VOLUME 25/ISSUE 2

APRIL 2017
US$15

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Front Cover Photo:
Malaysia's armed forces fall under AMR's spotlight in *Dzirhan Mahadzir's Malaysia Tightens Its Belt* article in this issue.

Editorial

IT'S A FAMILY **AFFAIR**

Every family has disagreements which can occasionally erupt into robust arguments. Yet in the ruling Kim dynasty which presides over the Democratic People's Republic of Korea (DPRK), familial *contretemps* assume their own unique characteristics.

Kim Jong-un, the DPRK's supreme leader, is known to settle family disputes using somewhat unorthodox approaches. The macabre soap opera that surrounds the affairs of the Kim family has witnessed some startling plot twists since Mr. Kim assumed power on 28th December 2011, following the death of his father Kim Jong-il, popularly referred to as 'the Dear Leader.' Mr. Kim the younger has not been loath to spare the most extreme retribution for those that displease him, be they kith and kin or otherwise.

Jang Song-thaek, Mr. Kim's uncle and alleged chair of the National Defence Commission, considered to be a position of power second only to that of the country's leader, was put to death on 12th December 2013 following his conviction by a special military tribunal convened by the Ministry of State Security. He was reportedly blasted to bits by six anti-aircraft guns. Several members of Mr. Jang's family have also reportedly been executed, including his grandchildren. The charges against Mr. Jang were that he was "despicable human scum … who was worse than a dog," and that he: "perpetrated thrice-cursed acts of treachery in betrayal of such profound trust and warmest paternal love shown by the party and the leader for him," according to an official DPRK announcement detailing his crimes.

Mr. Kim's purges against his family have not stopped with the execution of Mr. Jang. On 13th February, Kim Jong-nam, Mr. Kim's half-brother, was fatally poisoned with VX nerve agent in Kuala Lumpur International Airport. Malaysian authorities strongly suspect the DPRK regime to have masterminded the attack. Although initially expected to take the reins of power upon the death of Mr. Kim's father, Kim Jong-nam fell from grace with his sibling. Media reports have alleged that this was because the latter was advocating economic reforms for the DPRK, and also that Mr. Kim had issued a standing order for his half-brother to be killed.

Whether Kim Jong-nam's death is the result of this standing order or the result of some new consolidation of power by Mr. Kim is unknown. As *AMR* was going to press, on 6th March the DPRK performed four test-launches of ballistic missiles from the Sohae Satellite Launching Station in the west of the country towards the Sea of Japan. The extent to which these launches and Kim Jong-nam's death are connected, possibly as part of a bid by Mr. Kim to reassert his authority remains, like much in the DPRK, shrouded in mystery.

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Audit Bureau Of Circulations
Controlled circulation: 21,271 (average per issue)
certified by ABC Hong Kong,
for the period 1st January 2015 to 31st December 2015.
Subscription Information
ASIAN MILITARY REVIEW can be obtained
by subscription. Subscription rate for one year
(8 issues) is U.S.$ 100.00 Readers should
contact the following address:
Subscription Department,
Media Transasia Limited.
75/8, 14th Floor, Ocean Tower II, Soi Sukhumvit 19,
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ASIA'S ARTILLERY RENNAISSANCE

Artillery is experiencing a revolution in platform design, ordnance and fire control. Such advances are making artillery more deployable, enabling weapons to reach the battle easily and to move around the battlefield quickly to deliver more firepower.

by **Stephen W. Miller**

US Army

Towed guns remain the only field artillery that can be lifted by helicopter. This offers tactical mobility from one site to another, but once dropped they cannot move long distances under their own power.

Contemporary systems such as Nexter's CAESAR wheeled 155mm Self-Propelled Howitzer (SPH) can transition from moving to firing and back again in minutes. Moreover, engagements that previously required batteries of eight guns can now be delivered by two or even a single weapon with even greater effect. This is turning what was once an area weapon into a weapon with the capability for near pinpoint accuracy. An added benefit of today's artillery advances is that many such innovations can be directly applied to existing weapon inventories, thus making upgrades more economically attractive than procuring a new platform.

Many of the changes discussed above have occurred during the last decade. The result of these new developments is that artillery is not only being embraced by militaries worldwide but is taking on new roles that were previously impossible. Many Asia-Pacific armies have recognised the contribution and value of these new capabilities.

Platform Innovation

As the CAESAR SPH has illustrated, truck-mounted artillery is proving increasingly attractive. This product alone has won four customers (Indonesia, Lebanon, Saudi Arabia and Thailand) since the SPH was first ordered by the French Army in September 2000. Discussing the CAESAR, Benjamin Gautier, a spokesperson for Nexter, stated that the CAESAR concept: "originated as a company initiative based on a study of future needs. The idea was that a wheeled self-propelled system could more easily fit into transport aircraft and yet move around the battlefield." By maximising the automation of the gun and firing functions such a platform has the ability to emplace and displace quickly with minimal crews. For example, the CAESAR is outfitted with the Sagem/Safran SIMGA-30 inertial navigation system, which forms part of the weapon's automated gun laying system, and has the ability to be operated by a crew of two. An efficient counter-recoil system has permitted the CAESAR to fire 155mm rounds, while the SPH's wheeled chassis, based on either a Mercedes Benz Unimog U2450L or Renault Sherpa-10 six-wheel drive chassis offers a reduced maintenance and servicing burden, compared to a more complex tracked SPH design, while also permitting their wider use on existing roads and bridges: a key consideration for Asia-Pacific users.

According to official figures, in terms of striking power, the CAESAR has a 40 kilometres/km (24.9 miles) range and a six rounds-per-minute firing rate. It can stop, fire and move again in under three minutes, thus reducing exposure to counter-battery fire. Mr. Gautier indicated that: "the combat employment of CAESAR with French forces in Mali necessitated travelling extreme distances and then quickly responding to calls for fire despite rugged and inhospitable conditions. Its success (in this regard) further validates the concept."

The Royal Thai Army (RTA) has made a major commitment to truck artillery. Since 2010 the RTA has operated six CAESARs, and open media reports state that these platforms were used in April 2011 against Cambodian forces during clashes between Thailand and Cambodia which have focused on a border dispute between the two nations. Elsewhere in the Asia-Pacific region, Indonesia began acquiring 36 CAESARs in 2011 forming an artillery battalion. Meanwhile, in 2015, French and Vietnamese defence websites announced that Vietnam's army was considering the CAESAR with a potential requirement for 108 systems. The French Army has deployed the CAESAR in support of its counter-insurgency operations in Afghanistan and Mali since 2009. Media reports continue that, as of October 2016, four French Army CAESARs have been deployed to Iraq

French MOD

The CAESAR has proven itself in combat operations in Mali, Afghanistan and Iraq supporting the Mosel offensive against ISIS. Here a French Army system is in place ready to provide supporting fires.

