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Stealth Technology in Surface Warships; How This Concept Affects the Execution of the Maritime Strategy

by

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A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

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Stealth or (low-observable) technology is currently being incorporated into many new and existing classes of surface warships. This effort to reduce the ship's radar cross section (RCS) is aimed primarily at improving survivability against radar homing, anti-ship cruise missiles (ASCMs). "Stealth" warships offer potential advantages (and dis-advantages) for the operational decision makers in how they employ these ships in the execution of theNational Military Strategy. This paper explores the capabilities and limitations of current efforts to employ stealth in surface ships and discusses how a warship with a much reduced RCS might better execute various naval missions. It was found that actual stealth performance data is highly classified, but much open source literature is available whichaddresses the technical concepts of stealth. In theory stealth, when employed with chaff decoys, has the potential to enhance surface warship defenses against present generation ASCMs. Withthe proliferation of modern ASCMs to the Third World, stealth warships with an improved "soft kill" capability are better

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Stealth or (low-observable) technology is currently being incorporated into many new and existing classes of surface warships. This effort to reduce the ship's radar cross section (RCS) is aimed primarily at improving survivability against radar homing, anti-ship cruise missiles (ASCMs). "Stealth" warships offer potential advantages (and disadvantages) for the operational decision makers in how they employ these ships in the execution of the National Military Strategy. This paper explores the capabilities and limitations of current efforts to employ stealth in surface ships and discusses how a warship with a much reduced RCS might better execute various naval missions. It was found that actual stealth performance data is highly classified, but much open source literature is available which addresses the technical concepts of stealth. In theory stealth, when employed with chaff decoys, has the potential to enhance surface warship defenses against present generation ASCMs. With the proliferation of modern ASCMs to the Third World, stealth warships with an improved "soft kill" capability are better suited to conduct various sea control, power projection and crisis response missions than their non-stealth counterparts. While stealth is not sure to be effective against the next generation of ASCM nor is it feasible or economical for larger warships and sealift ships, it merits our serious consideration.

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INTRODUCTION

Following the attack upon USS Stark (FFG-31) by Iraqi Exocet missiles in May 1987, the U.S. Navy greatly accelerated its efforts to improve anti-ship missile defenses. There was much emphasis placed on improvements to "hard kill" point defense missile and close-in weapon systems, improvements to "hard kill" Standard (SM-2) missile warhead and fusing performance against sea skimming missiles, and improvements to electronic warfare detection systems aboard ship and in embarked helicopters. Another area of research which received increased attention was an ongoing effort to improve the "soft kill" performance of expendable chaff systems by significantly reducing the ship's radar cross section (RCS). By employing "low-observable" or "stealth" technology, designers attempted to reduce the ship's RCS to below that of a deployed chaff cloud. Theoretically, the chaff cloud would become a more attractive target to the missile seeker and therefore more effective at seducing the missile away from the ship.

Since many airborne and surface search radars also operate in the same I and J frequency bands as do many ASCM terminal radar seekers, it follows that the stealth treatment also makes the ship more difficult to detect by many ship and aircraft search sensors. This concept of decreased detectability offers additional advantages (and disadvantages) in the "stealth" warship's capability to perform various naval missions.

The use of modern stealth technology in surface warships differs from its use in military aviation. In aviation, the goal is to make the aircraft "disappear" to the maximum extent possible by reducing the visual, radar, infra-red, noise and electronic signatures; this strongly enhances a strike aircraft's capability to survive in a high threat area or to carry out covert missions. In the cases of the B-2 bomber and the F-117 fighter, stealth features dominated the entire design and manufacturing process, resulting in very expensive aircraft. Because of the laws of physics, we cannot make a large surface combatant completely "invisible" even if we are willing to radically alter surface warship design and spend vast sums of money. To attempt such a change is not cost effective or desired; there are missions where we want the surface ship to be very visible, such as Forward Presence visits overseas and Freedom of Navigation operations. The primary goal of the employment of stealth technology in a surface warship is to make the ship appear invalid (smaller than a chaff decoy) to the active radar, terminal guidance seeker of an anti-ship cruise missile...to improve the "soft kill" capability.

