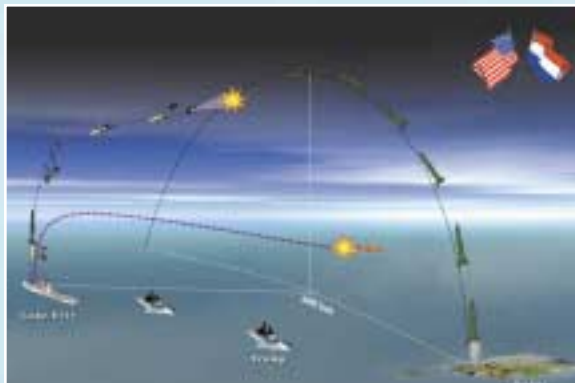# Detect to protect

Making maritime TBMD a reality

THALES

Extended Long Range
surveillance

It is often forgotten that the ballistic missile is not in itself a new type of threat. Indeed, it is now over 65 years since major population and industrial centres across Western Europe found themselves under sustained attack by the V-2 rocket, the first long-range ballistic missile to be operationally deployed.

The V-2 opened a new and frightening chapter in warfare. Launched from fixed sites or mobile trailers, it flew a high altitude (exo-atmospheric) ballistic trajectory to deliver a one-ton conventional explosive payload to a maximum range of about 360 km, arriving with no warning and impacting at three times the speed of sound with devastating effect. Its speed and trajectory made it invulnerable to interception by the anti-air defences of the day.

However, it took the 'Scud' offensive of the 1991 Gulf War to re-awaken governments and military commanders alike to the political and operational consequences of short-to-medium range ballistic missile attacks. It served as a catalyst for individual nations to start thinking seriously about how to acquire theatre ballistic missile defence (TBMD) capabilities. And it brought home the fact that ballistic missiles are not a future threat.

That was nearly two decades ago. The intervening period has seen the continued proliferation of missile propulsion, guidance and payload technologies, the corollary being that over 25 nations today possess ballistic missiles in their military inventories, including a number of so-called 'states of concern'.

What marks out the ballistic missile threat, and makes it so attractive, is its inherent 'asymmetry'. Compared to manned aircraft fleets, missiles have the advantage of significantly reduced maintenance, training and logistics requirements. They render conventional air defence networks ineffective. And even their limited use could prove devastating should they be configured to deliver chemical, biological or nuclear payloads of mass effect.

Moreover, the threat is not standing still. Theatre ballistic missiles are becoming variously more mobile, survivable, reliable, accurate and capable of achieving extended ranges.

It is against this backdrop that sizeable political, military, scientific and industrial efforts are now being brought to bear across NATO to fashion an effective TBMD capability embracing three interacting components: advanced sensors to pinpoint incoming missiles at the earliest opportunity; a robust command and control network to coordinate defences; and interceptor missiles to shoot down inbound threats.

Shared early warning is a critical enabler to any TBMD construct, providing the initial detection of a ballistic missile attack and buying valuable response time for military and civil authorities alike. Radar is an essential component, providing a capability that is inherently complementary to geo-stationary early warning satellites but equally capable of providing autonomous detection, accurate trajectory determination, launch point estimation and impact point prediction, and weapon system cueing.

Ballistic missile early warning radars have traditionally operated in the UHF frequency band, using fixed large aperture phased arrays to state over several thousands of kilometres. However, these sites are hugely expensive, immobile, overtly political, and not suited to the detection of short range, low apogee TBM threats.

Shipborne radars offer a more affordable and inherently flexible approach. Unfettered by the political issues that can complicate the stationing of land-based ballistic missile warning radars, they are mobile, responsive, and afford redundancy in numbers. They can be used to fill gaps in surveillance coverage, or to be forward deployed to provide the earliest possible detection against low apogee TBMs.

What's more, there are a number of significant operational advantages to be gained by netting radar sensor data from multiple sea-based systems positioned across a wide geographical area: surveillance coverage can be significantly improved by positioning appropriately-equipped ships as radar 'gap fillers', or forward deploying units to provide early threat detection; multi-sensor plot-level fusion improves the quality and robustness of target racking; and accurate cueing information can be used to expand the engagement envelope of interceptor missiles through launch on search/engage on remote techniques.