The dilemma of achieving strategic air mobility to get artillery to an area of operations, while maintaining tactical mobility once deployed on the battlefield was addressed by the CAESAR 155mm howitzer.

Nexter

to assist Iraqi and other US-led coalition forces seeking to expel the Islamic State of Iraq and Syria (ISIS) insurgent organisation from the northern Iraqi city of Mosul.

Local Efforts

The RTA apparently agrees that truck mounted artillery works. In 2015 the Thai Weapon Industry Centre displayed the Autonomous Truck-Mounted Gun (ATMG) 155mm weapon mounted on a Tatra six-wheel drive truck. In joint development with Elbit Systems, the design is reportedly based on the Soltam Systems ATMOS-2000 155mm SPH. Reports continue that fourteen guns are planned with local production. Other indigenous Asia-Pacific SPH efforts include Norinco's SH1 155mm and SH5 105mm weapons. Norinco likely drew influence for these two platforms from the firm's PCL-09 SPH developed for the People's Liberation Army (PLA). The SH1 has been fielded by Burma and Pakistan. It can fire standard NATO (North Atlantic Treaty Organisation) and Norinco ammunition including the firm's own round, the design of which is reportedly based on the KBP Instrument Design Bureau 30F39 Krasnopol 152mm Precision-Guided Munition (PGM).

Improved Ammunition

As the 30F39 illustrates, a key change in artillery employment has been the introduction of new ammunition exploiting advances in microelectronics. Such PGMs increase lethality, effectiveness and efficiency by significantly reducing the CEP (Circular Error Probability) of a round. The CEP is essentially an accepted measure of weapons precision, the circular diameter area into which 50 percent of rounds fired will fall. A 50 metre/m (164 feet/ft) CEP indicates 50 percent of rounds fired will land within a 50m area. PGMs can be guided or autonomous: Most guided projectiles use laser homing. Here a target is 'painted' by a laser designator aimed by an observer in the air or on the ground. The projectile homes onto the laser energy reflected from the target. Autonomous rounds are equipped with their own navigation and positioning, and have manoeuvring fins or canards so that they can glide onto the target. The navigation used by PGMs can employ either inertial or satellite technology, or be a combination of the two.

The benefit of PGMs is their lower CEP compared to conventional high explosive rounds. For example, official figures denote that the Raytheon/BAE Systems M-982 Excalibur 155mm artillery round has a CEP below five metres (16.4ft) as opposed to 200m (626.2ft) for conventional rounds. Although PGMs are more expensive per round than their conventional counterparts, being able to have the desired target effect while firing fewer rounds has major tactical benefits: So-called 'add-on kits', such as the Orbital ATK M-1156, have been developed that fit onto existing conventional projectiles that offer a performance close to purpose-designed PGMs.

Given the profusion of expertise and manufacturing capability *vis-à-vis* microelectronics in the Asia-Pacific region, it is not surprising that local PGM designs have surfaced. *AMR* confirmed that the Republic of Korea's (ROK) Hanwha Defence has developed a 155mm

munition: "designed to achieve high accuracy on first shot fired, especially in urban operations which require minimal civilian casualties," the company has articulated. This is understandable as the ROK's 2017 to 2021 defence plan places a significant emphasis on counter-artillery guided munitions. These plans prioritise destroying the Democratic People's Republic of Korea's (DPRK) multiple rocket launchers and other long-range artillery weapons during any war between the two Koreas; a task well suited to artillery PGMs. Elsewhere in the region, Norinco has developed a family of PGMs for the PLA's artillery units which include the firm's GS1 and GP6 laser-guided PGMs with a reported 90 percent accuracy to ranges of 25km (15.5 miles). There have also been reports of an extended range 155mm PGM, known as the WS-35, which is said to have a 100km (62.2 miles) range and 40m (131.2ft) CEP. The WS-35 is understood to use the Chinese Beidou satellite navigation system in tandem with an inertial navigation system. The munition is fired from the PLA's PLZ-05 tracked SPH.

As a BAE Systems spokesperson reflected to *AMR* that; "A major advantages of artillery PGMs is their capability to be fired from most fielded artillery pieces of the same calibre." Thus gun performance is enhanced without major investment in weapon modernisation. This makes PGMs an attractive acquisition. For example, the Australian Defence Force has fielded the M-982 to complement its 53 BAE Systems M-777A2 155mm towed howitzers acquired for $850 million in 2012. The guns are also compatible with Orbital ATK's M-1156 PGM kit and Diehl/Rheinmetall's SMArt155 155mm anti-armour round. The latter's projectile carries two sub-muntions that, upon arrival over the target deploy, and descend on ballutes. The dual infrared and millimetre sensors housed in the submunition trigger an explosively-formed penetrator which attacks the top of a target. Any of the other armies operating M-777 family (Canada, India and the United States) clearly have these munition options available to them. These will shortly include India which finalised a $750 million deal with BAE Systems in December 2016 for 145 guns.

Fire Control Systems

Fire Control Systems are the mechanisms through which guns are able to engage targets which they cannot see directly by connecting an observer, usually by radio, providing target information and target location to a Fire Direction Centre (FDC). The FDC computes and provides the guns with the data that allows them to be aimed and fired to hit the target. Today's digital communications and processing, inertial navigation and GPS (Global Positioning System) geolocating, laser ranging and gun automation have transformed what was previously a methodical and largely manual process. The digitisation of fire control permits a direct 'observer-to-gun' loop that can deliver rounds onto a target within seconds of a call for fire. Integrating this technology has increased artillery response, accuracy and effectiveness. At the observer end systems like Safran/Vectronix's GonioLight

Safran

Providing the artillery forward observer with portable observation, range finding, direction and positioning systems, such as the GonioLight, allows them to identify and determine the location of targets to within a few metres.

observation systems offer precise location, direction and range to the target. Another such system is the Rheinmetall/Vinghøg Vingtaqs-II. A Rheinmetall spokesperson indicated that this: "determines the exact coordinates of a target at long distances. As a standalone system, it can be deployed in a static fashion dismounted, or mounted on a wide variety of vehicles. The system also features laser-enabled target designation." The Vingtaqs-II was fielded by Malaysia as part of a $49.6m contract with deliveries beginning in 2014 and the product is installed on the Malaysian Army's DefTech AV-8 eight-wheel drive armoured vehicles. More information on Malaysian defence procurement can be found in Dzirhan Mahadzir's *Malaysia Tightens its Belt* article in this issue.

