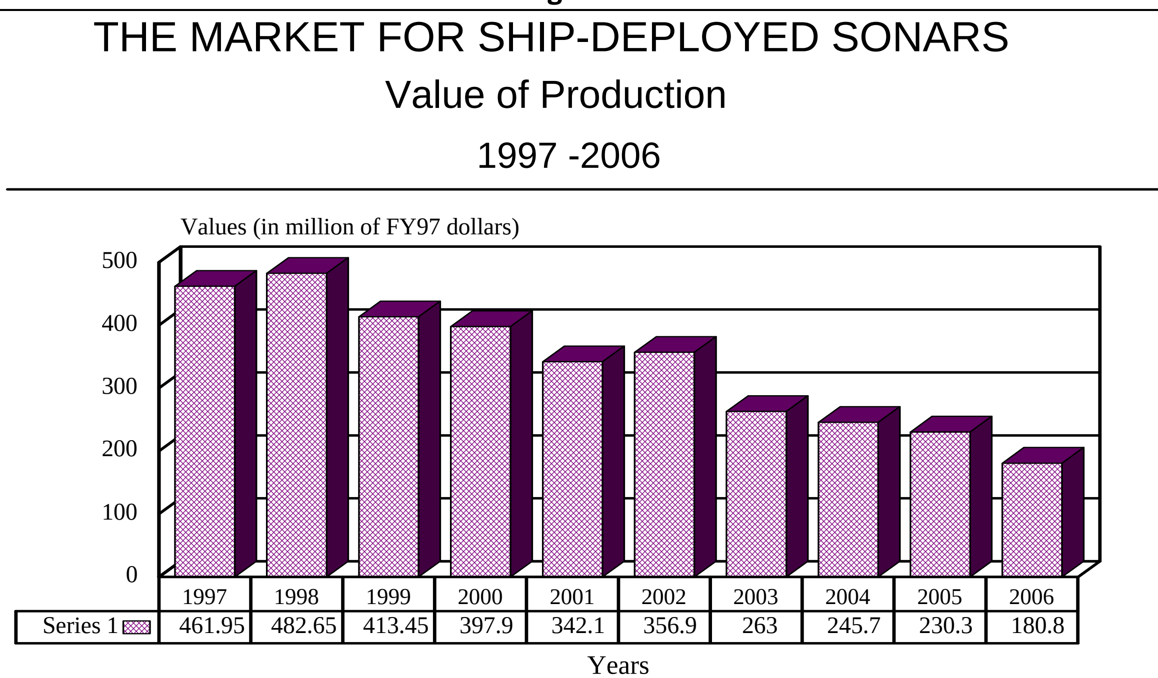
(TABLE 2 - end)

Figure 1



	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
	123	129	77	79	67	64	44	45	36	36

Figure 2



	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Series 1	461.95	482.65	413.45	397.9	342.1	356.9	263	245.7	230.3	180.8

Table 3
The Market for Ship-Deployed Sonars
Unit Production by Company

Manufacturer	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total 97-06
ALLIEDSIGNAL AEROSPACE CO	3	4	4	3	3	1	0	1	1	1	21
AUSTRALIAN DEFENSE RESEARCH CENTER	1	1	1	1	1	0	0	0	0	0	5
BREMER VULKAN GMBH	19	21	11	14	11	11	7	8	4	6	112
BRITISH AEROSPACE	1	3	1	2	0	0	0	0	0	0	7
CERIDIAN CORP	2	3	2	2	2	1	0	0	0	0	12
COMPUTING DEVICES INTERNATIONAL	2	1	1	0	0	0	0	0	0	0	4
CONTRACTOR TO BE SELECTED	0	0	0	1	0	3	3	3	6	1	17
HUGHES AIRCRAFT CO	0	0	1	0	0	0	0	0	0	0	1
LOCKHEED MARTIN CORP	46	47	13	13	13	12	10	10	10	10	184
NEC CORP	0	0	0	0	0	0	0	0	0	0	0
NORTHROP GRUMMAN CORP	3	3	3	3	3	1	0	0	0	0	16
RACAL ELECTRONICS PLC	1	1	0	1	0	1	0	0	0	0	4
RAYTHEON CO	7	2	3	3	4	3	1	1	1	2	27
THOMSON-CSF	35	40	37	36	30	31	23	22	14	16	284
ULTRA ELECTRONICS	3	3	0	0	0	0	0	0	0	0	6
Printout Total -	123	129	77	79	67	64	44	45	36	36	700

(TABLE 3 - continued)

