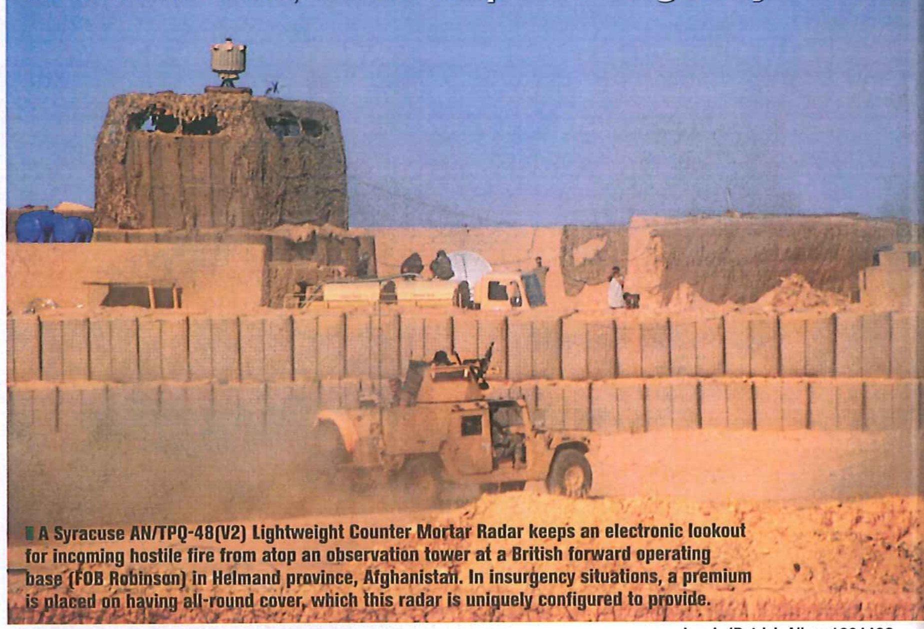
Armed forces seek the WLR connection

Modern militaries are increasingly networking their weapon-locating radars to improve sensor-to-shooter links, writes Rupert Pengelley



A Syracuse AN/TPQ-48(V2) Lightweight Counter Mortar Radar keeps an electronic lookout for incoming hostile fire from atop an observation tower at a British forward operating base (FOB Robinson) in Helmand province, Afghanistan. In insurgency situations, a premium is placed on having all-round cover, which this radar is uniquely configured to provide.

Jane's/Patrick Allen: 1324438

Operation 'Charge of the Knights', the controversial Iraqi Army operation that took place in Basra in March–April 2008, has been variously interpreted as a glorious assertion of new-found virility on the part of the Iraqi administration or as a less than glorious moment of powerlessness or inertia on the part of resident British forces.

An unpublicised sidelight of the operation is that, in the months leading up to it, the area had been turned – as a senior British military participant described it – into "a counter-IDF [indirect fire] testbox" for coalition forces.

A sensor-to-shooter network was created, with the Raytheon Joint Automated Deep Operations Coordination System (JADOCS) planning and execution tool at its heart, to pull together a gamut of US and UK artillery and non-artillery sensors and effectors. It was shown that by networking the elements of the 'kill-chain' using a common communications security standard (in this case the US SIPRNet [Secret Internet Protocol Router Network]), it was possible to generate a very rapid riposte to militia IDF, even in a restrictive urban operating environment.

In a typical engagement sequence the initial detection of hostile IDF would be made by a US Army AN/TPQ-37 Firefinder weapon-locating radar (WLR). This automatically fed point of origin (POO) and predicted point of impact (POI) information into the network via its associated Advanced Field Artillery Tactical Data System (AFATDS). The remainder of the engagement cycle (most simply rendered as 'cue Predator, cue lawyers, cue Paladin') would see sensor pods – carried by aerostats, orbiting fast jets such as the F/A-18C/F, or Predator unmanned aerial vehicles (UAVs) – slewed towards the reported POO and the resulting full-motion video imagery passed simultaneously to the targeting/fire-support co-ordination cell and to legal advisers for immediate target clearance.

In parallel, computerised mensuration programmes would be applied to the target imagery to produce refined co-ordinates, which would be passed via AFATDS to a US Army M109A6 Paladin 155 mm howitzer. Armed with GPS-guided Excalibur high-explosive projectiles, this would be able to place counterfire within less than 5 m of any target over a 20 km radius within tens of seconds of the appropriate authorisation coming through on the network. An F/A-18 or Predator would then follow up with further video footage to enable a battle damage assessment to be made.

To the chagrin of UK observers, the weapons and sensors operated by British Army units (viz AS90 155 mm howitzers and COBRA counterbattery radars) had to be 'overlaid' on this network. That is to say, their lack of an online data exchange capability meant they could not be incorporated directly within the data network and were thus only usable when the requisite operational tempo permitted the use of conventional (secure voice) telling.