At the battery level, gun laying and positioning technology provides fast and exceptionally accurate alignment in minutes often utilising hybrid land navigation systems comprising INS (Inertial Navigation System) and GPS technologies. This capability, once restricted to SPHs, is now increasingly common even for towed guns. This is a

Raytheon

The M-982 is a 155mm artillery projectile that contains it own GPS and uses fins that deploy after firing to glide to the location programmed by the gun crew. It has achieved an accuracy of better than five metres in combat.

direct result of electronics miniaturization. In fact, increasingly the FCSs for towed and self propelled guns are coalescing. This is the case with the M-777 and the M-109A6/A7 Paladin 155mm towed howitzers and SPHs which use digital fire control systems. A programme engineer from BAE Systems reflected that, thanks to its digital FCS, the M-109A6/A7 can transition from moving to a firing position, and have rounds on the way, in as little as one minute; a process that previously took as much as 20 minutes: "This means both a more rapid response to fire missions and reduced vulnerability to enemy counter-fire." The M-109A6, which is fielded by Malaysia, has this capability and the M-109A5 in RTA service could receive a digital FCS in the future. In addition, the ROK has implemented similar capabilities in both their Samsung Techwin K-9 Thunder SPH and the firm's K-55A1, itself an improved version of the M-109 family. The K-9's 155mm gun is also fully automated, allowing a burst rate of fire of three rounds in 15 seconds and a maximum rate of up to eight rounds-per-minute. The advanced state of the ROK's artillery development has earned it worldwide attention. The K-9 Thunder has been adopted by Turkey where it will be licence built. It is also the subject of collaboration with Huta Stalowa Wola in Poland, where it forms the basis of the AHS Krab SPH.

Artillery Going Forward

Some armies which had neglected artillery for the lure of aircraft-delivered firepower have again realised its unique benefits. Artillery fires can be available in seconds rather than minutes, and be available during the day or night, even in the worst visibility and weather conditions. Technology has enhanced and expanded the capability and roles of this restored "God of War", as artillery was once termed by the Soviet dictator Joseph Stalin. The degree to which technology has changed artillery is demonstrated by the evolution occurring in artillery organisation and tactics. A single gun, or a pair of guns, can now deliver fires not simply equivalent to, in terms of speed and accuracy, but exceeding that of a previous eight-gun battery. This has lead to a rethinking of concepts of operations for dispered guns. The Australian Army's Royal Australian Artillery has adopted a four-gun battery structure viewing it as both more flexible and saving resources. The adoption of fire support command and control systems like Raytheon's Advanced Field Artillery Tactical Data System (AFATDS) further facilitates this approach. The AFATDS, which is fielded by the US Army and the US Marine Corps and the Australian Army, allows fire support assets spread several kilometres apart to be integrated and their fires, as well as those of other supporting arms, to be coordinated and massed. That many of these artillery capability improvements can be adopted for existing gun inventories is a further major advantage particularly for those armies in the Asia-Pacific. Given this and the modest investments necessary to achieve such a substantial return in combat capability through the major enhancement of accuracy, the transformation of artillery is certain to proliferate across all armies in the region. AMR

PULSE

by **Thomas Withington**

Indonesia moves ahead with the acquisition of new ground-based air defence radars, while the US Navy works to strengthen its airborne defences against anti-ship missiles. Elsewhere, in the satellite communications domain, new products are launched at the IDEX exhibition.

Airbus

The AN/SPS-75 radar is to equip the last ship in the USCG's 'Legend' class of national security cutters. To date, Airbus has delivered nine radars to equip this class of ship.

Radar

The *Tentara Nasional Indonesia-Angkatan Udara* (TNI-AU/Indonesian Air Force) has outlined plans to enhance the country's ground-based air surveillance radar network, according to an announcement by Air Marshal Hadi Tjahjanto, the TNI-AU's chief of staff, made in late January. According to AM Tjahjanto, the TNI-AU will increase its inventory of ground-based air surveillance radars from 20 to 32 examples. He continued that the force is: "hoping to be able to cover more area in order to avoid violations of Indonesian airspace."

AM Tjahjanto's comments indicate that there is still domestic airspace which the TNI-AU is unable to monitor because of a lack of radar. Although the TNI-AU intends to procure new systems, no clues have been given as to when these radars could be procured, how many maybe purchased or when deliveries could commence and conclude. Furthermore, it seems that the TNI-AU has yet to decide precisely which model of radar it will purchase. According to publicly available sources, the TNI-AU operates diverse range of ground-based air surveillance radars. These include BAE Systems' AR-235 Commander S-band (2.3-2.5/2.7-3.7 gigahertz/GHz) radar, two of which entered service between 1993 and 1994. These two radars are reinforced with four Thales Master-T S-band systems delivered between 2006 and 2012 and Thales TRS-2215/2230 S-band radars; 14 of which were delivered between 1979 and 1981. This list excludes radars such as the Thales Ground Master-200 S-band and Saab Giraffe-40 C-band (5.25-5.925GHz) radars procured to support the *Tentara Nasional Indonesia-Angkatan Darat* (Indonesian Army) Thales Forcesheild and Saab RBS-70 surface-to-air missile systems. The TNI-AU has given no indication as to when this radar acquisition maybe performed.

Away from Indonesia, Lockheed Martin has told *AMR* that it expects to have the first of the Fleet Air Arm's (FAA/Royal Navy Aviation) AgustaWestland Merlin HM2 naval support helicopters equipped with the firm's Airborne Early Warning (AEW) mission system available for the FAA from June 2019. The AEW mission system, which includes Thales' Searchwater X-band

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Thales' Searchwater ASaC radar will be procured for the Royal Navy as part of the UK MOD's Crowsnest programme which will outfit the FAA with a new AEW capability to equip its Merlin HM2 aircraft.

(8.5-10.68GHz) family radar and Cerberus mission system, has been acquired by the UK Ministry of Defence (MOD) via its Crowsnest programme which adds an AEW capability to all 30 of the FAA's Merlin HM2 aircraft as a replacement for the FAA's existing AgustaWestland Sea King ASaC7 aircraft currently tasked with the AEW role which are due to retire in 2018, according to the MOD. It is expected that the Merlin HM2 will receive the Searchwater ASaC variant, itself the latest member of the Searchwater family. This radar can perform ground moving target detection, alongside conventional AEW tasks over land and sea, according to open sources. Publicly available figures regarding the radar's range are hard to find, although some open sources talk of the radar being capable of detecting targets at a range in excess of 85 nautical miles/nm (157 kilometres/km). Although all 30 aircraft will be able to accommodate the AEW mission system, ten systems will be acquired which can then be installed on any of these helicopters. Lockheed Martin continued that the first kit is expected to be delivered to the FAA in October 2018, with the system having its initial operational capability declared in 2020. The company continued that the value of the Crowsnest contact is worth $336.6 million.

