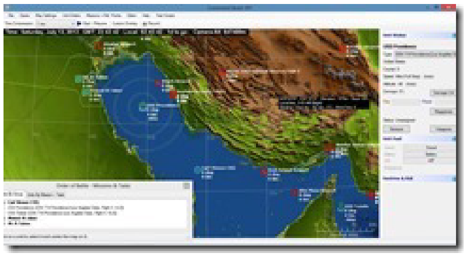
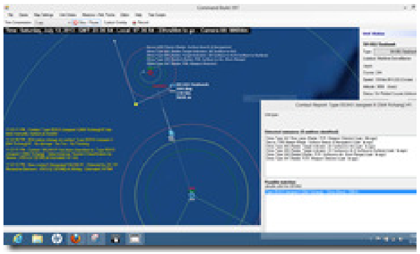
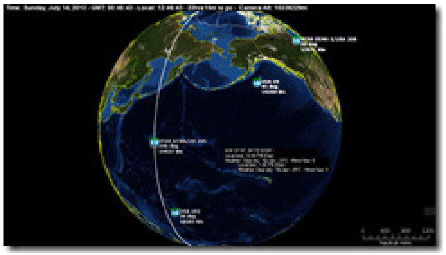

JED SPECIAL

UP PERISCOPE, UP ANTENNA

Hunter-killer submarines increasingly are hunter-gatherers of intelligence

By **Dr. Norman Friedman**

Lieutenant Commander Greg Sammut, commanding officer of the Australian attack submarine HMAS *Farncomb,* orders the firing of Mark 48 torpedo in a test off Perth in 1999. Submarine commanders are expected to fulfill a wide range of SIGINT and EW missions in addition to their traditional attack roles. (Royal Australian Navy photo)

Last year a senior submarine officer remarked that for some time all US nuclear attack submarines had been "nationally" tasked - assigned, not by fleet commanders who needed anti-submarine cover, but only by the US National Command Authority. That was a technical way of saying that submarine missions had almost reduced to only two: electronic reconnaissance and cruise-missile attacks against land targets. Of the two, electronic reconnaissance is by far the most important. Typically it is characterized as "indications and warning."

We now know that much of the US submarine force's Cold War time was spent in various forms of reconnaissance. For example, only a submarine could get close enough to shore to localize some air-search radars and to pick up their distinctive emissions. Because the submarine acted covertly, it could hope to detect tests of war-reserve operating modes, whereas the radar's operators would be well aware of the presence of ferret aircraft or of satellites. For that matter, a submarine might pick up reactions to the approach of an airplane. Overall, the submarine's advantages were its stealth and its ability to loiter. More than a decade ago, in connection with the design of what became the Virginia-class, a submariner commented that other platforms could pick up 97 percent of target electronic emissions - but that only a covert submarine could pick up the 3 percent a target normally turned off in the presence of known collection platforms.

Now, moreover, the percentages are changing. Many countries depend more and more on cellular-telephone nets, not for special purposes, but for most of their telephone service. Wiring their countries is just too expensive to be practical. Because cell phones are radios, their signals can be collected. Recently, for example, US prosecutors have cited intercepted cell-phone conversations between terrorists as evidence of Osama Bin-Laden's involvement in various plots. However, cell-phone emissions are necessarily quite weak, to avoid interference from signals emitted at much the same frequency in neighbouring cells. Many of these telephones operate at radar frequencies, so their signals can be trapped in atmospheric layers near the surface. Collection requires proximity to the emitters. It also entails considerable computing power, since a mass of signals must be disentangled. Both might be provided by an embassy or consulate in a city, but a submarine is a very attractive platform.

Silent Service Call

Covertness is obviously relative. A submarine loitering in waters subject to heavy surveillance will likekly be detected if her ESM mast remains above water for hours at a time. On the other hand, a glance at the naval reference books will show that Third World anti-submarine warfare capability is somnolent at best. Those promoting anti-submarine sensors and weapons seem to have had little sales success even in places, such as the Gulf, where submarine threats have recently escalated. Merely remaining submerged gives a submarine most of the necessary covertness. Moreover, a nuclear submarine can outrun most potential Third World pursuers.