Although more than 30 years old in conception, the relevance of the US Army's AN/TPQ-37 Firefinder radar to the contemporary battlefield has been maintained through effective networking with other sensors via AFATDS and JADOCS.

J Guillen/US Marine Corps: 0563374

Ironically the legal and operational clearances (fire-support co-ordination measures, airspace deconfliction, rules of engagement [RoE] compliance and collateral damage estimates, among others) that are these days a pre-condition for most forms of kinetic action potentially involve so many human interventions that they may negate any speed advantages that networking can bring. Pre-determined and pre-cleared engagement criteria are therefore a pre-condition for effective sensor-to-shooter links.

Promising potential

The above episode nonetheless provides a glimpse of the potential impact of digitised systems upon current operations, given adequate networking between all parts of the kill-chain.

With the latter proviso, even venerable systems such as the AN/TPQ-37 Firefinder radar (which entered low-rate production in the late 1970s and achieved an initial operating capability in 1983) can still be made to fulfil a useful role, although the nature of the target array has evidently changed somewhat on the contemporary asymmetric battlefield.

Almost all of those WLRs currently in service were originally designed to keep track of hundreds of simultaneous hostile artillery and mortar engagements under northwest European conditions. Today their users may be required to cope with rather fewer hostile munitions per minute but these can appear in testing shapes, sizes and trajectories; in highly restrictive urban operating and engagement environments; and in challenging heat and sand conditions.

One country that has moved to introduce a new radar with capabilities better adapted to its particular national territorial defence requirements is Israel, currently one of the users of the AN/TPQ-37 Firefinder radar. The IAI Elta EL/M-2084 is an AESA (active electronically scanned array) multimission radar with two main modes: a precision artillery mode within a fixed 90-degree sector; and a medium-range air-defence mode while rotating through 360 degrees. Several radars may be networked via a command-and-control (C2) centre.

In artillery mode, the S-band active-array radar of the truckborne EL/M-2084 is claimed by Elta to be able to locate the source of artillery fire with a circular error probable (CEP) of 125 m at 50 km, and is credited with a maximum detection range of 100 km against 'large' targets (presumably long-range artillery rockets or short-range tactical missiles). Locating ranges against short-range rocket and mortar positions are put at 20 km and 5 km respectively.

The target-handling rate of the EL/M-2084, which has already been adopted by the Israel Defence Force as the basis of a sensor for the Rafael Iron Dome missile and rocket intercept system, is given as 200 targets per minute for artillery projectiles and up to 1,200 per minute for missiles. In air-defence mode its detection range against aircraft is up to 350 km.

COBRA strikes a blow

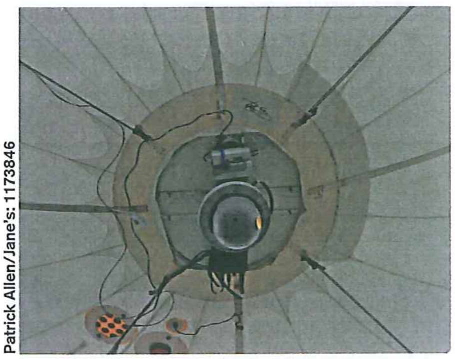
One of the legacy WLRs that has only lately begun to see active service is the COBRA C-band counterbattery radar. This has been developed and produced by the tri-national Euro-Art International consortium, which was formed in 1985 by the then Thomson-CSF, Siemens, Thorn EMI and General Electric companies, whose inheritors are Thales Air Defence (France), EADS Defence and Communications Systems (Germany), Thales Defence (UK) and Lockheed Martin in the United States.

COBRA's active-array emitter has an instrumented range of 40 km and a CEP of 50 m at 15 km (or 0.325 per cent of range). It is capable of producing the co-ordinates for individual hostile-weapon locations at a rate of around 120 per minute.

Production COBRA deliveries began in 2004 and all 29 originally ordered (10 for France, 12 for Germany and seven for the UK) had been handed over by August 2007. Two of the German Army radars have since been transferred to Turkey and Euro-Art is also understood to have negotiated a sale to the United Arab Emirates. Meanwhile the consortium has been developing improved processors and transmit/receive modules, both to enhance in-service radar capabilities and to fulfil new production requirements.

Three French Army COBRAs were deployed to Lebanon in the aftermath of the 2006 Israel-Hizbullah conflict, while three of the British Army's systems were likewise deployed until recently in Iraq. The latter were used to provide a continuous watch over Basra city, determining the POOs and POIs for munitions ranging from Chinese-made 107 mm rockets to Iranian-made 240 mm rockets. In 2007 these radars were said by users to have been typically involved in tracking 20 or more hostile-fire events per week, peaking at 15–20 per day at busier times.