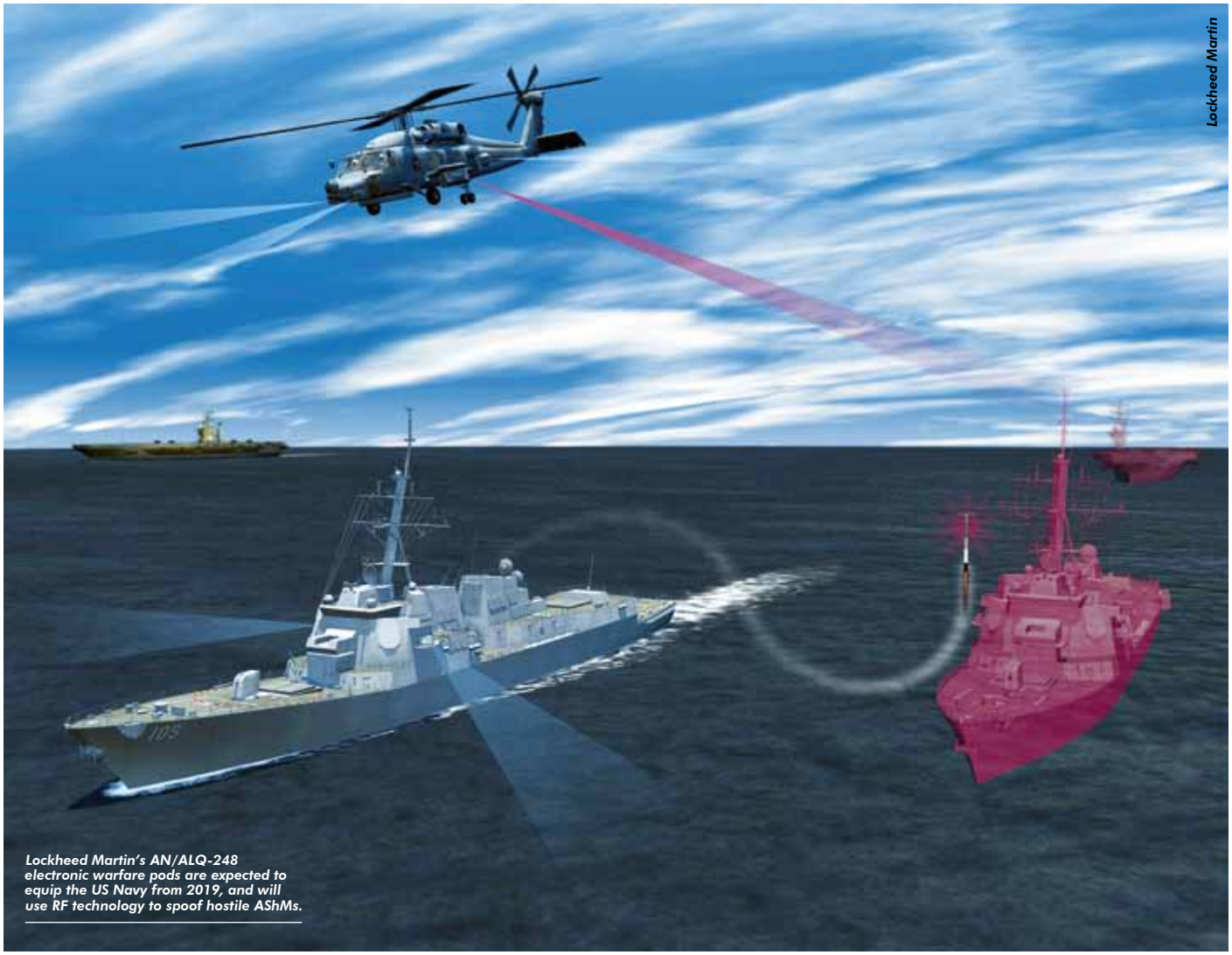
Airbus' defence and space subsidiary has told *AMR* that it has eight of its AN/SPS-75 (the local designation for the firm's TRS-3D product) naval surveillance radars on order from Lockheed Martin to equip the US Coast Guard's 'Legend' class national security cutters. In mid-January, Airbus published a press release stating that a ninth radar had been ordered to equip the final ship in the class, the USCG *Stone*. Three vessels are currently under construction, the USCG *Munro*, USCG *Kimball* and USCG *Midgett*. The TRS-3D is a C-band radar which can detect a sea-skimming Anti-Ship Missile (AShM) at a range of between eight and eleven nautical miles (15km and 20km). Detection of a fast jet can be performed at 59nm (110km). The radar has a surveillance range of up to 97nm (180km). The TRS-3D is available in the TRS-3D/16 and TRS-3D/32 variants; the designation corresponding to the number of vertical rows of radiating elements mounted on the antenna.

Electronic Warfare

Joe Ottaviano, director for electronic warfare at Lockheed Martin, has told *AMR* that the company's AN/ALQ-248 electronic warfare pods that it is supplying to the US Navy will employ Radio Frequency (RF) countermeasures to defeat AShMs. The company was awarded the contract, worth $93 million, to integrate the firm's AN/ALQ-248 electronic warfare pod onto the US Navy's Sikorsky MH-60R/S naval support helicopters in mid-January. According to news reports announcing the award, the firm is expected to provide up to 18 AN/ALQ-248 pods to

the navy from 2019, with an initial operational capability for the system being declared by the force in 2021. The task of the AN/ALQ-248 is to: "detect an incoming missile and then evaluate where it is going," Mr. Ottaviano continued: "The pod then uses radio frequency countermeasures to deter the missile." The detection is performed using an in-built Electronic Surveillance Measure (ESM). Although not confirmed by the company, this ESM may detect RF transmissions at comparatively high radar frequency bands. This could be a particularly important capability given the AShM threat faced by the US Navy. According to an article by Michael Milburn, entitled *Against the Growing Anti Ship Missile Threat, Are We Truly Semper Paratus?* published in December 2016 by the Centre for International Maritime Security, a think tank based in Maryland, and the 2014 article by Daniel Baart entitled *Responding to the New Anti-Ship Cruise Missile Threat*, published in 2014 in the *Canadian Naval Review*, a number of AShMs around the globe constitute a tangible threat to the world's navies. These include the China Haiyang Electromechanical Corporation's C-802 family AShM, the China Aerospace Science and Industry Corporation's C/CM-602 AShM, the Russian MKB Raduga P-270 Moskit AShM family and the Novator Design Bureau 3M-54 AShM family. As noted, all of these weapons employ Active Radar Homing (ARH), and open sources suggest that the C-802 and C/CM-602 both employ an X-band radar seeker, with the radar frequency for the P-270 and 3M-54 being unreported, though also possibly transmitting in the X-band. Lockheed Martin continues that the AN/ALQ-248 uses RF jamming to "deter the missile." Although not confirmed by the company, this presumably includes the means to jam the AShM's ARH seeker with electronic noise to render it benign to a warship. Another important aspect of the AN/ALQ-248 is its ability to share its information with the US Navy's Raytheon AN/SLQ-32(V)6 shipboard electronic warfare system. The AN/SLQ-32(V)6 Block-2 incarnation of this system has been realised via the US Navy's Surface Electronic Warfare Improvement Programme (SEWIP) initiative. Production of the AN/SLQ-32(V)6 Block-2 systems under the SEWIP for the US Navy was commenced by Lockheed Martin as part of a full rate production contract awarded in mid-December 2016 worth $148.9 million. The SEWIP Block-2 initiative improves the AN/SLQ-32(V)'s electronic support measures and upgrades its antennae leading to an overall improvement in the detection capabilities and accuracy of the AN/SLQ-32(V).