From the submarine's point of view, the signals being intercepted are changing quite rapidly. Open or flexible architecture is more and more important, and especially so for the submarine, as compared to other interception platforms. Because the submarine's innards must be contained within a hard pressure hull, it is especially difficult to install large pieces of equipment. Moreover, it is very difficult to enlarge the pressure hull; the volume available when the submarine is built is essentially the volume she will have throughout her lifetime. By way of contrast, a surface ship can easily grow extra deckhouses. Radomes and other bulges often emerge from veteran ELINT aircraft. For a submarine, however, the volume of the enclosed pressure hull must exactly match the submarine's underwater weight, so it can neither grow nor shrink. Ballast built in when the submarine is completed provides limited compensation for additional weight, but the key word is limited. From the Ohio-class on, American submarines have been designed with unusually large hatches for new equipment, but that does not change the very high cost of cutting open a pressure hull and installing, say, a new databus.

The old destroyer-escort HMAS *Torrens* dies at the hand of a Mark 48 torpedo fired by the Collins-class submarine HMAS *Farncomb* in a 1999 test. The submarine was over the horizon and submerged when it fired the torpedo. Real-life missions of submarines are more likely to feature over-the-horizon intelligence gathering and cell-phone interception. (Royal Australian Navy photo)

The new Virginia-class incorporates a high-capacity asynchronous-transmission-mode (ATM) bus, to support whatever new sensors she will need during her lifetime. That is usually taken to mean new sonars and perhaps new electro-optical periscopes, but it is probably even more applicable to new higher-capacity ELINT sensors, the input from which must be processed on board, hence must flow through some sort of databus. Traditional submarine ELINT systems were stand-alone affairs, in which mast-mounted sensors were connected directly to recorders and to analysis stations, but current submarines are built around distributed multi-computer combat systems. Several navies, including the US Navy, are installing photonics masts that carry electro-optical cameras in place of traditional periscopes. Such masts do not penetrate the pressure hull, and so are called "non-penetration masts."

For the future there are two very interesting possibilities, both being pursued actively by the US Navy. One is a remote sensing device mounted on an unmanned vehicle. The US Navy is currently fielding unmanned undersea vehicles for minefield reconnaissance, but electronic reconnaissance, using a mast deployed by the vehicle (or even a buoy deployed by the vehicle) is clearly a possibility. For that matter, current submarine masts (such as periscopes, as well as electronic sensing masts) may well ultimately be replaced by buoys connected to the submarine by fiber optics. The distance to a remote buoy is not too great, and the great advantage the buoy offers is that it does not mark the submarine's position the way a conventional mast does. Clearly the submarine would need to know the buoy's precise position, but existing technologies, such as fiber-optic gyros, promise exactly that.

The other possibility is the micro-UAV currently under development. The US Navy's Team Submarine, which is sketching out the next-generation US submarine, emphasizes the submarine's role in preparing a 21st-century battlespace, conducting reconnaissance and then providing valuable land-attack firepower. Such a submarine might easily launch an air vehicle which could dispense micro-UAVs. They, in turn, could seek out and land on the antennas of cell-phone nets. In such positions, the micro-UAVs would pick up cell-phone traffic and might even use the target cell-phone system to transmit their reports home. At the least, the micro-UAV would probably be able to take its power from the cell-phone antenna on which it landed.

The Telltale Sail

All of this is aside from the traditional target of submarine surveillance: enemy radar systems. Any US naval surface force attacking land targets faces, among other things, coast-defense anti-ship missiles. The missiles, in turn, usually depend on coastal radars for targeting. It follows that part of any large-scale littoral operation will be the detection (and, if possible, neutralization) of the radars and the missiles. Many of these radars exploit local phenomena such as ducting, which both increase their surface-surveillance range and greatly complicate detection from the air or from space. An offshore submarine is ideally placed to detect the radars, which will probably be used sporadically to complicate detection. The submarine may also be well placed to land SEAL teams to destroy both radars and missile launchers she detects.

Current US nuclear attack submarines bear physical evidence of the importance of electronic surveillance in the form of their tall sails. The sail houses the upper part of each retracted mast, so total mast length is roughly the sum of hull