This paper will evaluate the anti-ship cruise missile threat facing the surface warships today and explore how the incorporation of stealth technology can improve ship survivability in the face of this threat. Additionally, it will examine potential roles for a "more survivable" and "less radar detectable" warship in the execution of the Maritime Strategy.

While much of the actual stealth performance data is highly classified, all of the technical information presented below was obtained from numerous unclassified or open sources. Some of the findings presented are based upon the author's recent experiences aboard a guided missile frigate with this "stealth" treatment applied.

CHAPTER II

THE ANTI-SHIP CRUISE MISSILE (ASCM) THREAT

Surface warships today face a most formidable threat posed by the ASCM. With the breakup of the former Soviet Union and the end of the Cold War, there is actually more instability in the world today because of the lack of Soviet influence over former client states, particularly in the Third World. Many of these small Third World navies have purchased sophisticated, modern, anti-ship cruise missiles in an effort to exercise sea control in their local regions with only a modest expenditure of funds. Accurate, lethal, "shoot-and-forget" missiles such as the French built Exocet are widely exported. These missiles can be launched from surface ships, small patrol boats, helicopters, various tactical and maritime patrol aircraft, submerged submarines, fixed shore sites and even from mobile truck-mounted launch platforms. ASCMs vary in range, warhead size, and flight profile; many are sea skimmers and most employ an active I/J-band active radar seeker for terminal homing.

Using the MM-40 Exocet surface-to-surface missile as an example, the following is a sample threat scenario developed from capabilities listed in open source literature.

- Aboard a small patrol boat maneuvering about 23 miles from your ship, targeting information about your position is being processed and programmed into a watertight missile storage container which also functions as the missile launch tube. A 16 foot long, 14 inch diameter, 1875 pound Exocet missile with a 360 pound high explosive fragmentation warhead is launched; your ship is the intended target.

- Using its inertial guidance system and radar altimeter, the missile flies near the sea surface at about 600 miles per hour. Total time of flight is about 150 seconds.

- At a range of 12 miles, about when the Exocet crosses your radar horizon, the active radar seeker turns on and acquires your ship. The missile descends to its second cruise altitude, less than 10 feet above the water and commences its final approach. The missile is now less than 75 seconds from impact.

- Fortunately, you are operating in a high alert condition with the combat system fully manned by a well trained crew; the missile is detected. You now have little more than a minute to shoot down or decoy this missile.

- Stealth technology and radar absorbing materials are also being used by weapon manufacturers to diminish the RCS of many cruise missiles, making them more difficult to acquire, track and destroy with "hard kill" systems. Your search and fire control radars are most likely looking for a missile with a small RCS, similar to that of a large bird.

- If you do not successfully counter the missile, the damage resulting from this scenario could be similar to what happened to Stark in the Persian Gulf or to HMS Sheffield during the war in the Falklands.

This scenario becomes a more serious threat when we consider that as of January 1992, the reported world-wide inventory of Exocets included almost 5,000 missiles exported to 29 countries, including Libya and Iraq.[1] Additionally, the Soviets and Chinese have exported more than 10,000 Styx/Silkworm missiles. This is why stealth technology is being introduced into our surface warships; what follows is how this technology is employed to counter the enemy missile seeker...specifically, how we attempt to deny it the ship's RCS signature needed for missile homing.

CHAPTER III

HOW DOES STEALTH WORK IN A SURFACE WARSHIP ?

Stealth is not something new to naval warfare. For centuries man has used the vast area of the ocean to hide from the enemy. Submariners have long relied on stealth to avoid detection, to hide from enemy attack and to reach the optimum firing position to conduct a surprise attack on enemy shipping.

"Observable" Signatures

Today's gas turbine powered surface combatant has five distinct emission signatures which make the ship subject to detection and therefore subject to enemy attack. All of these signatures must be minimized. They are:

1. Acoustic: caused by machinery noise radiating from the hull into the surrounding water. Extensive efforts have been made to shock mount equipment and mask this signature, especially in ships with a primary ASW mission.