Confusion surrounds the status of a putative Electronic Intelligence (ELINT) gathering aircraft programme announced by Ukraine and Saudi Arabia in November 2016. Back then, news reports articulated that Saudi Arabia had initiated plans to procure up to six Antonov AN-132 turboprop freighters; two of which would be configured for ELINT gathering. Tellingly, no information was released regarding the possible specification of these aircraft, or when they might be delivered to the Royal Saudi Air Force (RSAF). Nevertheless, during the International Defence Exhibition held in Abu Dhabi in late February, Ukraine's state defence export company Ukroboronprom revealed to *AMR* that the exact specification of the ELINT aircraft had yet to be agreed by the RSAF and the Ukrainian company. Furthermore, Ukroboronprom sources were unable to provide any information as to when the configuration of the RSAF's ELINT aircraft could be frozen, or when deliveries of these platforms could commence and conclude. For now, the sources added, the initiative essentially remains a 'paper aeroplane' with no indication as to when the design phase could formally commence. The RSAF currently deploys three Boeing RE-3A Signals Intelligence/ELINT aircraft. According to open sources, all three of these aircraft are equipped with the upgraded version of the Tactical Airborne Surveillance System (TASS) which has been installed on the aircraft by Raytheon following a 2009 contract award to the firm worth $530 million, according to an official US Department of Defence statement. Although details are sparse regarding the performance of the TASS, open sources note that it is optimised to detect, analyse and geolocate communications in the High Frequency to Ultra High Frequency wavebands of three megahertz to three gigahertz. In



Lockheed Martin's AN/ALQ-248 electronic warfare pods are expected to equip the US Navy from 2019, and will use RF technology to spoof hostile AShMs.

addition, the aircraft may also be capable of detecting, analysing and geolocating radar emissions.

SATCOM

Airbus' defence and space subsidiary has provided *AMR* with further details regarding a framework contract awarded to the firm by the European Defence Agency, an agency of the European Union (EU) which fosters defence cooperation across the EU, on 2nd February to provide Satellite Communications (SATCOM) for the EU military training mission in Somalia (EUTM Somalia) and the European Union Capacity Building (EUCAP) missions in the Sahel regions of central Mali and southern Niger.

The EUTM initiative was launched in Somalia in April 2010 with the aim of strengthening the Somali Transitional Federal Government, and its accompanying institutions, to assist the stabilisation of the war-torn country. Meanwhile, the EUCAP missions in Mali and Niger are intended to strengthen the ability of both these nations to combat organised crime and insurgency, and to reinforce the rule of law in both nations. Under the contract, the value of which the firm states is confidential, Airbus will provide the required SATCOM ground terminals, communications equipment, services and airtime, the firm disclosed in a press release announcing the news. An Airbus spokesperson told *AMR* that the firm would select suitable satellite constellations across the L-band (240-270MHz), C-band (5.925-6.425GHz uplink/3.7-4.2GHz downlink), X-band (7.9-8.4GHz uplink/7.25-7.75GHz downlink), Ku-band (14GHz uplink/10.9-12.75GHz downlink) and Ka-band (26.5-40GHz uplink/18-20GHz downlink): "We select the satellites that fit best to the need of the end users," the spokesperson continued. The spokesperson added that SATCOM terminals to support these EU operations, as part of this contract, can be supplied by Iridium, Thuraya and Inmarsat, and that the communications services offered as part of this contract will be used by the EU members supporting these missions. Moreover, Airbus stated this contract will run for four years.

Meanwhile, at the International Defence Exhibition, held in Abu Dhabi in late February, Hughes debuted its new 360 degree HeloSat SATCOM system that the company has designed to equip helicopters. Using two antennae mounted either side of a rotorcraft's fuselage, the product is housed in a roll-on/roll-off configuration with the antennae being attached to the helicopter's

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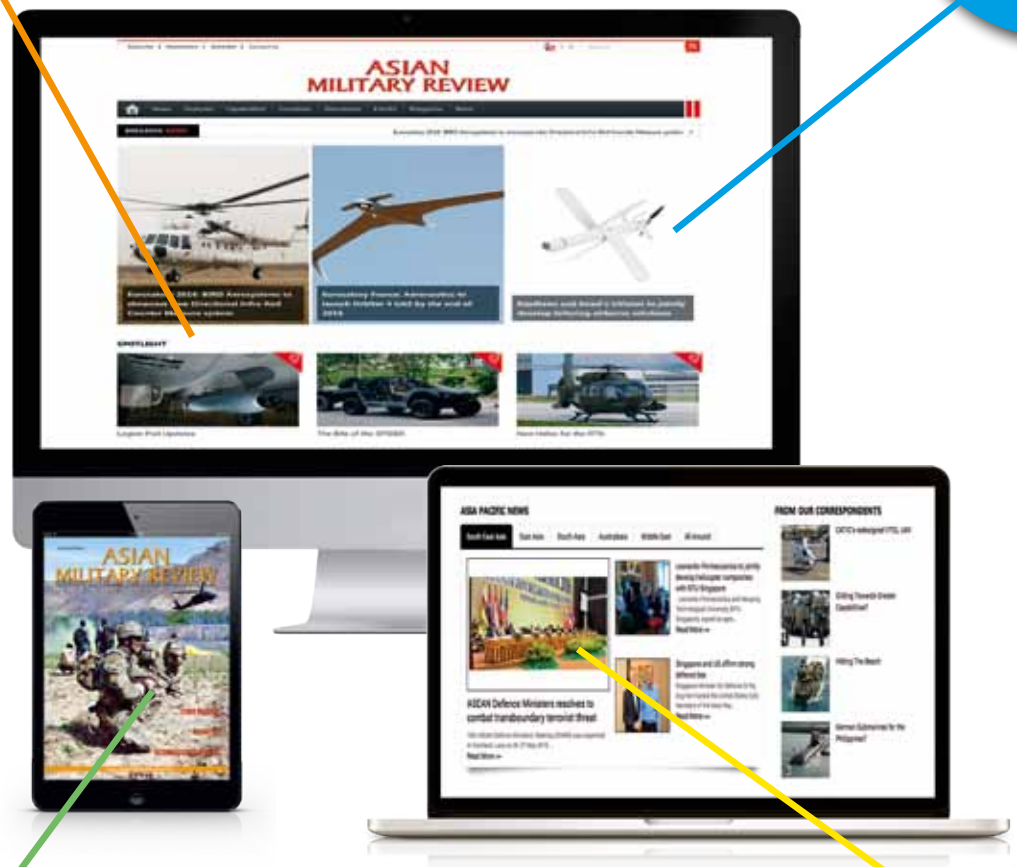

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Hughes' new HeloSat system was debuted at the IDEX exhibition. The product promises to offer 360 degree SATCOM coverage for rotorcraft, and is expected to soon equip the UAE Air Force.