Taking cognizance of these requirements, Thales has identified ballistic missile early warning as an area where its rich experience, depth of knowledge and innovative exploitation of advanced radio frequency technology can pay significant dividends. In particular, the further evolution of its shipborne SMART-L D-band volume search radar promises a cost-effective and low-risk path to achieving an Extended Long Range (ELR) capability to detect ballistic missiles at extended ranges.

Moreover, this is not tomorrow's technology. Building on the TBM search functionality already resident in the baseline radar system, the ELR modification brings to fruition a decade of engineering development, technology maturation, prototyping and capability demonstration, including successful tracking trials against live testing against a representative TBM target.

NATO's response to the growing ballistic missile threat

Following several years of study activity and threat analysis, NATO in 2005 established the Active Layered Theatre Ballistic Missile Defence (ALTBMD) programme to create a capability to defend alliance forces and other high value assets operating 'out of area' against ballistic missile attack. Its objective is to create a 'system of systems' that binds together various national sensor and interceptor components in a fully integrated command and control architecture to defend deployed force elements against the threat of short- and medium-range ballistic missile attack (translating to threats with a range of up to 3,000 km).

Building on an upgraded NATO command and control system infrastructure, the ALTBMD programme will deliver capability across the NATO strategic, operational and tactical command echelons through interfaces with the NATO General Communications System (NGCS), the Bi-Strategic Command Automated Information System (Bi-SC AIS) and the Air Command and Control System (ACCS). Development is proceeding according to a stepped three-phase programme: engineering risk reduction testing (entailing the early verification of technical interoperability); capability system integration testing (to verify system interoperability between the NATO command and control systems and national weapon and sensor systems); and final capability assessment tests (to ensure that the fully integrated ALTBMD architecture meets the approved NATO requirements).

ALTBMD capability is to be fielded in a series of increments. An early build Interim Capability (InCa) will capitalise on legacy infrastructures and research outputs – including testbed systems and prototypes – to establish a base level of functionality and reduce cost and technical risks for subsequent phases.

This spiral development processes, which will see command and control architectures upgraded and national sensors and weapon systems incrementally integrated into the ALTBMD architecture, is now gaining pace. The coming years will see both national laboratories and NATO assets contribute to a wide-ranging programme of technology development, systems engineering, modeling and simulation, prototyping, test and integration.

A key part of this is the NATO Integration Test Bed (ITB), located at NATO Consultation, Command and Control Agency facilities in The Hague. The ITB provides a technical framework to support the integration, validation and verification of the NATO ALTBMD capability, as well as support for training, exercise and final capability assessment.

What is readily apparent is that the inherent scalability and adaptability of the ALTBMD architecture very much aligns itself to the US government's new Phased Adaptive Approach for missile defence in Europe. This multi-phase endeavour projects the deployment of sea- and land-based missile interceptors, together with a range of sensors to detect and track ballistic missile threats.

One attraction of this Phased Adaptive Approach is that it offers the potential for European nations to make a credible contribution to burden-sharing through the provision of assets and infrastructure. In this regard, the ship-borne SMART-L ELR radar could play an important part in a shared early warning capability, providing midcourse radar coverage to enable launch on remote interceptor engagements and thereby significantly increase the defended area.

seeing is
believing

It was back in 1990 when what is today Thales Nederland began the development of the SMART-L radar to meet the three-dimensional air search needs of a new generation of European anti-air warfare (AAW) frigates that were then in their design definition phase. The primary role of this new sensor were to detect, identify and track air contacts at long range, and compile these tracks into a coherent and complete air picture so as to support force-wide picture compilation, air and fighter control, early threat warning, and cueing for target indication and weapon engagement sensors.

Capitalising on the company's previous multibeam radar experience, SMART-L was engineered by Thales to meet a requirement for a volume search radar capable of automatic detection, track initiation and tracking of up to 1,000 air targets at ranges up to 400km. Multibeam operation enables near-hemispherical coverage in a single scan, accurate target elevation measurement even in multipath conditions, and maximum dwell time (allowing high-resolution Doppler measurements at all elevations). This Doppler information is used for clutter rejection and target radial velocity determination for reliable and fast track initiation and track maintenance.

SMART-L has already earned an enviable reputation for outstanding performance and exceptional reliability on board the Royal Netherlands Navy's (RNLN's) four De Zeven Provincien class air defence and command frigates and the German Navy's three F124 Sachsen class AAW frigates. The system has also been selected to meet the needs of the Republic of Korea Navy and the Royal Danish Navy, while the closely

derived S1850M equips the Franco-Italian Horizon class AAW frigates and the Royal Navy's new Type 45 destroyers.