diameter and sail height. When the submarine is at periscope depth - i.e., with the mast fully raised - her steadiness depends on how deep in the water her hull is. The longer the mast (the higher the sail), the steadier the submarine, because the deeper her hull the less she is affected by waves on the surface. Sail height carries real prices. First, the sail is an important source of drag. Second, because the sail distorts water flow along the submarine's hull, it can create patterns that interact with the submarine's propeller to create noise (this is not a problem in new classes using pump-jets). Third, the sail causes snap roll; when the submarine turns, it acts as a plane and can cause inadvertent dives. These are real problems, and at least twice, in the designs of the Thresher- (later Permit) and Los Angeles-classes, there were serious attempts to eliminate sails entirely. In the Sturgeon-class, successors to the Threshers, the sail was considerably enlarged specifically to improve electronic-surveillance capability. During the Cold War, the Soviets apparently had far less interest in electronic surveillance (perhaps because they doubted their submarines could survive in US waters), and they used much lower sails - which the US Navy considered copying in the Seawolf-class. That this was not done suggests strongly that electronic-surveillance requirements carried the day.
Other navies vary in their interest in surveillance. At least during the Cold War, the UK Royal Navy was clearly intensely interested in surveillance, and indeed British firms sometimes displayed special receiving antennas. One US firm, Southwest Research, has made a special communications-band receiving antenna for British submarines, and the Royal Navy sometimes acknowledges submarine installation of COMINT receivers. The Royal Australian Navy sees its new Collins-class primarily as a surveillance platform. Although the submarine's ESM and ELINT capacities were not affected by current problems with the craft's combat system, the Australians have taken the replacement of the combat system as an opportunity to buy a new open-architecture electronic-surveillance system. The Israelis clearly see their new Dolphin-class at least partly as surveillance platforms, as indicated by the elaborate array of masts which have been shown protruding from their sails.

Surveillance places considerable demands on a submarine. She needs the space for system operators, and the system may need considerable electrical power for receivers and for computers. The submarine's sail must, at least for now, accommodate extra masts. On-site analysis is necessary both to focus the submarine's finite resources and because the submarine's ability to transmit back what she obtains can be quite limited. US submarines, for example, have EHF satellite dishes, but they cannot transmit lengthy messages, because sustained exposure can be dangerous. Considerable effort is currently going into increased antenna gain, which should make for higher data rates during the bursts available to a submarine. This same improved antenna performance is needed so that submarines can send images back via satellite. For the future, it may be possible for a submarine on surveillance duty to lay a fiber-optic net extending well out to sea. She may communicate acoustically with the net, and a node well out to sea, clear of likely surveillance, may retransmit messages to a satellite, thus evading the current limitations on transmission time and on antenna gain.

There is also a more traditional side to submarine electronic warfare, a combination of self-defense and tactical targeting (or situational awareness) support. Submarines are inherently quite vulnerable, and they are easiest to detect when they poke masts (or their hulls) through the surface. Thus, it has long been important for a submarine to be able to detect hostile radars, so that she can crash-dive before the users of those radars come within lethal range. Typically a submarine has an omni-directional warning antenna atop a periscope. It functions much like a radar warner on an airplane, and indeed some submarine warning systems are versions of aircraft systems.

The submarine *Seawolf* (SSN 21) puts to sea in Narragansett Bay for her first at-sea trial operations on July 3, 1996. The Seawolf-class represents the US Navy's most advanced attack aubmarine, and perhaps the end of the line dedicated attack submarines. Only three Seawolf subs are likely to join the fleet. The follow-on Virginia-class is designed for a broader array of missions, with an emphasis on intelligence gathering, EW, land attack, and covert operations. (US Navy photo, courtesy of General Dynamics)

The World Tools Up for Sub EW

Outside a few major navies, submarines are powered by diesels feeding batteries; those diesels breathe only when the submarine is either surfaced or snorkelling. In either case, a radar target is presented, and radar warning is vital. Clearly the antidote to radar warners would be the sort of stealthy radar typified by the Thales Scout or the Philips Pilot. It seems surprising, then, that serious proposals to develop versions for maritime-patrol aircraft have, apparently, found no buyers. The surface versions which have been bought seem to have been conceived mostly to preserve surface combatants from detection, rather than to promote attacks on submarines. It is possible that operators of maritime-patrol aircraft consider it more useful to force submarines to dive over a wide area, and thus to reduce their mobility, than to multiply the chances of a successful undetected attack. One argument would be that the sound of an airplane coming close enough to attack can be detected by the submarine, particularly if the latter has a very sensitive passive sonar, such as a towed array. Thus, reducing radar counter-detectability might not seem sufficiently valuable.

Then there is situational awareness. Fifty years ago, US submarines were exploiting ducting to detect and track surface formations passively, from well beyond the visual horizon. At the time, they had no weapon with long-enough range to exploit the data they were able to collect, but their ESM sets certainly clarified the tactical situation, far better than the traditional quick periscope scan. With the advent of anti-ship missiles like the US Sub-Harpoon and the French Sub-Exocet, such data became far more useful. If the target ship could be tracked precisely enough, she could be attacked. At the very least, a missile could be sent down the line of bearing to the detected ship. From a technical point of view, the requirement for targeting, as opposed to simple situational awareness, is reflected in a demand for more precise direction-finding. Simple ESM sets use six or eight ports (generally cavity-backed spiral antennas), the amplitude of whose outputs can be compared.