Although the procurement of new ELINT-equipped AN-132 aircraft by the RSAF was announced amidst much fanfare in 2016, little progress appears to have been made on the project.

sponsons, and the entire *ensemble* (the antennae, and two modems) weighing 60 pounds (27.3 kilograms). During the exhibition, the firm told *AMR* that HeloSat was capable of handling X-band, Ku-band and Ka-Band satellite traffic. Although HeloSat is not yet in service, a spokesperson for the company said that the technology underpinning the product is "production ready," and that deliveries could commence within "six months" of the firm receiving an order. The spokesperson continued that Hughes' Microsat Waveform was at the heart of HeloSat. This waveform helps to prevent any data loss which can result from the aircraft's rotor blades slicing through the satellite transmissions by using a process known as forward error correction which avoids any loss in data caused by the movement of the blades. The spokesperson added that HeloSat can carry voice, data and full motion video, at rates of up to four megabits-per-second, although they added that the system had demonstrated its ability to carry up to ten megabits-per-second of data.

Furthermore, the company stated that it has witnessed significant interest in the product. The United Arab Emirates (UAE) has issued the company a request for proposals for the acquisition of up to 29 systems to equip the Bell Helicopter/ Northstar Aviation 407MRH armed helicopters of which the UAE Air Force (UAEAF) has ordered 30, according to media reports. The UAEAF is expected to use the HeloSat to carry traffic across the UAE's YahSat C-band, Ku-band and Ka-band communications satellite constellation. The company continued that it expects to receive a contract to deliver these HeloSat systems to the UAE: "towards the end of this year, or early next year." Beyond the UAE, the firm added that the United States Special Operations Command (USSOCOM) had shown interest in the HeloSat technology, which has been tested to this end onboard the Bell-Boeing CV-22B Osprey tilt rotor, although there is no indication as to if and when USSOCOM might order the HeloSat, and how many systems it might acquire. AMR

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Controp

A tender for an undisclosed customer led Controp to develop the Speed-ER tactical observation system, which led to a contract award under which the company is currently delivering the system.

INTELLIGENT INTELLIGENCE

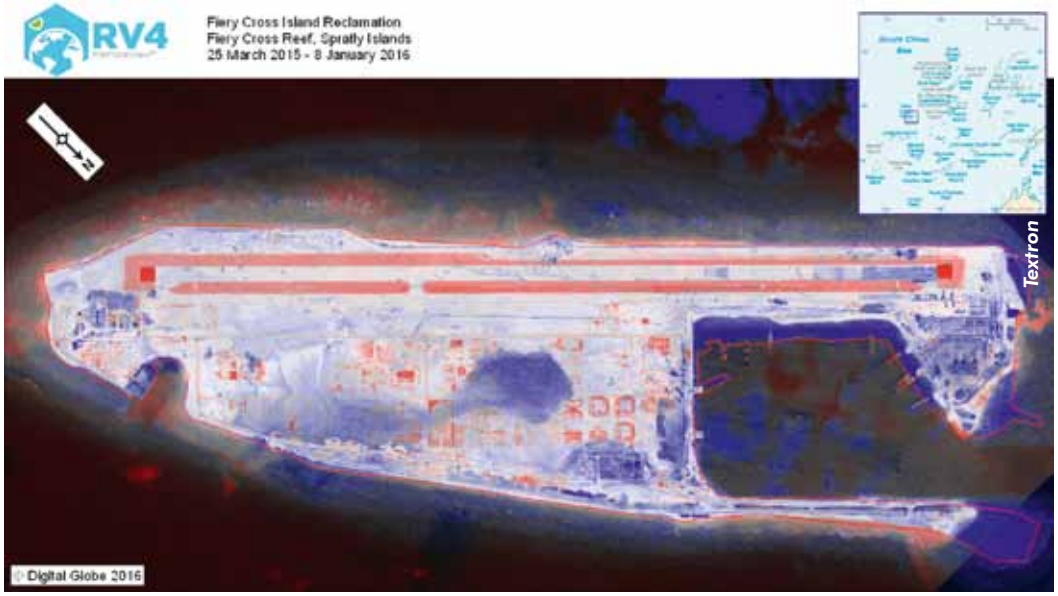
For a soldier, being able to rapidly deploy, or indeed have access to an already deployed surveillance asset is of paramount importance, and the timeliness of access to such a capability is key. Such a requirement was observed during recent combat operations in Iraq and Afghanistan.

by **Beth Stevenson**

The US-led interventions in both these countries saw significant operations in urban environments. This called for the overwatch of an area to provide immediate intelligence regarding the situation that personnel were about to enter. However, this requirement did not remain exclusive to these operations, as current theatres, such as ongoing US-led operations against the Islamic State of Iraq and Syria (ISIS) in both these countries, plus the ongoing requirement for nations to protect their borders as is prevalent throughout the Asia-Pacific, adds to the requirement for surveillance bolstered by overhead capabilities: "Most countries are interested in strengthening their security both in the coastal and border areas that they have with other countries," observed Hagay Azani, Controp's vice president for marketing and sales.

This is true for most nations around the world, as border disputes and the rise of political violence continue to be a problem for several countries within and without the Asia-Pacific region. Such security considerations have enhanced the importance of dismounted ISR (Intelligence, Surveillance and Reconnaissance). Dismounted ISR can be provided in a number of ways, ranging from ground-based sensors to Unmanned Aerial Vehicles (UAVs), satellites and aerostats. While satellites are classified as fixed

infrastructure, the ability of deployed troops to tap into them and receive ISR information on the move is a key capability. Textron Systems' geospatial division develops a range of analytical tools that can help process a number of data feeds, which can be fed to an observer to provide a common operating picture while on the move. For example, the firm's Remote View software takes in a host of different data feeds (such as imagery streams delivered from satellites and UAVs, for example) which can then be exploited to plan missions and execute different objectives.