So the SMART-L family is today widely recognized as setting the performance benchmark for long range AAW search radars. This is exemplified by its demonstrated ability to automatically detect and track the most stressing air targets, including stealth aircraft, helicopters and low radar cross section missiles.

What is not perhaps so well known is that SMART-L entered service already enabled to perform limited detection and tracking of ballistic missiles. Introduced as the result of a contract amendment requested by the Netherlands Ministry of Defence and the RNLN in 1995, the incorporation of this additional mode was spurred by a thorough analysis of the 'Scud' attacks launched during the 1991 Gulf War. Their studies con-

cluded that, given the nature of the emerging TBMD threat, a high elevation transmit mode for ballistic missile early warning represented a useful addition to the baseline AAW requirement.

This foresight resulted in a software engineering change, embodied in the system as the Basic TBM Search mode. In simple terms, the Basic TBM Search function combines the existing medium PRF waveform and pulse Doppler processing with a dedicated high elevation (20° to 70°) search pattern to provide a capability for detecting high altitude, high velocity targets (> 1,000 m/s) at ranges out to 600 km.

A land-based SMART-L pre-production model in 1998 demonstrated Basic TBM Search performance against outer atmosphere targets, including the Mir space station in a low orbit above the Earth. Analysis of the logged data revealed some artifact issues, such as missed plots and anomalous range/speed estimation, and it was acknowledged that a credible long range BMD warning sensor would require an effective range out well beyond 1,000 km. Nevertheless, it provided a platform from which to grow the radar's future TBMD capability.

Hawaii test success demonstrates ELR modification

Thales began work in 2000 to develop an Extended Long Range (ELR) search modification (its initial work contributing to, and being informed by, concept validation performed under a tripartite Maritime Tactical Ballistic Missile Defence feasibility study performed by the Netherlands and Germany with US technical support). The promise shown in modeling and simulation saw a decision taken in 2003 to build and test a prototype.

While textbook convention suggests that the obvious solution to extend radar range performance is to enlarge antenna size and increase transmitted power, this hardware-centric approach was both inelegant and impractical for SMART-L given the weight and volume constraints imposed by a shipboard installation. Instead, Thales Nederland's radar engineering team have looked to the science of software; their approach has been to introduce a high sensitivity BMD channel in SMART-L through the development of a dedicated ELR waveform and advanced Doppler processing techniques.

Land-based trials of the prototype ELR modification were undertaken from 2004, culminating in a highly successful trial at a Land-Based Test Site in the Netherlands in early 2005 that gave Thales the confidence to move forward with a ship-based demonstration of the SMART-L ELR upgrade.

A contract was signed in December 2005 for a technology demonstrator to be installed on board the LCF frigate HrMs Tromp to enable its participation in live TBM tracking trials off Hawaii. The SMART-L ELR proof-of-concept embodiment fitted to the ship saw the installation of an additional 19inch electronics rack hosting adjunct real-time signal processing hardware to support the ELR mode (no changes were required for the existing front-end hardware).

The SYPAT HLA-based system performance analysis tool was employed to perform pre-processing of SMART-L ELR plots and establish Space System Tracks including the Predicted Target Trajectory, Estimated Launch Point and Predicted Impact Point. These System Space Tracks were then passed through to the ship's GUARDION combat management system for further processing and promulgation via Link 16. SYPAT also generated a real-time 3D Situation Awareness picture, which was displayed on a large screen display in the Combat Information Centre.

Following a series of trials in the North Sea region, Tromp was in September 2006 certified to sail to the Pacific to join US Navy assets for two TBM exercises. While modelling and simulation had given Thales and the RNLN a high level confidence in the ELR enhancement, there was a recognition that performance validation could only be achieved by detecting and tracking a TBM target in a representative scenario.

A first target tracking event took place on the Pacific Missile Range Facility on 16 November 2006. For the purposes of the exercise, an ARAV-B medium-range ballistic missile surrogate was launched from Kauai Island.

Tromp was positioned approximately 200 km off Kauai. The ship's modified SMART-L radar acquired the ARAV-B target vehicle immediately after it ascended above the island landmass, and successfully held a track on the target through the major part of its trajectory. During this period, the radar was able to discern the ARAV-B nosecone-oriole separation at an altitude of approximately 150 km.