The step beyond clarifying the tactical situation, to support actual targeting, is interferometry, in which the phases of the signals picked up at the ports are compared. In US service, for example, the advent of a precision (interferometric) direction-finder (DF), the AN/BLD-1, presumably reflects a need to be able to target a missile beyond the horizon. The most publicized example of an upgrade to support missile targeting is the Racal Sea Lion, supplied to Denmark after the Royal Danish Navy bought Sub-Harpoon missiles. The Danes particularly wanted high precision so that they could distinguish neighbouring emitters in a crowded area.

The Lockheed Martin ASTECS (Advanced Submarine Tactical ESM Combat System) or AN/BLQ-10, for the Virginia-class integrates threat warning and intelligence gathering, as well as sufficiently good direction-finding for anti-ship and land-attack missile targeting. It may be backfitted to the Seawolf-class (to replace the AN/WLQ-4) and perhaps to some Los Angeles-class vessels. (US Navy photo)

The US Navy built the Sturgeon-class with electronic reconnaissance in mind; one series of submarine was specially enlarged to provide space for operators. The associated automated ELINT system was General Dynamics Mountain View's (ex-GTE) AN/WLQ-4 (Sea Nymph), which presumably could not fit on board a much more tightly designed Los Angeles. A modernized version is on the new Seawolf-class. Los Angeles-class submarines use the AN/WLR-18 (Classic Salmon) to cover 5 kHz-2 Ghz and the associated AN/WSQ-5 (Cluster Spectator) to cover 30 Mhz-40 GHz. Both are automated. The difference in code names (Classic vs. Cluster) suggests that the WLR-18 is primarily for SIGINT, whereas the WSQ-5 is primarily a radar-intercept system for tactical intelligence gathering. The standard narrowband submarine radar-analysis unit is General Dynamics Mountain View's AN/WLR-8, installed in place of the AN/WLQ-4 in the Los Angeles-class; the associated radar warner is the AN/WLR-10. Ohio-class strategic submarines carry a variant of the WLR-8. The standard US submarine suite includes the AN/BLA-4, a monopulse radar DF antenna, Litton's AN/BLD-1 radar DF (interferometer, for missile targeting), and the AN/BRD-7/8/9 for communications intercept and DF. The new Seawolf-class places the BRD-7 antenna atop a mast which includes BLD-1 functionality. There is also a periscope-mounted radar warning receiver, the AN/BLR-15, which provides limited directional information.

The next-generation system is Lockheed Martin's ASTECS (Advanced Submarine Tactical ESM Combat System), or AN/BLQ-10, for the Virginia-class; it may be backfitted to the Seawolf-class (to replace the WLQ-4) and perhaps to some Los Angeles-class boats. ASTECS integrates threat warning and intelligence gathering, as well as sufficiently good DF accuracy for anti-ship missile targeting. Presumably the same DF accuracy would support attacks against land targets by future short-range bombardment missiles.

ARGOSystems (now part of Condor) makes the AR-700 series of submarine ELINT/ESM systems, which have been bought by, among others, Australia (AR-740 for the Collins-class), Egypt (to support Sub-Harpoon), Germany (Ginny for Type 206A submarines, replacing the DR 2000), Greece (to support Sub-Harpoon), the Netherlands, Sweden, and Turkey. Chile is to use an improved version (the AR-900) on board her French Scorpene-class submarines. South Korea uses a GTE/Israeli ESM set. Litton Marine's Guardian Star is being installed on Canadian Victoria (ex Upholder)-class submarines.

Many German-built Type 209s, as well as older French export submarines, are equipped with the French Thales (formerly Thomson-CSF) X-band DR 2000U ESM set, essentially for radar warning. Originally, it did not even have an automatic radar identifier. This set provides limited radar direction-finding using six cavity-backed spiral antennas and simple amplitude comparison. The digital derivative is the DR 3000U (ARUR-13 in French service).

New German submarines (Type 212) use DASA's (now EADS) FL 1800U, which covers 0.5-18 GHz in five bands. The antenna, the USK 800/4, contains four spiral antennas under a dome which also accomodates a radar warner.