With geospatial intelligence requirements on the rise, Textron's RemoteView product line provides analysis of different data sources to allow operators to disseminate information and to use it effectively.

In addition to imagery intelligence, RemoteView can receive signals and human intelligence, to name but two extra sources. The firm's official literature states that the software can run on a computer using the Linux or Windows-7 operating systems. Daryl Madden, senior vice president and general manager of Textron's geospatial solutions division told *AMR*, adding that 'big data' is now a common problem, which is "exploding on a day to day basis." He added that: "It is all about making sense of this chaos of data." The baseline RemoteView system is still client-based, so the company introduced a web-based version, known as the RVcloud, in 2016, to allow for more digital access to this capability: "This is the transition we've been working on over the past few years," Mr. Madden said, noting that there are now a number of options for different requirements: "This is an extremely exciting and challenging time in the geospatial industry."

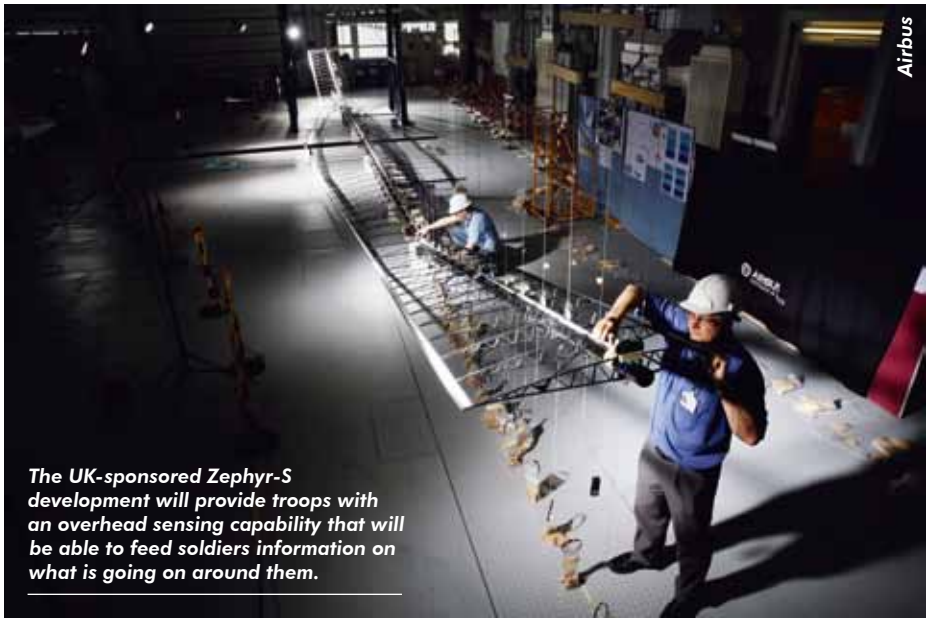
He continued that there is now an influx of small commercially-owned satellites becoming available, which are offering a high enough standard of resolution for military use, such as DigitalGlobe's WorldView constellation: "The challenge falls on us to take that data and make it useable," Mr. Madden said: "As we see this wealth in geospatial data, we need to create the tools to process it. In the end, the user just wants an answer to a question." The access to information that users want varies from a quick view of a particular real time image while on the move, to a more disseminated picture of a particular area and the change in those images over a period of time: "Each country is now realising that they want to keep an eye on their neighbours," Mr. Madden noted.

Full Motion Video (FMV) feeds from a UAV is another level of data that military users want adding to their intelligence feed, and Textron has also incorporated this into a system called V-Trac, which is a software exploitation tool for FMV that works alongside RemoteView. V-Trac takes a frame from the FMV feed, and then sends it to the RemoteView system for exploitation. Textron incorporates regular updates to the software, and is preparing to roll out the newest one this year: "Our latest version will be released in the first quarter of 2017, with over 100 different user updates," Mr. Madden continued: "Ten years ago, users used to be image starved…and now almost the opposite is true."

SWIR

In response to a tender from an undisclosed customer that it ultimately won, Controp developed a Short Wave Infrared (SWIR) ultra-long-range observation system dubbed Speed-ER. Launched officially during the June 2016 Eurosatory defence exhibition in Paris, the system is derived from the Speed-LR variant that is in operation with five undisclosed customers, but expands on the performance of the system, while adding SWIR sensing. SWIR, which covers a 1.4 micron (μm) to three micron range, offers a number of advantages to the user in that it does not require cryogenic cooling of the IR sensor, offers high resolution imagery and good penetration of smoke and fog: "What motivated Controp (to develop) the Speed-ER was a very important tender that one of our major customers published," Mr. Azani told *AMR*: "Since we were in the market for surveillance systems for border and coastal protection we started shaping our technical standpoint in taking the Speed-LR that we had at that time that one step forward, and bringing it to a level of performance in terms of longer range observation systems." This, Mr. Azani said, was in the field of detection, recognition and identification performance, so as to have larger sensors in terms of focal length (distance between the lens and the image sensor), and more sensitive detectors to increase the mechanical stabilisation level: "Once you go into a very narrow field of view…you still have some vibrations entering the system because of wind and other inner influences in the system … Therefore, if you are going into a 0.2 degree level Field-Of-View (FOV), or 0.4 degree FOV with the thermal imager, you need to have a very good level of stability. We needed to somehow take our systems to the next level."

The tender for this ultra-long-range system was released and awarded in 2014, but the company began work on it prior to that: "First, the sensor; we knew our customer required a SWIR sensor because when looking at far distances, the day channel which has some atmospheric limitations, essentially does not do the job," Mr. Azani continued: "The SWIR technology, which of course was known to the market but was not applicable at



The UK-sponsored Zephyr-S development will provide troops with an overhead sensing capability that will be able to feed soldiers information on what is going on around them.

the time for these kinds of observations and applications, needed to be taken off the sketching table into the actual design and development programme work, and eventually be integrated into a camera." The SWIR technology had not previously been used for this application by Controp or anybody else, the company says, but this type of sensing lent itself to reducing the burden laid on the thermal imager.

Many systems rely on the thermal imager in a multi-sensor observation system like this to carry out surveillance in harsh atmospheric conditions when the conventional camera struggles to operate, which in turn shortens the lifespan of the camera. This is because it puts pressure on the system's cooler, which is the most sensitive element of the camera, and if this is operated constantly, the camera will have to be repaired every six months or so: "The SWIR channel allows the operator to see extremely well through those bad atmospheric conditions," Mr. Azani said.