Table 4
The Market for Ship-Deployed Sonars
Values of Production by Company

Manufacturer	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	TOTAL 97-06
ALLIEDSIGNAL AEROSPACE CO	27.300	29.300	15.100	6.000	6.000	2.000	0.000	2.000	2.000	2.000	91.700
AUSTRALIAN DEFENSE RESEARCH RESEARCH CENTER	10.000	10.000	10.000	10.000	10.000	0.000	0.000	0.000	0.000	0.000	50.000
BREMER VULKAN GMBH	85.000	103.000	67.000	81.000	62.000	66.000	53.000	54.000	32.000	38.000	641.000
BRITISH AEROSPACE	1.000	3.000	1.000	2.000	0.000	0.000	0.000	0.000	0.000	0.000	7.000
CERIDIAN CORP	6.000	9.000	6.000	6.000	6.000	3.000	0.000	0.000	0.000	0.000	36.000
COMPUTING DEVICES INTERNATIONAL	6.250	0.750	0.750	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7.750
CONTRACTOR TO BE SELECTED	0.000	0.000	0.000	15.000	0.000	45.000	45.000	45.000	90.000	15.000	255.000
HUGHES AIRCRAFT CO	0.000	0.000	18.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	18.000
LOCKHEED MARTIN CORP	61.800	71.300	50.900	50.900	50.900	47.800	41.600	41.600	41.600	41.600	500.000
MULTI-CONTRACTORS	3.900	6.000	7.400	9.200	9.300	9.400	9.800	10.000	11.000	11.000	87.000
NEC CORP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NORTHROP GRUMMAN CORP	17.200	18.800	22.800	25.800	25.300	19.600	16.500	16.000	16.000	14.000	192.000
RACAL ELECTRONICS PLC	1.000	1.000	0.000	1.000	0.000	1.000	0.000	0.000	0.000	0.000	4.000
RAYTHEON CO	81.500	18.000	30.500	30.500	42.000	29.500	9.500	9.500	7.500	20.000	278.500
THOMSON-CSF	143.000	194.500	184.000	160.500	130.600	133.600	87.600	67.600	30.200	39.200	1170.800
ULTRA ELECTRONICS	18.000	18.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	36.000
Printout Total -	461.950	482.650	413.450	397.900	342.100	356.900	263.000	245.700	230.300	180.800	3374.750

(TABLE 4 - end)