2. Electronic: caused by active electronic emitters radiating into the atmosphere. This signature can be silenced by turning the equipment off (EMCON); however, the ship loses its active detection and radio communications capabilities.

3. Visual: caused by the fact that a large ship is visible to the human eye during daylight hours. A ship's wake is visually detectable from the air and from space; the wake has a surprisingly long persistence. Little can be done to alter a

ship's visual signature in daylight, beyond the improvement of paint schemes already in use. Operational planners cannot depend on weather conditions to mask the visual signature unless the ship operates extensively in areas prone to fog or inclement weather. They can plan to conduct night operations in order to deny the enemy a visual detection.

4. Infra-red (IR): caused by thermal radiation in the electromagnetic spectrum, and particularly in the Middle IR (MIR) region. This region corresponds to a heat source temperature between 500 and 1000 degrees Kelvin. "Hot sources (exhaust uptakes and exhaust gases) with temperatures in the region of 750 degrees Kelvin radiate strongly in the MIR region....Indeed, such is the level of IR radiation in these areas that what amounts to two percent of the ship's (total surface) area can produce 99 percent of the (ship's) total MIR signature."[1] It is important to note that it is these concentrated MIR sources which serve to attract anti-ship missiles with IR or dual mode (IR/radar) seekers. Extensive research is currently aimed at masking the concentrated heat source of machinery exhausts.

5. Radar Cross Section (RCS): caused by radar energy reflected by the ship and, "...influenced by the size of the ship, its angular orientation, the absorption coefficient of the materials from which it is constructed, and by the frequency of the illuminating radar."[2] Since most ASCMs employ active radar terminal seekers, the RCS signature is the most important.

Accordingly, further discussion will focus primarily on the surface warship's RCS signature and how it can be minimized.

Radar Cross Section (RCS)

The radar cross section of an object is defined as "a measure of the power reflected in a specific direction and is normally expressed in square meters or logarithmically in decibels per square meter (dBsm). While an entire ship will reflect radar energy as a whole, individual parts of the superstructure and smaller objects such as gunmounts, radar antennas, lifeline stanchions and deck lockers will also reflect energy separately due to each object's shape, size and orientation to the direction of the incoming radar energy. Because many of these smaller objects are approximately the same size as the wavelength of the incident radar, they are called "prime" or "resonant" scatterers. All of these reflections add coherently to influence the total RCS.[3] Most superstructures (and the hull form) have been constructed with large, flat, vertical surfaces and include many dihedrals and trihedrals intersecting at 90 degrees. Topside configurations include numerous cylindrical kingposts, stanchions and antennas. These shapes, vertical plates, planes joining at 90 degrees, and cylindrical objects all intensify an already large RCS.

The two principal ways of reducing a warship's RCS are the application of radar-absorbent material (RAM) to the most reflective parts of the ship, and the use of computer-aided design (CAD) programs to optimize the shape of the hull and superstructure. This modeling helps to estimate, and then minimize by shaping, the estimated radar energy reflections from various three-dimensional shapes which make up the ship. With shaping, the goal is to eliminate sharp corners and vertical surfaces and to cause the radar energy to be scattered away from the enemy rather than be reflected back in the specific direction of the enemy radar receiver. By using RAM, the goal is to absorb radar energy...trap it in a medium where its microwave energy is dissipated as heat and thereby eliminate most of the reflection. Obviously, if the ship has already been constructed, the incorporation of stealth technology will consist largely of the installation of RAM. It is noteworthy that the emerging stealth technology is producing a variety of new and more effective materials, including structural RAM and RAM with IR suppression characteristics.

The following are some specific examples of stealth applications in surface warships:

- In its narrative description of USS Arleigh Burke (DDG-51), Jane's Fighting Ships: 1991-1992, notes, "Stealth technology includes angled surfaces and rounded edges to reduce radar signature and IR signature suppression."

