New technologies impacting maritime warfare

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The USS Zumwalt class destroyer sets the benchmark for stealth shaping in future surface combatants.

The technologies employed in maritime warfare inevitably reflect the basic technology available for the construction of naval vessels, but also weapons and sensors in use. This was true 2000 years ago as it is true today. The ‘digital era’ brought explosive growth in Intelligence Surveillance Reconnaissance (ISR) capabilities following the Cold War, and this more than anything else has impacted how surface and subsurface combatants are built, equipped, armed and employed. Fundamentally, the technologies driving maritime warfare today are high density photolithography and semiconductor materials and fabrication technologies, as these drive exponential growth in high density computing chips, imaging chips and radio-frequency chips. These are the basic building blocks from which ISR sensors, ISR processing and networking equipment are built, as well as weapon seekers and guidance systems.

The exponential growth observed in computing technologies, and resulting non-exponential but still very significant growth in sensor technologies used for ISR and weapon guidance, has impacted the development of warships and submarines in two very significant ways.

The first of these is the monotonically increasing cost of surface combatants and submarines observed since the 1940s. This reflects the increasingly sophisticated and expensive sensor, combat system and weapons suites carried. The pattern observed is identical to that observed with combat aircraft over the same period, but much less frequently discussed. Whereas competitive pressures a century ago led to warships with ever larger guns and ever thicker armour plating, the main game in this period is ever longer ranging sensor suites and missile armaments.

The second trend is a progressive effort to reduce the signatures of surface combatants and submarines, to reduce the effectiveness of ever improving sensor technology, and where feasible increasing transit speeds to frustrate wide area ISR capabilities. This also reflects the pattern observed in combat aircraft, in many respects also evolving to overcome improving ISR by stealth and supersonic cruise.

COMBAT SYSTEMS AND WEAPONS

The most significant developments in combat systems and weapons revolve almost completely around the shift from traditional analogue technologies to modern digital technologies.

Shipboard radars for surface search, AAW and ASMD tasks are progressively shifting away from traditional mechanically steered or pointed antenna designs to digital electronically steered fixed arrays, be it Passive or Active Electronically Steered Array (PESA/AESA) designs. These are harder to detect and track through lower sidelobe performance, and provide beam-steering agility essential for tracking small and fast moving targets, such as ASCMs and ASBMs. AESAs are also orders of magnitude more reliable than traditional mechanically steered antennas.

Importantly, AESAs also provide a good basis for Low Probability of Intercept (LPI) or ‘radar stealth’, where the signals are made extremely difficult to detect by an opponent.

The concurrent evolution to emerge is the use of these radars as ‘multifunction apertures’ supplementing datalinking for high rate digital communications, and providing in-band passive and active Electronic Warfare capabilities. These trends follow an identical pattern to that observed in airborne radars for ISR and combat aircraft.

Fast computers and fast datalinks are the enabler for fast networks, which in turn are the enabler for fast data fusion, where the outputs of multiple sensors on multiple platforms are fused to overcome individual sensor limitations and hostile jamming or stealth.

Passive sensor technology, be it radio-frequency Emitter Locating Systems (ELS) or imaging infrared or visual band sensors, continue to improve in capabilities as microelectronic device densities improve. This trend will continue as commodity imaging and radio-frequency technologies improve.

The increasing use of persistent Unmanned Aerial Vehicles (UAV) as offboard sensor platforms, and certain future use as secure digital communications relays, has also been enabled by high density digital microelectronics.

Acoustic sensors used for detecting and tracking submarines and surface combatants have continued to improve as computing power has improved.

Weapons technology has also been impacted enormously by improving microelectronic technologies. While anti-ship and land attack cruise missile airframes and propulsion, and torpedo hulls and propulsion have only evolved incrementally since the end of the Cold War, digital guidance systems and seekers have made these weapons far more difficult to defeat by jamming or decoying. Importantly, smart seekers have found their way into artillery rounds, vastly improving the odds of a kill using a traditional naval gun in surface actions or coastal bombardments.

What is abundantly clear is that as long as exponential growth continues in microelectronics, there will be ongoing growth in the capabilities of sensor suites, combat systems and weapons guidance. While the growth in the latter will not be exponential, it will still be significant. Future sensors will be better at detecting faint targets, future combat systems will be better at fusing data and extracting information, and future weapons will be harder to defeat by decoys and jamming.

Zumwalt class DDG.

Stealth in submarines and surface combatants

Improved sensor technology and combat systems, networking, and improved weapon seekers have shifted traditional boundaries in how soon an opposing submarine or surface combatant can be detected, and how effective a guided weapon will be in engaging and killing it.

Stealth has thus become a capability of high importance, which will grow in importance as sensors, combat systems and weapon seekers improve.

Submarine warfare has been centred on stealth since the 1940s, and the submariner community remains deeply immersed in the underpinning rationale. This is less true of the surface warfare community, where stealth often remains poorly understood, and thus not as strongly reflected in design requirements for warships.

In submarines, the traditional stealth imperative has been the defeat of passive and active sonar sensors. Most submarine noise is produced by the propulsion system, especially propeller cavitation, but also by internal machinery, and less so fluid flow around the hull.

The design of propellers and propulsors, and hull shaping, is increasing reliant on high performance computing simulations, the performance of which more than often grows with exponential growth in computing chips. No differently, the precision machining of propulsion components is enabled by numerically controlled milling machines, a technology that has grown from the digital technology base.

Exponential growth in radar signal and data processing has been an enabler for radar technology capable of detecting the surface wakes of submerged submarines, but especially snorkelling diesel-electric submarines. In turn this has seen increasing use of Air Independent Propulsion (AIP) in conventional submarines. To evade surface wake radar detection, submarines will have to transit much deeper and at slower speeds.