Figure 3

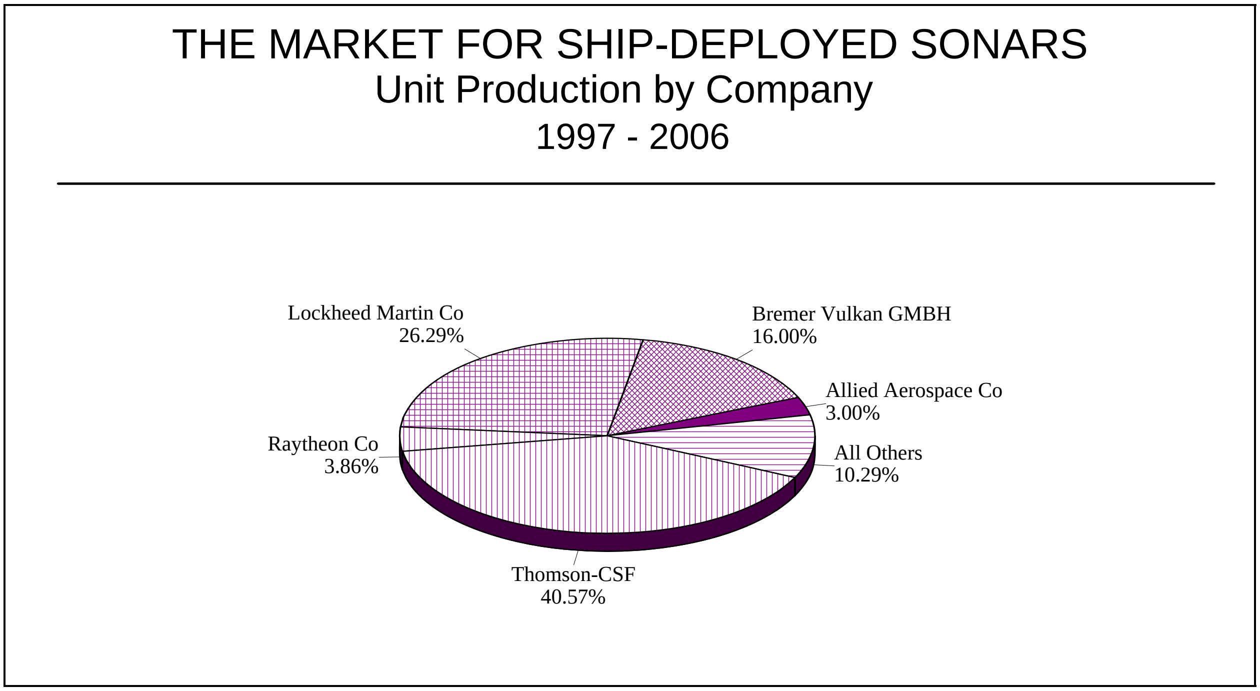


Figure 4

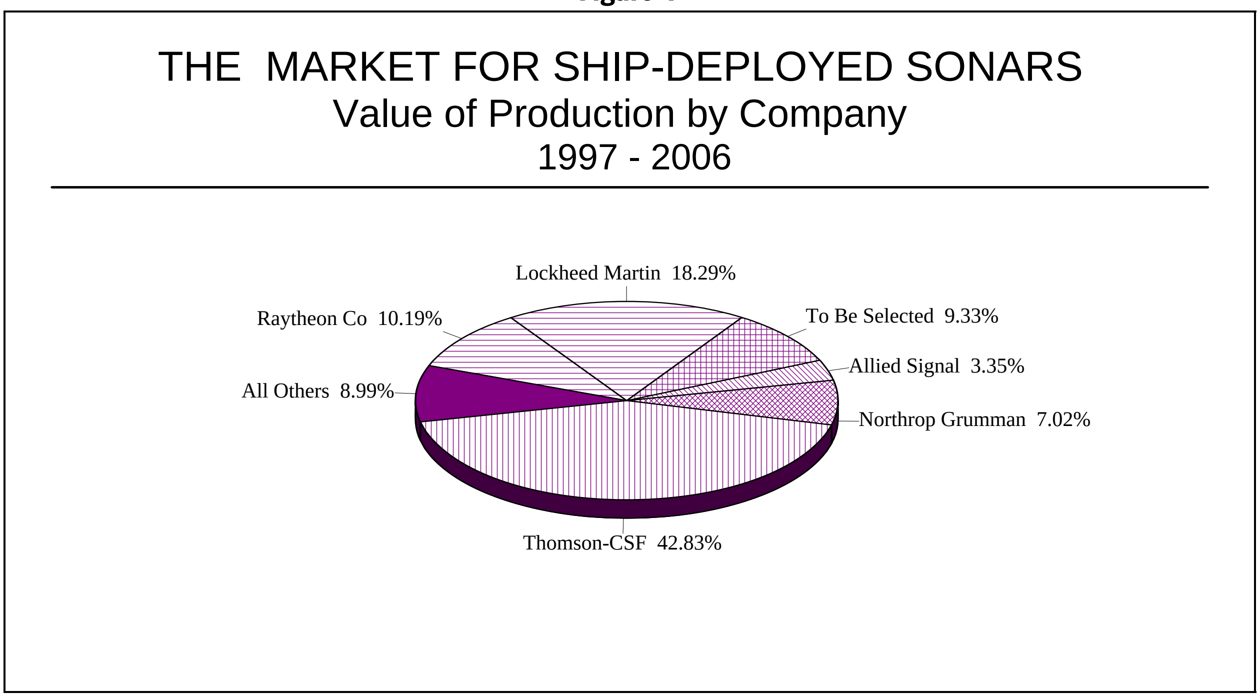


Table 5
The Market for Ship-Deployed Sonars
Units of Production % Market Share by Company

Company	Total 97-01	% Mkt Share	Total 02-06	% Mkt Share	Total 97-06	% Mkt Share
ALLIEDSIGNAL AEROSPACE CO	17	3.58%	4	1.78%	21	3.00%
AUSTRALIAN DEFENSE RESEARCH CENTER	5	1.05%	0	0.00%	5	0.71%
BREMER VULKAN GMBH	76	16.00%	36	16.00%	112	16.00%
BRITISH AEROSPACE	7	1.47%	0	0.00%	7	1.00%
CERIDIAN CORP	11	2.32%	1	0.44%	12	1.71%
COMPUTING DEVICES INTERNATIONAL	4	0.84%	0	0.00%	4	0.57%
CONTRACTOR TO BE SELECTED	1	0.21%	16	7.11%	17	2.43%
HUGHES AIRCRAFT CO	1	0.21%	0	0.00%	1	0.14%
LOCKHEED MARTIN CORP	132	27.79%	52	23.11%	184	26.29%
NORTHROP GRUMMAN CORP	15	3.16%	1	0.44%	16	2.29%
RACAL ELECTRONICS PLC	3	0.63%	1	0.44%	4	0.57%
RAYTHEON CO	19	4.00%	8	3.56%	27	3.86%
THOMSON-CSF	178	37.47%	106	47.11%	284	40.57%
ULTRA ELECTRONICS	6	1.26%	0	0.00%	6	0.86%
Total -	475	100.00%	225	100.00%	700	100.00%

