A digital battlespace

Eur Ing Paul Parkinson, of Wind River Swindon, discusses the impact of changing world threats on the development of naval systems, and how to achieve superiority with software...

In today's uncertain world, governments are striving to deal with new emerging threats to their countries and their nation's 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. Therefore, the development of new surface ships and submarines to fulfil specific roles, such as anti-submarine 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 has 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 theatres 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 non-traditional combat techniques to deadly effect.

The changing response

The United States has continued to maintain the world's largest naval fleet, sustaining constant 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 minimise growth in defence 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 Defence's 1998 Strategic Defence Review[1] identified a change in the primary role for aircraft carriers from North Atlantic anti-submarine 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 defence destroyer providing self, local and fleet area defence; but it could potentially provide air defence 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 anti-submarine 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.

Fig. 1: Artist's impression of Astute submarine at sea

Other European NATO countries are also upgrading their naval fleets, with the French Marine Nationale, and Italian Marine Militare taking delivery of the Horizon frigates, which will provide enhanced air defence capabilities using the EMPAR multi-function radar, Principal Anti-Air Missile System (PAAMS) and Aster surface-to-air missiles. In addition, France and Italy are also collaborating on the development of the FREMM multipurpose frigates, which use a common platform that can be customised for anti-submarine warfare or land attack roles.

The Israeli Sea Corps has used fast patrol boats in littoral defence and counter-terrorism operations for many years, and the latest generation Super Dvora Mk III[2] will further extend this world class capability through use of state-of-the-art technologies. It uses engines designed for competitive speedboats to achieve near 50 knots performance, whilst providing exceptional agility through vectored thrust drives

Fig. 2: Type-45 Destroyer HMS Daring during sea trials

more usually associated with fast military jets. When this speed and agility is coupled with the Super Dvora's stabilised canon system with long-range Electro-Optic/Infra-Red (EO/IR) sensors, it provides a formidable capability for high-speed engagements.

In the Far East, the role of the Japanese Self-Defence Maritime Force (JSDMF) has also changed drastically since the end of the Cold War, from an anti-submarine warfare role, to participation in peacekeeping operations. However, the role of JSDMF in the theatre air defence of Japan has increased too 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 JPS Kongo Aegis-equipped destroyer during a joint exercise with the US Navy.[3] The Republic of Korea Navy and Republic of China (Taiwan) Navy are both increasing their air defence capability, but this is dwarfed by the rapid expansion by the People's Republic of China, with 60 new ships being 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 defence 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 programmes 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 multi-function systems that could not easily be achieved through 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 Non-Cooperative Target Recognition (NCTR) and cross-referencing a NATO target signature database.[4] 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 to manage the increasing complexity of combat systems. The Type-45 Destroyer's air defence systems provide an excellent example in both cases. This uses the S1850 Long Range Radar, PAAMS and Aster surface-to-air missiles similar to the Franco-Italian Horizon Frigates, but uses the SAMPSON multi-function 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 metres above the waterline (nearly double that of its US equivalent), extending the horizon distance and providing better coverage against low level threats such as sea-skimming anti-ship missiles. In addition, the air defence 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 homing.[5] This provides the Type-45 Destroyer with world class air defence 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, 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 the surface, enabling the commander to analyse the image data immediately afterwards, minimising risk of detection.

Designing software for the future

The digitisation of the battlespace continues to gather pace, and even more advanced capabilities are being considered, including real-time information flow for situational awareness and co-ordination 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 sharing of data between coalition forces at differing NATO security classifications (Cosmic Top Secret, Nato Secret, Nato Confidential, Nato Unclassified)[6] places additional security requirements on the systems concerned, in particular the need to partition data of different classifications and enforce authorised data flows whilst preventing the unauthorised disclosure of sensitive information, known as Multi-Level 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 not only detect the QE2 cruise ship leaving New York harbour on the other side of the Atlantic but even identify the vessel.[7] 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 submarines hull. It is theoretically easier to achieve active sonar cancellation than active radar cancellation, because the speed of sound in water is around 1,500m/s, whereas the speed of light (and radio waves) in air is 300,000,000m/s. So, if sensors were installed one metre from the submarine’s hull this 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.

1 UK Strategic Defence Review (PDF), UK Ministry of Defence, July 1998 – www.mod.uk/NR/rdonlyres/65F3D7AC-4340-4119-93A2-20825848E50E/0/sdr1998_complete.pdf.

2 Super Dvora Mk III, Israeli Weapons website – www.israeli-weapons.com/weapons/naval/super_dvora3/SuperDvora3.html.

3 Japanese Destroyer JS Kongo Intercepts Ballistic Missile – www.defenseindustrydaily.com/japanese-destroyer-js-kongo-intercepts-ballistic-missile-04454.

4 S. J Gelsema, ‘The Desirability of a NATO-central Database for Non-Cooperative Target Recognition of Aircraft’, NATO, 2005 –ftp.rta.nato.int/public//PubFullText/RTO/MP/RTO-MP-SET-080/MP-SET-080-23.pdf

5 Principal Anti-Air Missile System, Navy Matters website – navy-matters.beedall.com/paams.htm.

6 ‘NATO Security Committee Directive on the Security of Information’, AC/35-D/2002-REV2 (NATO UNCLASSIFIED), NATO, 4th February 2005.

7 ‘Astute submarine prepares for June 8 naming and rollout for launch’ press release, BAE SYSTEMS website, 8th May 2007 –www.baesystems.com/Newsroom/NewsReleases/autoGen_1074119838.html

Eur Ing Paul Parkinson BSc CEng MBCS MIET
Senior Systems Architect
Aerospace & Defence
Wind River Swindon
Wind River House
10 Viscount Way
South Marston Park
Swindon
Wiltshire SN3 4TN
Tel: 01793 831831
Fax: 01793 831808
www.windriver.com