The problem of surface wake detection by radar also impacts stealth in surface combatants, as even a hypothetical completely radar invisible surface ship produces a surface wake. This was one of the first lessons learnt when the US Navy and DARPA contracted Lockheed to construct the Sea Shadow demonstrator.

The radar bands of most interest in ASuW and ASW are the centimetre wavelength X-band and Ku-band. This is because they are most effective at detecting periscopes, snorkels and their surface wakes, but also because the complex shapes in traditional surface combatant superstructures can have very large signatures in these bands. This was learned during the 1940s and all maritime radars built for ASW/ASuW since, from the enormous long range Uspekh / Big Bulge carried by maritime Tu-95RTs Bear D down to the smallest helicopter and UAV radars, operate in these bands.

What parts of a conventional surface vessel contribute the most to its radar signature depends to a large extent on the shape, size and speed of the vessel, but no less importantly on the range and elevation of the radar in question.

If the vessel is anywhere between the radar and the radar horizon, the superstructure and hull sides are the biggest contributors, followed by the wake. If the ship is just behind the radar horizon, the superstructure will be above the horizon while the hull sides and wake are below the horizon and in the ‘radar shadow’ of the wavetops at the horizon. This is also why ships designed for low radar signature display most effort invested in the superstructure, especially upper superstructure, as that most effectively degrades long-range detection. Stealth shaping of hull sides extends that advantage to the radar horizon, and beyond.

How much stealth is enough? A conventional ship with traditional boxy superstructure has a beam aspect broadside radar cross section equivalent to hundreds of thousands of square meters or more in the upper X-band or lower Ku-band. A carefully shaped design with absorbent materials can be as low as square meters or less under ideal conditions. Signatures lower than that may be irrelevant due to wake signatures, although for these to be prominent the radar must be looking down at a reasonably steep angle to see over wavetops, which otherwise shadow the wake.

The US Navy Sea Shadow demonstrator proved the viability of faceted hull shaping. A period anecdote was that to find this vessel on radar, the operator needed to look for a black spot on the screen comprising the radar shadow of the vessel, where wavetop clutter was hidden by the invisible ship.

While ships are large enough to carry significant dead weight in absorbent material panels, shaping is still the cheapest and most effective method. The notion that materials are more important is not true, and very apparent once you perform mathematical modelling on a computer or measurements – the idea of materials being most important is a marketing myth promoted by manufacturers lacking the technology to shape designs properly.

As with stealthy aircraft, precision shaping and concealment of small radar reflecting features adds up to 30 per cent or more in costs incurred in design, test and manufacture. The payoff is not only in reduced detection ranges, but also much improved effectiveness of radar jamming equipment and radar seduction decoys like the Nulka.

The preferred shaping technique in ships is faceting, which does not incur the prohibitive aerodynamic drag costs incurred in fast jets, such as the F-117A. Typically, superstructure facets are tilted upward to bounce incoming radar signals away upward. Forward or downward tilting is not favoured as the facet forms a corner reflector with the nearby electrically conductive sea surface and actually increases the radar signature.

The best hull shaping design seen to date is that on the US Navy's DD(X)/DDG-1000 Zumwalt class destroyer, of which only three have been funded so far. The hull sides are tilted upward from above the waterline, and the superstructure follows very disciplined faceting and edge alignment rules. The Zumwalt class will be the benchmark in stealth shaping for future surface combatants, whatever its other virtues or failings might be.

The Swedish Kockums Visby class corvette also employs very good shaping, although the lower hull angles involve some less desirable compromises.

Less effective in shaping, but still much superior to traditional frigate sized surface combatants is the trimaran hulled Austal LCS-2 Independence class Littoral Combat Ship, being built by Perth based Austal in the US for the US Navy.

The popularity of catamaran and trimaran designs in smaller combatants reflects the reality that speed matters in low radar signature surface vessels, as it allows the ship to retreat from radar detection ranges faster. In ship-to-ship and ship-to-shore surface actions, this allows a commander to dart into hostile radar coverage, launch weapons, and then quickly retreat out of radar tracking range to avoid counter-fire.


Kockums Visby class corvettes.

Stealth is not a panacea for survivability problems in surface combatants, as feasible designs and wake signatures still leave enough signature for a fast aircraft with a powerful radar to detect and engage the vessel from tactically useful ranges. It does, however, significantly reduce the number of shipboard, coastal and heliborne radars, that can be tactically useful against the vessel, and it reduces the coverage footprint of larger radars carried by shipboard helicopters, maritime patrol aircraft and UAVs. It also drives up the radar power requirements on ASCM seekers, and may wholly defeat older analogue ASCM radar seekers.

What is clear is that the contest between sensors and stealth has expanded from aerial combat to maritime surface combat, and this trend will continue in coming decades. Vessels being built today without significant stealth design features will be operationally obsoleted before their time. This remains to be understood by most naval planners, globally, reflecting the same planning lag that led to armoured battleships being pitted against aircraft carriers during the 1940s, with disastrous results. Douhet's dictum, penned nearly 90 years ago still holds: "Victory will smile upon those who anticipate changes in the character of war, not upon those who wait to adapt themselves after changes occur".


The Austal Independence class Littoral Combat Ship.


Austal's other export success has been the US Navy Joint High Speed Vessel fast catamaran.


The carbonfibre "M-Hull" M-80 Stilleto demonstrator was developed as a platform for deploying SEAL special forces. It combines very good hull faceting with an "M-hull" configuration to provide 50 - 60 knot speeds.