(TABLE 5 - end)

Table 6
The Market for Ship-Deployed Sonars
Value of Production % Market Share by Company

Company	Total 97-01	% Mkt Share	Total 02-06	% Mkt Share	Total 97-06	% Mkt Share
ALLIEDSIGNAL AEROSPACE CO	83.700	3.99%	8.000	0.63%	91.700	2.72%
AUSTRALIAN DEFENSE RESEARCH CENTER	50.000	2.38%	0.000	0.00%	50.000	1.48%
BREMER VULKAN GMBH	398.000	18.97%	243.000	19.03%	641.000	18.99%
BRITISH AEROSPACE	7.000	0.33%	0.000	0.00%	7.000	0.21%
CERIDIAN CORP	33.000	1.57%	3.000	0.23%	36.000	1.07%
COMPUTING DEVICES INTERNATIONAL	7.750	0.37%	0.000	0.00%	7.750	0.23%
CONTRACTOR TO BE SELECTED	15.000	0.71%	240.000	18.80%	255.000	7.56%
HUGHES AIRCRAFT CO	18.000	0.86%	0.000	0.00%	18.000	0.53%
LOCKHEED MARTIN CORP	285.800	13.62%	214.200	16.78%	500.000	14.82%
MULTI-CONTRACTORS	35.800	1.71%	51.200	4.01%	87.000	2.58%
NORTHROP GRUMMAN CORP	109.900	5.24%	82.100	6.43%	192.000	5.69%
RACAL ELECTRONICS PLC	3.000	0.14%	1.000	0.08%	4.000	0.12%
RAYTHEON CO	202.500	9.65%	76.000	5.95%	278.500	8.25%
THOMSON-CSF	812.600	38.73%	358.200	28.06%	1170.800	34.69%
ULTRA ELECTRONICS	36.000	1.72%	0.000	0.00%	36.000	1.07%
Total -	2098.050	100.00%	1276.700	100.00%	3374.750	100.00%

(TABLE 6 - continued)

Figure 5

THE MARKET FOR SHIP-DEPLOYED SONARS
Unit Production % Market Share by Company
1997 - 2006

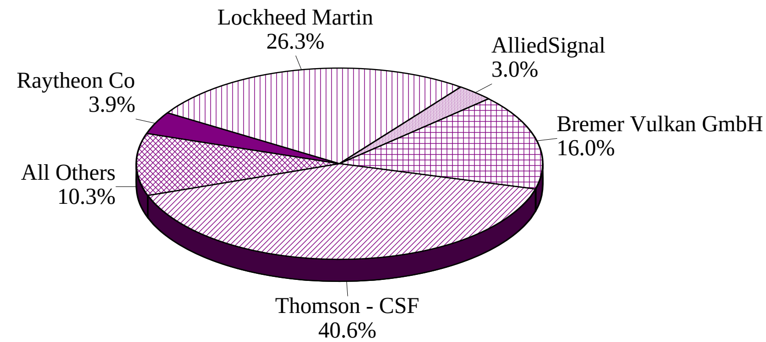
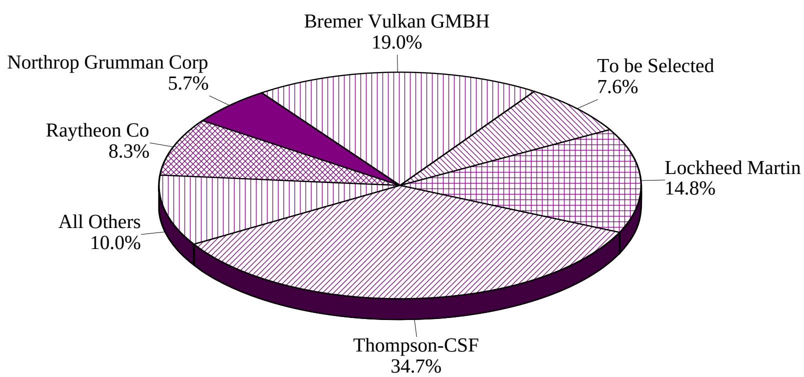


Figure 6

THE MARKET FOR SHIP-DEPLOYED SONARS
Value of Production % Market Share by Company
1997 - 2006



Conclusion

ASW Role. Sonar technology is, and will remain, the primary means of detecting, locating, classifying and tracking submarines. While sonar is effective, its capabilities are constrained by highly variable conditions such as varying ocean layers that resist signal penetration, quieting of submarines, use of decoys or jammers, and the extensive varieties of noises emitted by ocean life. Sonar systems primarily developed for use in blue water are not very effective in green and brown water environments.