According to Euro-Art, an improved software tool was developed to support the Iraq deployment, enabling COBRA to compute impact and firing points from shorter tracks. The system has also been augmented with data-recording facilities for post-mission analysis of returns from non-standard targets, or from targets otherwise assessed as false. As shown during a NATO DAMA (Defence Against Mortar Attack) Working Group demonstration at Todendorf in Germany in March 2007, in addition to POOs and POIs, COBRA has the capacity to provide real-time trajectory information on multiple projectiles, a pre-requisite for effective employment of counter-rocket, artillery and mortar (C-RAM) hard-kill systems in defended localities.



Patrick Allen/Jane's: 1173846

(Above) The validity of hostile-fire points of origin pinpointed by WLRs can be rapidly corroborated through full-motion video systems carried aloft by fixed-wing jets or UAVs, or, in static situations, by aerostats such as that seen here.

Combined effects

Combined-capability air-defence and weapon-locating radars are already being delivered for active service with coalition forces in Iraq and Afghanistan, in the shape of the Giraffe Fires radar. This has been evolved by Saab Microwave Systems as an extension of its established Giraffe AMB (agile multibeam) mechanically scanned three-dimensional (3-D) air-defence radar product line.

The term 'Fires' is a nod to current US Army doctrine, whereby its air-defence and artillery fire-support branches are being rolled into a single battlefield organisation. According to Saab, weapon-location functionality can be implemented in any version of the Giraffe AMB simply by adding some new cards. The only changes required are to the tracking capability and treatment of the data, there being none to the radar itself. The supplementary processing software is derived from that developed for the company's sector-scanning ARTHUR Artillery Hunting Radar. It thereby provides simultaneous 360-degree coverage against air targets out to 180 km and ballistic weapons out to 20 km, in addition to its integral C2 and fire-support co-ordination facilities. The latter include a built-in datalink or networking capability inherited from the Giraffe AMB, which enables all the radars in a given network to exchange information to create a common operating picture.

Both Saab radars use transceivers operating in the C band rather than the S or X bands. S band has potential advantages in propagation range but it is more complicated to generate beams narrow enough to give the desired precision. X band might be considered optimum in terms of precision but can

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The COBRA counterbattery radar incorporates a C-band active array. In service with the French, German, Turkish and UK armies, it is carried as a single integrated command and sensor system aboard a Foden 8x6 truck in the British case.

suffer from range and weather limitations. C band is thus Saab's preferred compromise, although this too has drawbacks in view of potential civil communications interference.

When speaking at Defence IQ's Future Artillery Conference in London in 2007, Saab's Product Marketing Manager Bard Frostad noted that, in its first live-fire trials staged in March that year at Todendorf, the Giraffe Fires radar demonstrated that it could locate a mortar firing position 17.8 km away with a 10 m CEP. As an illustration of its sensor-to-shooter counterfire potential, he observed that an M270 multiple-launch rocket system (MLRS) firing GPS-guided M31 GMLRS Unitary rounds would be able to put a round on the position of a mortar 10 km away within 34 seconds of the mortar firing its first round, "given a direct link between the Giraffe Fires radar and the MLRS, and supportive fire-support co-ordination measures".

Giraffe Fires development today is focused on improving accuracy against certain types of munition, such as the Chinese 107 mm rocket – which is spin-stabilised and therefore finless – and other low-angle threats. In principle, the AMB's clutter suppression capabilities enable it to scan all the way down to ground level. With a 60 Hz rotation rate, its mechanically scanned passive array could not be said to provide a high enough update rate for all eventualities, and Giraffe Fires is therefore presented as a complement to, rather than a replacement for, a sector-scanning WLR such as the company's ARTHUR.

ARTHUR the hunter

Originally introduced into service in 1999 for the Norwegian and Swedish armies, ARTHUR has since also been sold to the Czech Republic, Denmark, Greece, Singapore, Spain and the UK, additional examples having been leased for operational service with Canadian and Italian forces.

The initial Mod A version had a 15–20 km gun-detection range and a 30–35 km 120 mm mortar-detection range, its location accuracy being 0.45 per cent of range. The Mod B version, which is the basis of the British Army's Mobile Artillery Monitoring Battlefield Radar (MAMBA) system, has extra output power and improved signal processing, the latter including enhanced trajectory calculation, an improved ballistic tracking model for greater tracking stability, enhanced target classification based on 'fuzzy logic', and improved projectile calibre discrimination based on relative drag co-efficients. This gives it an improved detection range (20–25 km against howitzers and 35–40 km against mortars) and better accuracy (0.35 per cent of range).

The latest Mod C Increment I version of ARTHUR has been in serial production since the beginning of 2008 for an unnamed customer (believed to be South Korea, which was reported in late 2007 to have ordered six units valued at USD120 million, for delivery in 2010). According to Saab's Frostad, its antenna is 60 cm taller than earlier versions and improved range and accuracy are its principal operational benefits. It is credited by the company with the ability to detect a mortar bomb (0.01 m radar cross-section [RCS]) at 55 km, an artillery projectile (0.001 m RCS) at 31 km, and rockets with 0.009 m and 0.018 m RCS at 53 km and 60 km respectively. (The latter is a target in the class of a 227 mm MLRS rocket and its detection is said to be a performance unmatched by either the larger AN/TPQ-37 or COBRA radars.)