- The new French La Fayette-class frigate apparently is being built with stealth features to reduce RCS. The shape of the hull and superstructure avoids any vertical surfaces, most of the superstructure is enclosed, and RAM is also reported to be widely used to further reduce RCS.[4]

- During the visit of Soviet warships to San Diego in 1990, the author toured the *Udaloy*-class destroyer, *Admiral Vinogradov*. I observed numerous rounded edges on the superstructure which appeared to be covered with RAM. When asked, Soviet officers confirmed the purpose of the covering was to "absorb radar."

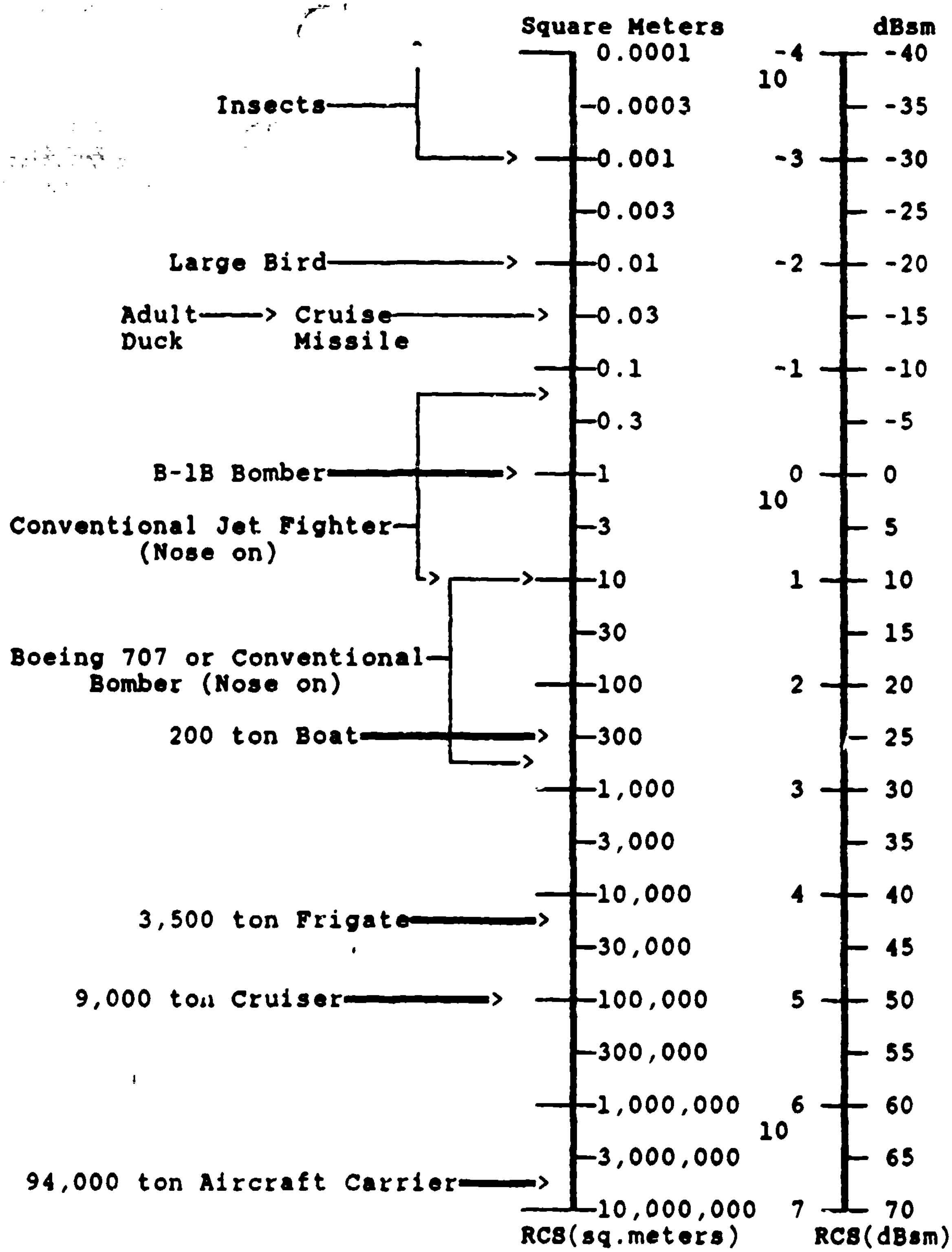
- The British are experimenting with "multi-spectral" materials...RAM that will include IR reflective materials and simultaneously reduce both RCS and the ship's IR signature.[5]

