Achieving Naval Superiority with Software

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Executive Summary

This paper discusses the impact of changing world threats on the development of naval systems, in particular the role of software in enhancing the capabilities of fleets to address new threats and extend the in-service lifetimes beyond those originally envisaged.

The Changing Threat

In today’s uncertain world, governments are striving to deal with new emerging threats to their countries and their nations’ interests around the world. They are changing the roles and the composition of their surface and submarine fleets to address these new types of threats.

During the Cold War era, the role of the navy was well-defined and changes to the nature of the threat and an enemy’s capability could be predicted. The development of new surface ships and submarines to fulfill specific roles, such as antisubmarine warfare, could be planned and implemented with reasonable expectation that the threat would not change substantially during the development phase.

Since the end of the Cold War, the upsurge in political instability and emerging conflicts around the world have led to governments asking their naval forces to undertake wide-ranging missions, from UN peacekeeping operations to military strikes, in diverse climates and geographically dispersed theaters of operations. These varied operational parameters present new challenges to naval systems that may have been developed for more narrowly defined roles, especially when considering asymmetric warfare in counter-terrorism operations, where an opponent may use nontraditional combat techniques to deadly effect.

The Changing Response

The United States has continued to maintain the world’s largest naval fleet, maintaining continuous readiness to deploy six carrier strike groups simultaneously, providing a global force projection capability even where foreign basing may be denied. However, many other western governments have been under political pressure to minimize growth in defense budgets so that spending can be increased in other more expedient policy areas and have sought to achieve greater breadth of capabilities without significantly increasing the size of their fleets.

In the United Kingdom, the Ministry of Defense’s 1998 “Strategic Defense Review” identified a change in the primary role for aircraft carriers from North Atlantic antisubmarine warfare to force projection anywhere around the world. In the intervening years, the UK Royal Navy fleet has significantly reduced in size, but the introduction into service of the Queen Elizabeth class aircraft carriers, Type 45 Daring class destroyers, and Astute class submarines will provide greater expeditionary capabilities (also known as a blue water navy) than in the Cold War era. However, given the long lead times for development and construction of completely new naval vessel designs to meet these requirements, an interim change in capability can be achieved through adaptation and upgrade of existing in-service vessels and the addition of capability to vessels already undergoing development. For example, the Type 45 destroyer was conceived as an air defense destroyer providing self-, local, and fleet area defense; but it could potentially provide air defense for London in an airborne terrorist attack or missile attack by a rogue state. In addition, the Astute submarine, which was originally conceived for an antisubmarine warfare role, can now also participate in a Maritime Contribution to Joint Operations (MCJO) with the ability to fire Tomahawk cruise missiles from its torpedo tubes or possibly assist in the deployment of special forces.
Other European NATO countries are also upgrading their naval fleets, with the French Marine Nationale and the Italian Marine Militare taking delivery of the Horizon frigates that will provide enhanced air defense capabilities, using the EMPAR multifunction radar, the Principal Anti-Air Missile System (PAAMS), and Aster surface-to-air missiles. In addition, France and Italy are collaborating on the development of the FREMM multipurpose frigates, which use a common platform that can be customized for antisubmarine warfare or land attack roles.

The Israeli Sea Corps has used fast patrol boats in littoral defense and counterterrorism operations for many years, and the latest-generation Super Dvora Mk III² will further extend this world-class capability through the use of state-of-the-art technologies. It uses engines designed for competitive speedboats to achieve near 50 knots performance, while providing exceptional agility through vectored thrust drives more usually associated with fast military jets. When this speed and agility is coupled with the Super Dvora’s stabilized cannon system with long-range electro-optic/infrared (EO/IR) sensors, it provides a formidable capability for high-speed engagements.

In the Far East, the role of the Japanese Self-Defense Maritime Force (JSDMF) has also changed drastically since the end of the Cold War, from an antisubmarine warfare role to participation in peacekeeping operations. However, the role of JSDMF in the theater air defense of Japan also increased following the North Korean test of the Taepodong-1 missile over northern Japan in 1998; and in December 2007 the JSDMF demonstrated the ability to intercept a ballistic missile in a test of the JS Kongo Aegis-equipped destroyer during a joint exercise with the U.S. Navy³. The Republic of Korea Navy and the Republic of China (Taiwan) Navy are both increasing their air defense capabilities, but this is dwarfed by the expansion by the People’s Republic of China, with 60 new ships built for the People’s Liberation Army Navy between 2001 and 2006.

The Role of Software

In recent years, as naval systems have become more and more sophisticated (with advances in combat management systems, radar, sonar, electronic surveillance, missile defense systems, and countermeasures), the complexity of the underlying systems has increased dramatically. This is particularly evident in relation to software, which in earlier generations of naval systems could be measured in tens of thousands of source lines of code (SLOC), and for current programs is measured in millions of SLOC.