IAI Elta: 1332380

(Above) The IAI Elta EL/M-2084 S-band active-array multimode radar functions as a precision sector-scanning artillery counterfire radar and also as a rotating air-defence surveillance radar. A version is being used as part of the Israel Defence Force's Iron Dome missile and rocket defence system.


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The Euro-Art COBRA was configured for online integration with the French ATLAS, German Adler and UK BATES artillery command systems. By the time it was ready for service, BATES and its associated Clansman radio system (seen here in 2005) had been withdrawn. The British have yet to manage to introduce a comparable networking system running over the current Bowman radio infrastructure.

Its target-location capability is 100 targets per minute, with a storage capacity of 10,000 targets. Weapon-location accuracies have been given as 0.2 per cent of range for howitzers and rocket systems, and 0.1 per cent of range for mortars (CEP50).

Keeping a cool head

Another of this version's features is the use of a closed-loop liquid cooling system, first introduced with late-production Mod B radars supplied to the Spanish Army. Earlier ARTHURs use air cooling, which is normally sufficient in European conditions but in Middle Eastern conditions does not suffice to prevent automatic shutdown of computing systems when their threshold safety temperature (around 45 degrees Celsius) is reached. Dust in electronics is also inimical to reliability – another reason for the adoption of closed-loop liquid cooling not only for the radar but also for its associated crew cabin, which is fitted with an overpressure system to further impede dust ingress. This change has had a major effect on the extent of preventative maintenance required to keep ARTHUR running.

ARTHUR Mod C does not offer full 360-degree coverage but its azimuth sector coverage has nonetheless been expanded from 90 to 120 degrees, reducing the number of systems required to give instantaneous all-round cover from within a specific defended locality. An alternative approach to providing 360-degree cover is to place a sector-scanning radar at an appropriate standoff distance from the protected site such that its arc becomes wide enough to cover the entire area of interest. In other instances it might be possible for adjacent operating bases to give reciprocal cover using their respective WLRs.

An Increment II version, optimised for force protection, is already being worked upon. This is to have an additional mode enabling it to track a complete trajectory for intercept purposes (as Giraffe Fires already does). Thus it will serve not only to pinpoint the POO for counterbattery fire or ground-force cueing and to provide selective warning for personnel on or near the predicted POI, but also to provide real-time track data to cue an interceptor against the incoming munitions.

Saab has also recently introduced low-angle improvements for ARTHUR, which, in a South African demonstration of the Mod B version in late 2008, enabled the radar to locate firings down to elevations of less than 100 mils (lowest 87 mils). Originally designed to a Norwegian Army specification, ARTHUR has in fact always had a capability to operate below the radar horizon, searching for and tracking targets against a mountainous background. This is particularly pertinent should a WLR be called upon to fulfil look-down or overwatch operations from a hilltop, for example when monitoring urban areas for ceasefire infractions as was sometimes the requirement in Bosnia in the 1990s.

Rising to the challenge

Asymmetric warfare has also thrown up other challenges that it was not originally envisaged should come within the purview of WLRs, which are normally deployed at brigade level. One aim is therefore to improve their performance against 60 mm mortar rounds. While the RCS of the latter generally falls within system capabilities, their low muzzle and radial velocity at very close ranges can nonetheless be problematic.

Although ARTHUR is rated a comparatively low-signature system – having very low sidelobes and no main lobe (only fire lobes) – and has a power output significantly lower than that of the AN/TPQ-37, Saab has designed a decoy system to go with it. This consists of three small transmitters linked by fibre-optic cable to the radar. The latter cues one of the decoy transmitters to send a pulse masking each of its emissions.

ARTHUR was originally designed for the support of manoeuvre forces and its target data is ordinarily co-ordinated through a troop command post linked to all the radars within a given brigade, providing them with current and future operations planning support. In principle this command post could also serve to fuse the data inputs, which it receives via narrowband combat net radio. However, for static C-RAM applications, use would instead most likely be made of the high-capacity fibre-optic cable connections generally found within forward operating bases (FOBs).

3-D visualisation tool

Meanwhile, to aid the planning, deconfliction and clearance processes, Saab Microwave has started to develop a real-time 3-D visualisation tool that presents the situation in the vicinity of a FOB. This includes its airspace, data for which would come from an associated air-defence radar such as Giraffe Fires. The new visualisation system expands upon the capabilities already resident in ARTHUR's Racoon mission planner, which has been in use for some years to assist in optimising WLR positions in relation to terrain and to friendly and enemy ballistic firings.