Typical DF accuracy is 5°, obtained by integrating DF values as the periscope mast under the antenna rotates. DASA also produces a submarine HF intercept and DF receiver and antenna, which the Royal Navy uses on board all its nuclear attack submarines as CXA(2); the German designation is Telegon 12.
In Israel, Elbit produces the TIMNEX 4 CH series of ELINT and missile-targeting sets. The system covers 2-18 GHz in four bands, and there is also a radar warner for the submarine's periscope. DF resolution is 1.4° (accuracy is 5° at 2-8 GHz and 3° at 8-18 GHz). Besides Israel, the system is reportedly used by China, Taiwan, and South Africa, and it was formerly on board Australian Oberons, now retired.

Existing Italian submarines use the Elettronica THETIS (BLD-727, a designation suggesting a DF unit rather than an entire ELINT or ESM system). However, the new Type 212s are to use German systems, probably including FL 1800U.

The standard Japanese submarine intercept suites are the ZLA-6 (Yuushio-class) and ZLA-7 (Harushio- and Oyashio-classes).

Russian submarines and their export variants all carry radar warners (with DF arrays). The simplest is the 1-10 GHz Nakat (Flag; NATO Stop Light), whose antenna carries four tiers (bands) of DF antennas, eight per tier. Some carry a pimple at the top for an omni antenna feeding an IFM. The antenna feeds a simple CRT, and analysis is generally manual. For example, a Foxtrot (Project 641)-class submarine decommissioned in 1994 had only a simple commercial CRT, and its ELINT library seems to have consisted of a blueprint listing the frequency ranges of Western radars (some of which, such as the SPY-2, did not exist). The successor was the radome-enclosed array which NATO called Bald Head (MRP-10 Zaliv-P). Typically, the dome is integrated with a radar antenna. It covers the usual tiers of DF ports. Modern submarines, such as Akulas (Project 971) and Oscars (Project 949), carry Rim Hat (Nakat-M), which is integrated with the Snoop Pair back-to-back search- radar antennas. The radome conceals tiers of DF spirals; the name implies similarity to the original Stop Light (Nakat-M reportedly dates from 1961). Russian diesel-electric submarines of the Tango- (Project 641B) and Kilo-classes (Projects 877 and 636) are equipped with the MRM-25EM (NATO Squid Head) ESM set. The latter's intercept array incorporates an IFF transponder, an unusual feature for an ESM set. During the Cold War, the Soviets exploited ducting and tropospheric scattering to target missiles beyond the horizon, but they claimed that submarine antennas were far too small, hence their beams too broad, to exploit such phenomena; submarines apparently relied either on their sonars or on third-party targeting assistance (ducting systems were placed aboard many surface units). Soviet submarines also carried HF/DF loops (NATO name, Park Lamp), but they seem to have been intended primarily to support reception of radio command signals at periscope depth rather than for intelligence-gathering. (US submarines used DF antennas for much the same purpose, from World War II onwards)

Republic of Korea ship *Lee Jong Moo* (SS 66) (left) and the USS *Columbus* (SSN 762) steam off the cost of Hawaii during RIMPAC '98 exercise. A P-3C Orion patrol aircraft flies over the formation. World submarine fleets increasingly are tasked to support their nations' intelligence services. (DOD photo)

In South Africa, Avitronics (a Celsius/Grintek company) developed the Shrike ESM system for both modernized submarines and modernized fast attack craft. It covers the 2-18 GHz band, and offers 5-6° DF accuracy.

Spanish submarines have been refitted with the locally-produced (Indra) BLQ-355 ESM system, which replaces the British Manta system. This system has reportedly been exported.

In the UK, Racal (now part of Thales) produced a series of submarine ESM systems, beginning with Porpoise (used by Chile and by Turkey). A high-precision (2° DF accuracy) version substituting a more powerful processor, Sadie, was developed for the Royal Danish Navy as Sea Lion. The latter uses amplitude comparison for 5-8° accuracy and interferometry for 2° accuracy. The Royal Navy submarine equivalent is UAP. Versions for attack submarines employ a separate missile-targeting mast carrying a pair of large spiral antennas on its back. At least three British nuclear attack submarines are equipped with a COMINT system employing a US-made (Southwest Research) AU-506 antenna, under the name Cluster Sentinel, which suggests a joint US-British program.

Crises and potential crises can occur anywhere in the world, and of all naval forces, a fast nuclear submarine can probably reach a crisis area in the least time. Moreover, it can go entirely alone, and it can arrive and stay covertly. The submarine's ability to loiter for weeks in a target area sets it apart from transitory platforms such as stealthy aircraft. For statesmen, its inherent stealth promises that its mere presence is not likely to exacerbate the crisis it is monitoring, as may be the case with surveillance aircraft. These reasons suggest that the role of the submarine will continue to evolve, and the electronic tools it carries will evolve along with it.