- The Royal Navy is developing a new topside deck locker made from a structural RAM, to store Sea Gnat chaff decoys. The new locker replaces a "prominent piece of reflective clutter on the superstructure of Royal Navy warships."[6]

- A British advertising leaflet describes the complexity of this material, "...ADRAM (Advanced Dielectric RAM), which covers the range 6-35 GHz, and reportedly employs a honeycomb with a radar-transparent outer skin of Kevlar, a Nomex core containing an absorber, and a reflective carbon fibre inner skin."[7]

To illustrate the concept of RCS measurements, the diagram at Figure 1. was adapted from a published study. The RCS figures shown should be regarded as approximate since (1) they have been taken from published sources which may not be accurate, and (2) RCS varies greatly with aspect, radar frequency and polarization, roll of the ship and other factors.[8]

FIGURE 1 - RADAR CROSS SECTION

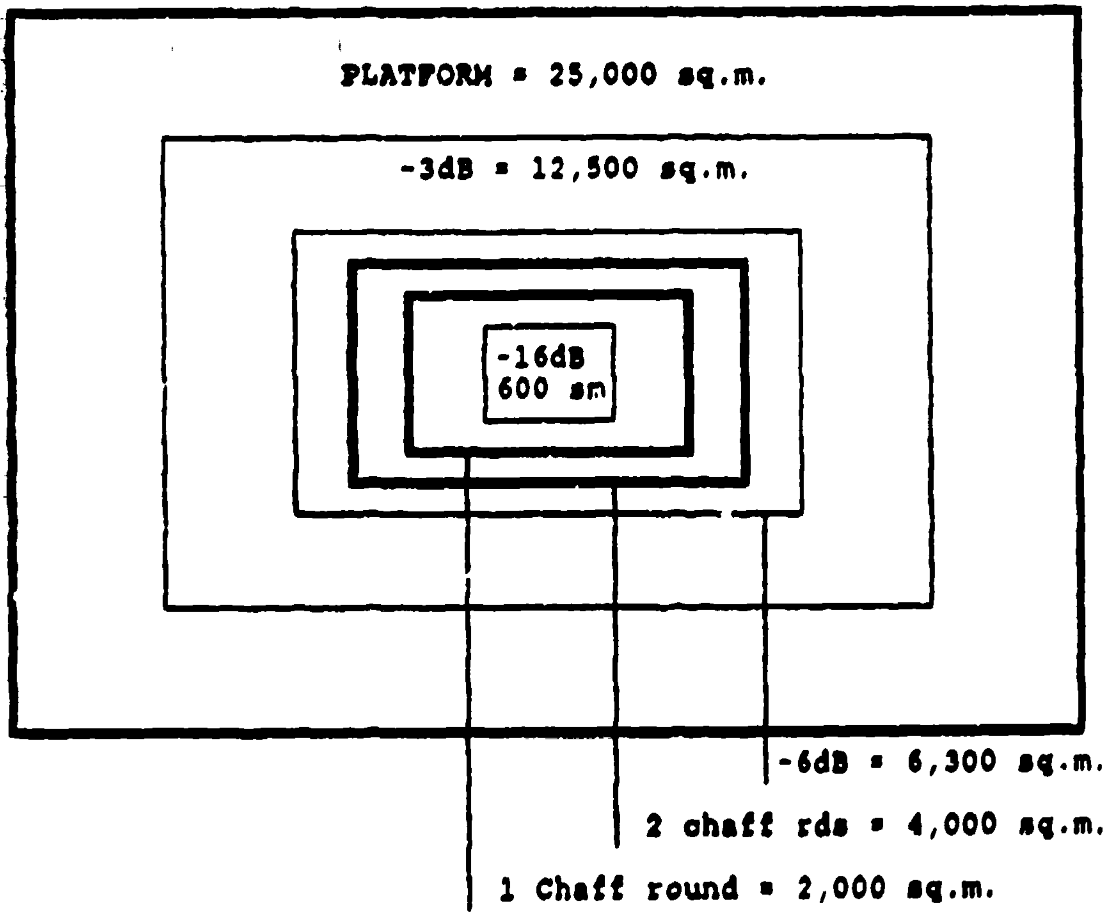


Source: William D. O'Neil, "Don't Give Up On The Ship," U.S. Naval Institute Proceedings, January 1991, p. 48.

As was previously noted, the actual performance of the stealth treatment in various ships is carefully guarded. There is no unclassified data available which shows actual RCS measurements or actual test results noting the effectiveness of stealth against various missile seekers. Another published study clearly illustrates the theory of a stealth warship's increased survivability with the following example. "A typical frigate or destroyer might have an RCS of 25,000 square meters (44 dBsm). This can be reduced to 12,500 square meters by a 3 dBsm reduction (achievable with some low-performance radar absorbing paints) and to as little as 6,300 square meters (38 dBsm), a 75 percent reduction, with other RAM materials....On a platform equipped with modern chaff launchers, where RCS is reduced (with shaping and the application of RAM) by as much as 16 dBsm, the overall radar cross section is less than the echoing of the protective chaff bloom."[5] In other words, if a destroyer with an RCS of 44 dBsm is "treated" to achieve a -16dBsm reduction, theoretically now it has an RCS measuring 28dBsm...less than 1000 square meters. This is slightly larger than that of a 200 ton boat and well below the RCS of a two-round chaff cloud. The diagram at Figure 2., adapted from the above noted study, graphically illustrates this example of how stealth works in theory.

FIGURE 2