British forces have been deploying WLRs on operations continuously over the past six years, beginning in 2002 with four ARTHURs loaned by the Norwegian Army for deployment in Afghanistan. Under a similar arrangement, four Norwegian and four Swedish ARTHURs saw extensive service with the British Royal Artillery in Iraq from 2003, these being returned once delivery had been taken of four ARTHUR Mod B radars previously ordered in fulfilment of the MAMBA core equipment requirement. These entered service in June 2004 and from 2007 were joined on operations by some of the seven WLRs long-since ordered under the much-delayed multinational COBRA programme.

A Giraffe AMB radar forms part of the C-RAM force protection system at the coalition base at Basra in Iraq. With additional Fires software, Giraffe can generate point of origin and trajectory data for hostile mortar and rocket fire, as well as air-defence surveillance data.

The WLR role has latterly been expanded for UK forces through the addition of US AN/TPQ-48(V)2 Lightweight Counter-Mortar Radars (LCMRs – see later US reference), which provide a 360-degree surveillance and warning capability over short ranges (typically 5–6 km). Having been acquired in response to an urgent operational requirement (UOR), more than 10 LCMRs are now in service with British forces and more are understood to be on order.

The limited range of the LCMR is acceptable as it is intended only to be used for platoon- or company-based protection purposes. At the moment it serves chiefly to provide warning of hostile fire but in principle it would also be desirable to be able to use the data produced to direct counterfire. Hence in the UK the possibilities are being explored of refining system performance through improvements to the LCMR's signal processing and software, and of triangulation through networking.

COBRA/MAMBA wind-down

According to Colonel David Challes, Deputy Director, Joint Land Forces Engagement, within the UK Ministry of Defence's (MoD's) Directorate of Equipment Capability, Deep Target Attack, since its service introduction "COBRA has shown a very impressive capability" but "there is a huge obsolescence bill coming". Further, it is based on a Foden 8x6 truck chassis and is therefore not notably tactically or strategically deployable; nor was it originally designed to function in A1 (desert) environmental conditions. Extempore air-conditioning systems have therefore had to be devised for it in theatre.

MAMBA may not be fully able to match the range capabilities of COBRA but, being based on a Bv206 tracked chassis, it is more deployable. However, the Bv206 itself faces long-term obsolescence issues relating to protection levels and fleet commonality.

A capability investigation has resulted in a decision in the last planning round (PR08) to bring forward the out-of-service dates of both COBRA and MAMBA, enabling them to be replaced at the same time with a standardised WLR. This should yield economies of scale by cutting the training and logistics bills currently associated with having small numbers of differing systems.

FWLR programme

The UK's programme for the replacement Future Weapon Locating Radar (FWLR), which began in June 2008, is currently in its concept phase. An Initial Gate decision is due in the first quarter of 2009, leading to the start of the assessment phase. The intention, according to Col Challes, is "to be very quick", with the FWLR Main Gate decision being taken in 2010. A firm in-service date (ISD) has yet to be endorsed but the planning assumption is that entry to service would take place in Fiscal Years 2012–13 (FY12–13). Six companies are understood to have responded to the initial FWLR request for information, comprising Euro-Art International, Lockheed Martin, Northrop Grumman, Oerlikon Contraves, Saab Microwave and Thales Raytheon Systems.

Along with a reduction in whole-life costs and improved strategic mobility, the range performance sought from the FWLR is pitched at the longer end of the scale – "but that depends on what the bill is", says Col Challes.

There is also an aspiration to develop WLR precision to give a more accurate POO, since this is not always sufficiently precise for compliance with RoEs (that is, fire cannot be returned). Col Challes notes

A Danish ARTHUR system mounted on a Unimog truck, as deployed to Afghanistan in 2007.

A British Army MAMBA radar on its Bv206 tracked carrier. An improved version of ARTHUR is a candidate for MAMBA and COBRA's FWLR replacement, which is likely to be based on an enhanced protected high-mobility platform.

that "bistatics are looking very promising", the UK MoD having funded some initial research that is being furthered in order to arrive at a potentially fieldable solution.

The short-range case is being addressed through the use of LCMRs, which, as long as operations persist in Afghanistan, are expected to continue to be funded as a UOR. The FWLR, however, as the designated successor to two core programmes, is itself a core programme and funding for it will therefore be found from within the normal MoD budget.

Curiously in the light of the evident operational debits of non-networked WLRs such as COBRA and MAMBA, the FWLR seems destined to become one of a number of emerging surveillance and target acquisition sensors that the British Army 'aspires' to network with its various effectors (for example, AS90, GMLRS and Apache) and other sensors. For the timebeing the Watchkeeper UAV system is still the only one of these sensors that definitely will be networked.

Another incipient failure in 'joined-up thinking' would appear to have arisen in the case of the five Giraffe AMBs that the British Army is buying in fulfilment of its Land Environment Air Picture Provision (LEAPP) battlefield air-defence programme. "Within the equipment procurement plan I don't believe there is any intent to add [WLR] software" to these radars, Col Challes observes.