A second test event was conducted on 7 December, co-incident with US Navy Standard Missile-3 (SM-3) Flight Test Mission-11 (FTM-11), with the target on this occasion being an ARIES target vehicle replicating a low-apogee 'Scud' type target. For the purposes of this exercise, known as 'Stellar Hunter', Tromp was stationed around 300 km off Kauai together with the cruiser USS Lake Erie (the SM-3 firing platform) and the destroyer USS Hopper, all three ships netted via Link 16.

The ARIES target was launched as planned, and Tromp's radar once again achieved an early detection. It subsequently tracked the surrogate TBM throughout its flight until just before impact 400 km from Kauai. Tromp was also able to pass its track data to the US ships in the area via Link 16, proving tactical-level interoperability.

The two Hawaii tracking events offered a flawless demonstration of the increased sensitivity conferred to SMART-L by the ELR modification, drawing praise from the US Navy and proving the TBM early warning performance of the sensor. Extended Long Range had come out of the lab and into the field – and conclusively demonstrated the art of the possible.

delivering ELR
capability

Thales is now ready to retrofit the ELR modification in order to confer the SMART-L radar with dual AAW and BMD functionality. Building on the success of the prototype trials programme, it has developed an ELR production-standard technology insertion that introduces a package of engineering changes to SMART-L, that collectively deliver an outstanding TBM early warning capability.

Central to this update is the 'productionised' embodiment of the ELR waveform and Doppler processing proved in the prototype phase. In addition, Thales has made a series of additional hardware, software and operating mode improvements in order to achieve further performance gains.

What should also be borne in mind is that the series of improvements packaged into SMART-L ELR will deliver significant improvements in AAW performance. This ensures that the system will maintain its qualitative edge against the full spectrum of aircraft and air-breathing missile threats.

While a single SMART-L ELR offers very good BMD tracking accuracy, it is necessarily limited in its area coverage. Accordingly, Thales sees the true potential of the system being realised through the netting of multiple distributed radars so as to greatly expand the surveillance footprint, and fuse plots from individual radars into a single high quality precision track. It has already performed a number of modeling and simulation experiments on behalf of NATO nations to confirm its technical and operational feasibility.

The sensor data fusion concept exploits the very good range and Doppler measurement performance afforded by SMART-ELR. Outputs from each sensor node would be transmitted, using the Link 16 message standard, on a satellite bearer to provide Beyond Line-Of-Sight (BLOS) communication. This could in the future be replaced by a more flexible IP-based NATO Secret BLOS network.

Systematic errors, such as misalignments, refraction and ship flexure, are compensated for, as is link latency. The end result is a robust fused track offering significantly improved position and velocity accuracies, and providing four-dimensional information of sufficient precision to support Launch on Remote interceptor engagements.

A springboard to maritime TBMD in Europe

The advent of SMART-L ELR presents NATO navies with a low cost, high Technology Readiness Level route to grow the capability of their latest AAW surface combatants to encompass maritime TBMD surveillance and early warning. Furthermore, it opens the door for European naval forces to make a credible contribution to the alliance's evolving TBMD construct.

SMART-L has, de facto, established itself as the long range shipborne radar of choice across NATO. Already in service with the RNLN's four De Zeven Provincien class air defence and command frigates and the German Navy's three F124 Sachsen class frigates, it will also form a key component of the advanced AAW suite being supplied by Thales for the Royal Danish Navy's three new Ivar Huitfeld class frigates. The latter are due to enter service from 2012.

At the same time, the derivative S1850M radar uplifts the same technology already proven in SMART-L. The S1850M system is now on board the two new Horizon air defence frigates acquired by both France and Italy, and is also equipping the Royal Navy's six new Type 45 destroyers (under the designation Radar Type 1046).

The result is a total of 20 state-of-the-art volume search radars all with the potential to receive the baseline or enhanced ELR backfit in the medium term. This would create a flexible pool of frigates and destroyers offering the capability to interoperate with US Navy BMD platforms and provide a defensive shield for deployed forces and sovereign territory. Forward deployed, and exploiting the unfettered manoeuvre space of the sea, they could provide early warning of TBM launches, track missiles along their ballistic trajectory, calculate launch and impact points to inform defensive and offensive countermeasures, and cue suitable land-based or sea-based interceptors.