INCREASE IN SURVIVABILITY OF
A "TYPICAL" FRIGATE OR DESTROYER



Source: David Foxwell, "Stealth: The Essence of Modern Frigate Design," International Defense Review, no. 9, 1990, pp. 988-990.

Other Advantages of "Low-Observability"

As was previously mentioned, the application of RAM, "tuned" to be most effective against I/J-band radar seekers, to a warship's superstructure will also affect the performance of search sensors operating in the same frequency range. In the case of the typical destroyer noted in the example, with the theoretical stealth RCS of less than 1,000 square meters, it is likely that the surface search radars carried on many ships and aircraft will see a smaller radar target. It is equally likely that the smaller target will be detected by these radars only at a closer range.

The treatment with RAM of large areas of the superstructure is likely to reduce electromagnetic interference (EMI). Lifeline arrays, topside lockers, various deck fittings and mast structures which previously reflected radar energy and enhanced the ship's RCS will now be covered with a material which absorbs electromagnetic radiation. This reduction of spurious electromagnetic energy in the vicinity of topside antennas will likely improve the performance of installed radar and communications receivers.

For ships equipped with active electronics countermeasures, a reduced RCS is of great benefit. When an incoming missile is "jammed" with active ECM, there is a "Burn-Through" range where the actual missile radar energy reflected by the ship overcomes the jammer's power. At this point, the active ECM is no longer effective, and the missile will attempt to maneuver to hit the ship. With stealth, less radar energy is being reflected back at the missile. The jammer, without increasing its power out, becomes more effective. Burn-Through occurs closer to the ship.

While not a significant operational advantage, the installation of stealth technology will improve the appearance of topside areas by requiring the removal of all unnecessary lockers and "stuff" which tend to clutter the weather decks. Conversely and very important to understand, the operational performance of the stealth treatment will be significantly degraded if the topside areas are not kept free of reflective clutter. It has been shown that something as insignificant as three strategically placed mop pails with wringers ("cadillacs") can significantly enhance a ship's RCS.