Beyond the FWLR there will be a Next-Generation Weapon Locating System (NGWLS) – another core programme with a tentative ISD in the 2030 timeframe. This will be a system of systems, sweeping up the locating capabilities today collectively provided by WLRs, acoustic detectors, infrared tracking technologies and so forth.

US programme developments

As related above, the US may have been showing the way of late in networking sensors and effectors but even in that country the practice has been slow to keep up with the technical possibilities. (*Jane's* is aware, for example, of experiments conducted under the auspices of the Army Research Laboratory in the 1980s in which 'quickfire' links were established by hardwiring the output of an AN/TPQ-37 Firefinder radar to the onboard computing system of an M270 MLRS rocket launcher.)

Having, it is thought, exhausted the growth potential of their long-serving and widely sold Thales Raytheon Radar Systems AN/TPQ-36 and TPQ-37 Firefinder radars, and having had a false start with the aborted AN/TPQ-47 Phoenix WLR project, US forces now have two new long-range WLRs on the stocks. The first of these is Lockheed Martin's EQ-36 counterfire target acquisition (CTA) radar, which is under development for the US Army and is described as combining the TPQ-36/37 performance envelopes.

Lockheed Martin Radar Systems received the EQ-36 development contract in January 2007. The prototype, based on the Syracuse Research Corporation's Advanced Technology Objective (ATO) radar, had earlier completed CTA testing in both 90-degree and 360-degree scanning modes at Yuma Proving Ground in Arizona. Air surveillance testing was also conducted with the ATO at White Sands Missile Range in New Mexico. Lockheed Martin was at the same time contracted to deliver an initial lot of five operational systems: two in July 2009, two in October 2009 and the last in December 2009. Twelve additional units have since been ordered, the first of which is expected to be delivered in January 2010. The total requirement for TPQ-36 replacements has been put at 180 radars.

In addition to being prime contractor, Lockheed Martin is responsible for the transmit/receive modules embodied in the EQ-36's S-band active-array antenna and for the digital module assemblies. The transceiver modules are based on those of the ATO (modified at the substrate level) and incorporated in a 20 per cent larger array. Syracuse Research Corporation retains responsibility for the digital signal processor and Burtek Inc for the operations shelter and stationary platform.

In standard configuration a system comprises two two-man 5-ton 6x6 medium tactical vehicle (MTV) trucks, one carrying the radar and towing a 60 kW generator and the other the Burtek operations shelter and backup power supply. For early-entry purposes all of the mission-essential equipment for 72 hours of operation can be accommodated aboard a single MTV, with a laptop control device used instead of the Burtek shelter provided for sustained operations. Export versions could alternatively be mounted on a JLTV (Joint Light Tactical Vehicle)-type vehicle.

According to Lockheed Martin, the user has been continuing to press for early access to the 360-degree coverage and low false-alarm capabilities prospectively offered by the EQ-36. By early October 2009 the first production unit was in final component and system-level testing prior to live-fire testing at Yuma in February 2009. Characterised by the company as "optimised for the CTA mission", it will come with an interface for AFATDS. It is also to have an interface for the US Army's FAADS (Forward Area Air Defense System) C2 system, which is currently a central plank in deployed C-RAM force-protection systems (see below).

The US Army's long-serving AN/TPQ-36 Firefinder radar has a 24 km-range weapon locating capability. Its successor will have a longer range and a smaller footprint.

Front face of the antenna group of Lockheed Martin's prototype EQ-36 counterfire target acquisition radar, which is mounted on an MTV 6x6 chassis at AUSA 2008.

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According to Lockheed Martin representatives, thanks to the EQ-36's active array there is only "a millisecond degradation" in its track performance when switching from the sector-scanning to the 360-degree rotating mode. Thus the system is able to maintain a continuous track of hostile projectiles for C-RAM engagements, as well as determining their points of origin. In comparison with conventional mechanically scanned passive-array radars, it has a larger aperture, higher energy levels and a lower rotation speed, as well as a longer dwell time.

Jane's/Patrick Allen: 1342386

An AN/TPQ-48(V)2 LCMR in operation at the Canadian FOB Frontenac in Afghanistan in early 2008.

G/ATOR multirole radar

Having passed its preliminary design review in October 2007 and its critical design review (CDR) in January 2008, the EQ-36 is about a year ahead of Northrop Grumman's rival G/ATOR (Ground/Air Task Oriented Radar) multirole radar, under development for the US Marine Corps (USMC). Northrop Grumman was first awarded the G/ATOR system design and development and low-rate initial production contracts in September 2005 and won them again in March 2007 after a further round of competition against solutions offered by Lockheed Martin, Thales Raytheon Systems and Technovative Applications.

G/ATOR is intended to replace five out of six in-service USMC radar types, one of which is the TPQ-46A, the marine corps' version of the Firefinder TPQ-36 WLR. Operating in the S band, it will embody technologies evolved for airborne AESA radars (APG-68/81) and TPS-75/78 air surveillance radars, and will have a variable scan rate.