The forecast period will see a fundamental change in the sonar market worldwide. The existing systems were designed and developed to detect Soviet submarines operating in the blue water environment. The Soviet threat is now all but gone, and the evolving threat is that of diesel-electric submarines operating in the shallow green and/or brown water environment. The conventional sonar in use is very limited in this new environment. Companies must develop sonar for the new market. There will still be a small market for blue water sonar for the blue water navies.

The United States possesses the numerically dominant naval force in the world and will continue to do so for the remainder of this decade. The service has reorganized its various operational communities – surface, submarine, and carrier aviation – under a senior admiral for planning, a step that has reduced the influence of these individual groups on funding requests. In terms of funding, the service's strategy is to pump scarce dollars into higher priority programs to include anti-surface and anti-air warfare. The US Navy has already formulated plans to accelerate decommissioning of older ships and submarines and will maintain a fleet consisting of less than 350 ships by the year 2000. This will lead to a substantial reduction in the number of sonar systems procured.

All the traditional naval powers are also reducing the size of their navies. To this end, the sales of sonar systems will be reduced. In the aftermath of the canceled SQY-1 program, the USN is going to upgrade the SQQ-89 with selected SQY-1 enhancements for backfit to its DDG-51 Flight I/II ships. The less costly Flight IIA ships that will enter construction later in the decade will feature a partial ASW suite, as these ships will only be equipped with the SQS-53 hull sonar.

For companies to survive in this time of reduced defense budgets worldwide, they must aim for new markets and the development of new systems. The new markets will be developing countries and Pacific Rim countries. Many of these developing maritime powers will be purchasing new, larger and more effective ships than was previously the case and will be operating in unfamiliar tactical roles. These new multirole vessels will have effective and capable sonars installed. At present, ASW is a matter of supreme indifference to these clients; this will change.

Basic theoretical, operational and environmental research will be the most important area of the sonar market for the remainder of this decade. Sonar systems will continue to be improved, but these advances will be more or less canceled by improved submarine technology (including quieter powerplants), anechoic coatings, and active countermeasures. Developments in the art (not science!) of signals processing will be key. Sonar users are likely to see reductions in operational manpower requirements, increased automation, integration of weapons systems and associated countermeasures, and enhanced data presentation through the use of large, unambiguous color displays. Furthermore, improved efficiency, lower maintenance costs, and the capability to tailor solutions to particular circumstances will also be forthcoming.

System reliability must be very high. Customers want systems that will be up more than they will be down. Finally, training and support will be a high-profile area. Companies that manufacture a system must train operator and maintenance personnel. In addition, companies must be available to go to remote locations to aid in repairs of the system.

MCM Role. The use of sonar in the mine countermeasures role faces a different future. Sonar is still quite effective in MCM and represents the single best solution. However, even here sonar technology has to be constantly advanced as the mine threat evolves technologically. As mines aimed directly at the destruction of MCMVs spread, emphasis must be placed on standoff mine warfare using unmanned techniques and expendable mine destructors. Sonar technology will be downsized to allow the fit of a full sonar suite onboard these tiny platforms.

Another technological focus will be on ways of defeating anechoic coatings for mines and those that bury themselves in the seabed. The intelligent mobile mine is the most significant threat in the near future, so there will be an emphasis on early detection and the ability to classify the mine from as far away as possible. A possible further mine development could be a minefield provided with self-defense mines that home in on sonar signals generated by an MCM craft. Such systems are already being advertised, most notably by the Gidropribor Design Bureau in Russia.

There are even fewer players in the MCM market, with Thomson-Marconi Sonar Systems undoubtedly being the biggest single player. The US has now entered this market with the SQQ-32, which proved itself during the Persian Gulf War.

Perhaps the most remarkable event of the last year is the speed with which the sector has been rationalized. There are now just three major companies involved here with two more hovering on the borderline. The rest of the participants are niche groups of relatively little significance. In an environment where opportunities are limited and great corporate strength is required to maintain the ability to seize business when it appears, this is not an undesirable state.

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