Disadvantages

Reduced detectability on radar can be a significant disadvantage when maneuvering in fog or reduced visibility, particularly in an area of high commercial shipping density. When operating on the bow of a large oil tanker in thick fog, I would want my frigate to appear as a large, sharp, radar target to the tanker's I-band surface search radar. This disadvantage can be overcome either mechanically, by attaching portable radar reflectors topside, or electronically, by using an electronic repeater or "Blip enhancer" when an enhanced RCS is desired. As a matter of routine, it might be desirable to operate with portable radar reflectors rigged in order to "hide" the ship's smaller, stealth RCS until it is tactically needed.

The stealth treatment using RAM adds several tons of high topside weight to a warship and adversely affects the ship's stability and sea keeping ability. For older ships which already have a topside weight problem, this could be a serious concern. As new ships are designed to include this technology, initial weight and moment calculations can account for stealth additions. With new construction ships, the shaping of superstructures requires less application of RAM and therefore less topside weight.

Stealth technology in a surface warship is part of a "soft kill" capability which lacks credibility and proven performance in the minds of some naval officers. The natural inclination is to act aggressively and attempt to shoot down an incoming missile rather than to launch a decoy and wait to see if it works. With the lack of an integrated electronic warfare suite in many warships, it is difficult to tell if the decoy is working. Even if the "stealth-enhanced" chaff appears to be working, many would still question; "Will the chaff continue to be effective as the missile closes the ship?" or, "Are we 100 percent certain stealth will be effective against all radar seeker equipped ASCMs?" or, "Are we presenting the ship's 'stealthiest' aspect?"

Maintainability

While this issue of maintainability does not have significant operational importance, it has generated many questions and will be discussed briefly. Based upon my experience, the system requires very little maintenance. My crew was indoctrinated that the "rubber tiles (RAM) are very important and should not be damaged." If properly installed, the material adheres well, can be painted sparingly with normal haze gray paints and is barely visible. The system has been subjected to wave action, high winds, cold weather and a long overhaul in a private shipyard. After overhaul, it required only minor patching to restore system integrity; subsequent RCS measurements showed no degradation.

Again, it is noteworthy that the topside configuration must be strictly controlled in order to maintain the system's effectiveness. This would include keeping the embarked helicopter(s) in the hangar with the hangar doors closed, except for launch and recovery.

CHAPTER IV

POTENTIAL ROLES FOR "STEALTH" WARSHIPS

When operational planners in a maritime theater ponder the three essential questions of, "What military conditions must be produced to achieve the objective?", "What is the optimum sequence of actions to produce those conditions?" and, "How best to apply the available forces to accomplish that sequence?", the threat of the anti-ship cruise missile will undoubtedly influence the third answer.[1] Planners will attempt to concentrate superior combat power against the enemy's operational center-of-gravity in an environment where Third World patrol boats or helicopters armed with modern ASCMs can threaten our efforts to establish local sea control, project power, or respond to a crisis. Assuming that stealth technology is actually effective in helping to counter ASCM seekers and can be affordably incorporated into surface warships, the following is a discussion of roles for these ships.

Forward Presence and Crisis Response

Stealth adds to the mission of forward presence in that U.S. warships can operate more safely in sensitive parts of the world as visible evidence of our commitment to our allies in maintaining peace and stability. As the U.S. Navy gets smaller and fewer ships are available to carry out this overseas mission, we must be able to provide naval presence with one or two smaller combatants, often without the mutual support of an entire Aircraft Carrier Battle Group (CVBG). These fewer combatants must be perceived to have a combat capability for carrying out an implied threat; Tomahawk, Harpoon, and Standard missiles provide an impressive combat capability to a cruiser or destroyer platform Equally important, these ships must be able to defend against an ASCM threat without CVBG air protection, particularly in littoral areas. Stealth should give ships an edge in defending against such an attack.

In responding to a crisis situation, naval forces have long been seen as the military instruments of first choice. They are rapidly deployable, can remain in a region indefinitely, or can be quietly withdrawn if the policy makers choose not to intervene. As we exercise "Gunboat Diplomacy" and threaten the use of force to support U.S. foreign policy objectives, we will do so in a tense environment made more dangerous by high technology weapons. In such an environment where fewer ships might be available to respond, stealth offers us a greater degree of protection against enemy attack by radar guided weapons.