According to the originally announced schedule, the first G/ATOR engineering development model was due to be delivered in 2009. In November 2008 a Northrop Grumman representative told *Jane's* that ever since the programme had been reinstated on 31 March 2007 it had passed all of its major milestones on time. The USMC's CDR is now due to take place in early 2009, although the company has already undertaken its own internal design reviews, stating that "we are ready now".

G/ATOR is to be delivered in four increments that reflect its various modes or capabilities. In principle the hardware baseline now in development is to remain unaltered, the only changes being the number and types of software upload that each incorporates. Increment I software, due to be rolled out for service in 2012, is for air-defence surveillance purposes, or tactical air operations control (TAOC) in USMC parlance. It will provide continuous 360-degree surveillance coverage with a high update rate, and will be able to provide target-cueing data precise enough for C-RAM weapon system intercepts as well as intercepts by MANPAD/SHORAD/SLAMRAAM-type ground air-defence systems.

Increment II, dubbed Ground Weapon Locating Radar or 'Growler' by the USMC, will introduce software optimised for the counterfire mission, giving POOs and POIs for hostile rocket, artillery and mortar attacks. It will have a 360-degree coverage capability, with an instantaneous sector coverage of greater than 90 degrees.

Increment III is expected to be an enhancement of Increment I, with features such as combat identification or non-co-operative target recognition, as well as counter-countermeasures decoy systems. Increment IV will bring additional air-traffic approach control facilities

While for the timebeing G/ATOR developments are nominally focused on Increment I, a Northrop Grumman representative notes that the company has unavoidably "already done much of the tough sledding involved in the hardware and software for increments II, III and IV". In particular the company (the current incumbent contractor for the US Army's AN/TPQ-36 Firefinder counterfire radar) has "for some time" been working on Increment II. "From our perspective there is a large degree of continuity between the two increments," notes the spokesman.

Essentially all G/ATORs will be the same, the various functionalities being selectable at the flick of a switch, but in addition the company acknowledges that "simultaneous multimission" capability studies have been undertaken, potentially enhancing the system's real-time multifunctionality.

Originally designed to be moved around the battlefield by a single HMMWV (High-Mobility Multipurpose Wheeled Vehicle), the 5,000 lb (2,270 kg) G/ATOR system includes a command element as well as its antenna group. In its most basic form the command element is a display in the cab of the vehicle platform, but depending on its role the system can also be operated from a multiple-display console in a command post, its data being fused with various USMC command systems such as the TYQ-23 TAOC or the AFATDS fires management and co-ordination system.

L-band LCMR

Currently the fastest-selling US WLR is the short-range AN/TPQ-48 LCMR, originally developed in the late 1990s as a two-man portable warning system for the US Army's

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Model of the complete EQ-36 vehicle set, showing the antenna group on the vehicle to the right and the Burtek operations shelter on the other.

75th Rangers and now in service with the USMC as well as the US and other NATO armies (including those of Canada, the Netherlands and the UK). Designed and developed by Syracuse Research Corporation, the L-band LCMR has an omnidirectional electronically scanned antenna array, for which Aethercomm provides the power- and phase-matched dual 30 W-output amplifiers. By its own account Aethercomm has also designed power- and phase-matched 10 W power amplifiers for a novel UAV-based Airborne Counter Mortar Radar System.

The LCMR can be powered by either a 60 Hz generator or six BA-5590 radio batteries. When an incoming mortar round is detected, the LCMR sends an immediate acoustic alert via a wired or wireless link to the operator, who has a ruggedised PDA (personal digital assistant) or laptop display on which a 10-figure grid giving the computed hostile mortar location is also presented.

The baseline version was credited with providing continuous all-round detection and tracking capabilities against mortar bombs out to a range of 6 km, the target location error (TLE) being around 100 m at 5 km.

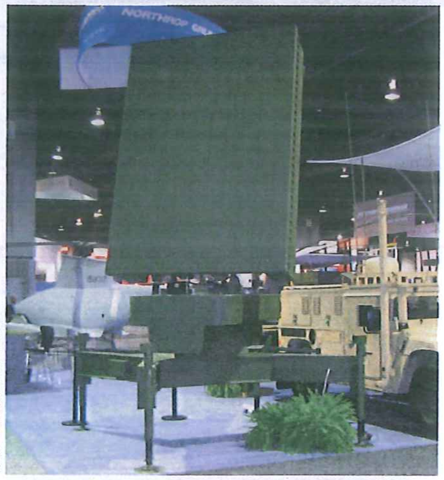
In 2004 the US Army put out a requirement for an enhanced LCMR with the following characteristics: reduced size and weight (below 55 kg) and a lower false-alarm rate; improved POI prediction; reduced TLE (60 m) out to 6 km on 60 mm mortars; increased range (8 km with a 60 m TLE against an 81 mm mortar, or 10 km with a 75 m TLE against a 120 mm mortar); reduced minimum-range capability (500 m); automatic self-survey; and automatic online digital communications for early warning and calls for fire.