One of the underlying reasons for the increasing software content is that software provides the ability to deploy flexible multifunction systems that could not easily be achieved though hardware alone. This can provide benefits in terms of a reduction in the number of dedicated systems. For example, in radar systems, software configuration can be used to exploit the fundamental capabilities of the radar for different modes of operation. These include modes for tracking surface and airborne targets, but this could potentially even include an advanced inverse synthetic aperture radar (ISAR) mode for noncooperative target recognition (NCTR) and cross-referencing a NATO target signature database⁴. This would enable faster classification of a target as either friendly or hostile, enabling appropriate action to be taken more rapidly as required.

Software is being used to both provide tactical advantage in combat engagements through superior capability and also to manage the increasing complexity of combat systems. The Type 45 destroyer’s air defense systems provide an excellent example in both cases. It uses the S1850 long-range radar, PAAMS, and Aster surface-to-air missiles similar to the Franco-Italian Horizon frigates but uses the SAMPSON multifunction radar instead of EMPAR, which provides the ability to defend the ship and fleet against multiple threats simultaneously.

SAMPSON is an active electronically scanned array (AESA) radar and uses software to shape and direct its beam, enabling surveillance, tracking, and targeting to be performed simultaneously, and it only uses two rotating planar arrays rather than the multiple arrays conventionally used. This enables the SAMPSON radar to be placed at approximately 40 meters above the waterline (nearly double that of its U.S. equivalent), extending the horizon distance and providing better coverage against low-level threats such as sea-skimming antiship missiles. In addition, the air defense system can launch up to eight Aster missiles against the most dangerous targets within 10 seconds and once airborne can provide radar guidance updates to up to 16 Aster missiles simultaneously before they switch to the final-stage active homing⁵. This provides the Type 45 destroyer with world-class air defense capability and is a significant improvement over previous-generation systems that could be susceptible to being swamped by multiple simultaneous threats.

Software is also being used to improve situational awareness through sensor fusion, where data from different sensor inputs is processed and integrated and presented to the crew in a coherent manner to enable them to make rapid decisions about their next actions. The implementation of many such systems is classified due to their sensitive nature, but this could include, for example, the fusion of radar data, geographic data, and identification friend or foe (IFF) data.

The Astute submarine provides another example of increased capability through software, where its vulnerability to detection is reduced through deployment of a non-hull-penetrating optronic mast design, which can be extended from the submarine fin and rapidly perform a 360-degree scan of the above surface, enabling the commander to analyze the image data immediately afterward, minimizing risk of detection.
The Software of the Future

The digitization of the battle space continues to gather pace, and even more advanced capabilities are being considered, including real-time information flow for situational awareness and coordination of joint operations. These operational requirements will continue to have an impact on the design of naval systems and the software that they will contain.

Interoperability and the sharing of data between coalition forces at differing NATO security classifications (Cosmic Top Secret, NATO Secret, NATO Confidential, NATO Unclassified) places additional security requirements on the systems concerned, in particular the need to partition data of different classifications and enforce authorized data flows while preventing the unauthorized disclosure of sensitive information, known as multilevel secure (MLS) systems. Traditionally, these systems have involved multiple subsystems at different classifications, physically separated from each other; however, this approach is very expensive in terms of size, weight, and cost and can become impractical due to the limited space available on a navy warship or submarine. In recent years, an alternative approach has been developed through software implementations based on the multiple independent levels of security (MILS) software architecture, and this approach is already being adopted in the field of military avionics, which faces similar challenges.

In addition, many systems are now being developed using planned obsolescence, whereby a system is designed at the outset so that it can be upgraded through technology insertions during its in-service lifetime. This enables hardware obsolescence to be overcome more readily and also makes capability upgrades easier and less costly to implement. At the software level this can be achieved through the development of portable applications using open architectures and open standards, enabling the migration to newer platforms.

So what other functions might we expect to be performed by software in the future? It is claimed that the sonar system on the Astute submarine in the English Channel could detect the QE2 cruise ship leaving New York harbor on the other side of the Atlantic and even identify the vessel1. But could this enormous processing power and the right software algorithms be employed to render the submarine invisible to sonar itself? At present, Astute deploys passive measures, using 39,000 acoustic tiles on the hull to absorb incoming sonar waves, whereas an active sonar cancellation would need to sample the incoming sonar waves and generate waves of identical frequency, amplitude, and direction but 180 degrees out of phase in order to cancel out the incoming waves as they are reflected off the submarine’s hull.

It is theoretically easier to achieve active sonar cancellation than active radar cancellation because the speed of sound in water is around 1,500 milliseconds, whereas the speed of light (and radio waves) in air is 300 million milliseconds. So if sensors were installed 1 meter from the submarine’s hull it would mean that there would be less than a millisecond to sample incoming sonar waves across multiple frequencies and perform the complex computations to determine the cancellation pulses that would need to be generated. A millisecond might not be long enough for today’s technologies, but this could become feasible in the not so distant future.

About the Author

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