Crisis response tasking could likely include enforcing economic sanctions or more precisely, a naval blockade. This mission, frequently executed by a few small combatants operating independently, frustrates a potential enemy's efforts to import or export materials. These ships would be ideal candidates for stealth treatment, especially if the sanctions were inclined to hurt that potential enemy to point of him challenging our local sea control and retaliating with an ASCM.

Sea Control

In carrying out the essential mission of sea control in today's world environment, we are more likely to find our warships operating in littoral areas such as the Persian Gulf where they are at much higher risk of ASCM attack from a wide variety of smaller platforms than would be encountered in open ocean. Be[illegible] of the advantage offered by stealth enhanced defenses, such equipped warships are better suited to operate safely in this near-land environment.

Stealth does not do much to improve our ability to conduct anti-submarine warfare as part of sea control operation, until the enemy submarine launches an ASCM; then it could be a very important asset in what is now an AAW engagement.

Stealth warships, operating at night, in strict EMCON, with targeting information provided by a receive-only data link, and employing stealthy, missile-equipped, attack helicopters, could offer an impressive capability to seek out and destroy enemy naval forces.

This technology provides a defensive edge to the "treated" combatant ship, but does little to protect sealift ships or large amphibious ships which might be under escort as part of a sea control operation. The incorporation of stealth into large "boxy" sealift ships would be cost-prohibitive, especially for leased commercial vessels.

Power Projection

After the impressive performance of Tomahawk capable ships during Operation "Desert Storm", it is likely that these ships might be targeted as part of an enemy first strike. Stealth technology offers the Tomahawk-equipped combatant a greater degree of protection from enemy ASCMs and would allow the stealth warship to project power from a position where the aircraft carrier might not be able to operate safely. Stealth would allow combatants to conduct NGFS close to the beach or to transport Special Operations forces close to shore with an improved capability to defend against an land-based ASCM attack.

It is questionable whether stealth treatment is feasible, physically or economically, for larger ships which project power ashore such as the aircraft carrier or the larger amphibious ships. A Naval Studies Board review of future aircraft carrier technologies, "Carrier-21: Future Aircraft Carrier Technology," concluded that, "attempting to reduce the radar signature of aircraft carriers would be prohibitively costly."[3]

CHAPTER V

CONCLUSION

Some might ask, "Is it worth the effort to try to protect our surface ships?" or, "Why do we need to establish local sea control?" One author stresses, "...the day of the surface warship has not passed...recent events in the Gulf have shown that sea transportation is still essential for the passage of raw materials and heavy military equipment. Surface ships will continue to be needed until peaceful nations stop using the sea for economic survival and until military nations no longer perceive a need to project power beyond their own borders. The debate must be about ways of ensuring the survival of ships." [1]

Stealth is not magic, it is not the ultimate protection against every sort of enemy attack, and it is very doubtful that stealth will defeat every radar homing ASCM, every time; however, stealth treatment of surface warships does offer some potential value. This system, when used with properly deployed chaff decoys, has the potential defend against the present generation of radar homing ASCMs widely available today.

Due to the laws of physics, it is doubtful that we can physically or economically install stealth technology into some of our largest warships and our sealift ships. Stealth might not be effective against the next generation of ASCM which uses another signature for homing or is better able to discriminate between a chaff decoy & a warship. But today, it offers an increased degree of protection to a large number of our surface combatants. Stealth renders less-effective, the bulk of 15,000 radar homing ASCMs presently in the arsenals of nearly 60 nations.

It is not a question of "Hard kill" or "Soft kill" as some would contend. We must take advantage of every tool available ...it is both "Hard kill" and "Soft kill enhanced by stealth technology" which will give us the greatest chance of survival against the ASCM. Stealth technology in surface warships is worth our serious consideration...it can contribute to the successful execution of the Maritime Strategy.

NOTES

Chapter II

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