This became the AN/TPQ-48(V)2, of which there is a version (Lightweight Surveillance and Target Acquisition Radar/LSTAR) capable of tracking small aircraft to a range of 18 km simultaneous with mortar location. In a dedicated air surveillance mode, LSTAR will track small aircraft to 30 km. Significantly, a US Navy contract amendment in July 2008 noted that "the US Marine Corps is procuring several LCMR and LSTAR radars to serve as subsystems in the Mobile Optical Search System [MOSS], which is currently in the prototype development phase for the USMC".

In April 2008 further upgrades were being sought to improve the LCMR's ability to handle rocket as well as mortar attacks. These involved hardware upgrades and further development of its software algorithms.

Evolutionary enhancements

Some or all of these improvements can be expected to be embodied in the next LCMR evolution: the AN/TPQ-48(V)3. In September 2008 it was announced that the US Army is planning to acquire some 200 examples, with an initial contract award due in mid- to late FY09, over a five-year span. A limited user test of the (V)3 is planned for April 2009 with the initial operational test and evaluation following in early 2010, permitting the first user unit to be equipped by July–September 2010.



Jane's/IDR: 1332385

(Above) Mockup of Northrop Grumman's G/ATOR multirole radar, which was originally designed to be transported as a complete system by a single HMMWV.

Jane's/Patrick Allen: 1368579

A Raytheon LPWS seen at Basra in mid-2008. WLRs integrated into a networked C-RAM system provide such base protection assets with early warning and trajectory information to achieve successful hard kills.

Like its predecessors, the (V)3 is expected to provide continuous all-round coverage but with its nominal effective range against hostile IDF systems extended to 10 km. Setup and teardown times are to be 20 minutes and 10 minutes respectively. The (V)3 is also to be capable of being operated mast-mounted on an HMMWV-category vehicle. Its features include a target record storage capability for post-mission analysis, and a data interface with 'selected' C2 systems (for example, AFATDS). To that end it is to be capable of communicating its target location data to an operator in a remote centre at a minimum distance of 1 km via a secure (Type 1 encrypted) radio or wire link.

This modus operandum builds on experience gained with the (V)2, which among its other applications has been integrated within the C-RAM systems that defend the main coalition bases in Iraq and may in today's terms be considered the acme of real-time networking.

In a typical C-RAM base-protection setup a legacy Thales Raytheon Systems AN/TPQ-64 Sentinel or new Giraffe AMB air-defence search radar performs persistent surveillance of the base environs, providing friendly aircraft locations to a Northrop Grumman FAADS C2 centre that relays the data to one or more Raytheon Land-based Phalanx Weapon Systems (LPWSs). The latter automatically establish a 'no fire' zone round each of the friendly aircraft contacts to preclude a potential 'blue on blue' incident.

Within approximately two seconds of an insurgent mortar or rocket being fired into this tranquil scene, it is detected by both an AN/TPQ-36 Firefinder radar and an LCMR. The former is the first to provide the location and launch point of the incoming munition to the FAADS C2 centre, which approximately three seconds later receives corroborative data from the LCMR.

The C2 centre correlates their respective data inputs (minimising the incidence of false detections) and, assuming the hostile firing has been thereby confirmed, passes the POO co-ordinates to an Air and Missile Defense Workstation. This concurrently sends a call-for-fire message to AFATDS and to the Base Defense Operations Center (BDOC). The BDOC co-ordinates the counterfire response (if any) with the tactical commander responsible for the area of the computed POO. The counterfire choices take the form of precision field artillery fires (Excalibur/GMLRS), ground attacks, or air attacks by attack helicopters, fixed-wing aircraft or armed UAVs.

At the same time the FAAD C2 centre is calculating the POI of the incoming round; initiating localised alarms within the base if appropriate; and sending the location of the munition(s) in flight to all of the LPWSs, directing them to acquire the rounds with their integral tracking radars. The LPWSs duly acquire the incoming rounds and report their status to the FAAD C2 centre, while sending imagery of the tracked objects from their integral thermal cameras to the C-RAM battle captain in the BDOC.

This imagery is checked to ensure no friendly aircraft are in the field of view, and once the battle captain has verified that firing will not endanger friendly aircraft, the FAAD C2 centre directs engagement of the mortar or rocket by the optimum LPWS. This begins its engagement as soon as the mortar or rocket is within range of its 20 mm multi-barrel Gatling cannon, preferably destroying the round at a height sufficient to prevent collateral damage to personnel or equipment at the base.

In microcosm, intimately linked C-RAM sensors and effectors such as these are prototypes for the networked systems now beginning to be put in place to handle the wider multidimensional battlespace of tomorrow – one in which WLRs can be expected to continue to make a significant contribution. ■

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