The range of the system from the Speed-LR to the Speed-ER increases from 20 kilometres/km (12.4 miles) to in excess of 30km (18.6 miles) for some of the product's sensors, and the Speed-LR is an all-round less sophisticated sensor than its new counterpart, according to the firm. Nevertheless, Mr. Azani said that there is still a market for both variants: "The Speed-LR still has a place … Not all of the customers require that sort of performance (of the Speed-ER) from their observations system." He added that the legacy the company has in long-range observation systems in the fields of thermal imagers, day sensors, pan and tilt, and stabilisation levels: "enabled us to take the SWIR into that capability and promote a multi-sensor system for long ranges … We (also) understand that most customers do not just require one system. Their requirement is to protect (coastal and border areas). Therefore one advantage of the Speed-ER is that, because it has long ranges of observation, you can eventually use less systems, because you can get a good overlap (of coverage)." Controp is in the process of delivering the system to its undisclosed launch customer, with 100 examples expected to roll off the production line by the end of 2017. The firm is also eyeing other opportunities for the system, but declines to say where: "We have (significant) interest from customers that come to us wanting to understand if this product can be a solution for them, so the interest is very high throughout the world."

HAPS

A new technology that could help change the way soldiers receive ISR information on the move is through High Altitude Pseudo Satellites (HAPS). The most prominent technology to this effect is Airbus' defence and space division's Zephyr-S/T UAV that can fly overhead for days on end to provide intelligence and a communications relay to soldiers below. Three Zephyr-S examples have been purchased by the UK Ministry of Defence (MOD) for an Operational Capability Demonstration (OCD), the first two in February 2016 with a third option under the terms of the contract executed in August 2016, under a $15.2 million contract, according to the MOD: The: "Zephyr is a cutting-edge, record-breaking piece of kit that will be capable of gathering constant, reliable information over vast geographical areas at a much greater level of detail than ever before," the UK's secretary of state for defence Sir Michael Fallon said in August 2016.

The OCD is on track to be carried out in the second half of 2017, an Airbus spokesperson told *AMR*, during which the MOD will assess the operational

The Zephyr-S/T will be available in two variants that will have different payloads, both of which are solar-powered and can stay aloft for days on end.

Elbit's ISTAR-DS system collects a number of different feeds together to provide a common operating picture to the dismounted soldier.

capability of the aircraft. All three examples are new-build aircraft that will be owned by the UK government, but what will happen after the testing is yet to be determined, and little detail on the progress of the OCD is expected to be released until after the testing.

The concept of Zephyr-S/T resonates with the use of a high-altitude, long-endurance UAV such as the Northrop Grumman RQ-4B Global Hawk which flies for long periods of time and provides intelligence on what is going on over large areas and ranges. The difference with the Zephyr-S/T is that it is self-propelled by solar power, so is more energy efficient, and can stay aloft for longer periods of time.

The downside comes from the size of its payload, which is approximately eleven pounds (five kilograms), Airbus said, so the UK government is sponsoring a number of efforts to develop technology that can be used on the Zephyr-S.

The MOD announced in April 2016 that its Centre for Defence Excellence had funded a number of studies into different technologies, including a foliage-dispersing radar, software-defined laser radar, synthetic aperture radar and optical systems that would be suitable for the lightweight airframe. Additionally, Roke Manor was contracted at the end of 2014 to develop a communications payload for the HAPS aircraft, funded by the UK government's Defence Growth Partnership (DGP) which works to develop affordable capabilities for the UK armed forces and international customers, the DGP website notes. Over distances of 27 nautical miles (50km), Roke Manor's High Altitude Cellular Communications payload will communicate with ground-based cellular infrastructure, transmitting high-bandwidth, real-time images and video, the company said. The payload uses commercial off-the-shelf third-generation cellular communications technology, to transmit to a defined point on the ground. While the development of this will ultimately be applied to the Zephyr-S programme, neither Roke nor Airbus were able to provide comment on the progress of the payload development, other than to say more detail is expected to be released once testing is complete.

Airbus, meanwhile, is developing a twin-tailed variant of the HAPS dubbed the Zephyr-T, which will allow it to carry four times the payload capacity of the Zephyr-S (or single-tail). This, the company has said, would allow a radar to be integrated onto the airframe. Airbus is testing a scaled-down version of the Zephyr-T in parallel to focusing on fulfilling the MOD's requirement, and a first flight of a full-scale variant is expected in 2019, the Airbus spokesperson added. The Zephyr-T development is customer-driven, the company says, with interest coming from all over the world. The Asia-Pacific is a significant area of interest for the larger system, and while the spokesperson could not discuss payloads, it is expected that a maritime radar on-board the Zephyr-T could be of interest to customers in the region. The Zephyr-S OCD that is planned for later in 2017 will involve a limited amount of payload testing, Airbus said.

In an effort to move away from stovepiped ISR capabilities for dismounted troops, by which information is not federated when it reaches the hands of the soldier, in June 2016, Elbit Systems revealed its new ISTAR (Intelligence, Surveillance, Target Acquisition and Reconnaissance) Dismounted Solution (DS), that it claims is a "holistic ISTAR solution" designed for forward-deployed troops. The ISTAR-DS is a hardware and software combination designed for use by artillery observers, joint terminal attack controllers and special forces: "Utilising the latest in surveillance technology, the ISTAR-DS effectively synergises various systems and assets into an all-in-one ISR solution, giving decision makers in observation posts the ability to quickly process and disseminate information collected from various platforms and sensors, and as a result, allocate the required munitions for the specific target, at the right time," the company told *AMR*.

It can coordinate fighters, helicopters and unmanned aerial vehicles, using a handheld mission computer that is central to the system. The ISTAR-DS is designed around a number of other Elbit products, including a long-lasting battery pack and handheld video downlink terminal. The Elbit sensor systems that are incorporated include the Supervisir wide area persistent surveillance system, the Skylark mini UAV, plus multiple sensors including the LVSW-D laser designation system, SWIR and forward-looking IR. The: "ISTAR-DS is a unique solution that offers dismounted teams an independent intelligence collection and analysis capability for immediate target engagement from the ground, air or sea," said Elad Aharonson, general manager of Elbit's ISTAR division.

While the operational environments that troops find themselves in is changing due to the nature of the threats they face, the need for intelligence has always been, and will continue to be, the key to mission success. Quick access to the most up-to-date intelligence is paramount to achieving a tactical advantage, as the situation can change in mere minutes. While the need to have access to this information remains the same, the way in which intelligence is acquired and presented to the soldier is what continues to evolve. Today, commanders are provided a wealth of different inputs to help gain the information that is needed to complete the mission, and to keep their troops alive. As this article has shown the need to gather intelligence using innovative means like SWIR or HAPSs remains as important as the need to appreciate this intelligence in a clear fashion using innovative software. AMR

Singapore's space constraints have led the country's armed forces to rely on training with regional partners including Australia.

Australian DOD

INSTRUCTING THE INFANTRY

Infantry training is a core skill for any army and how it approaches this element often says much about the competency and capabilities of the army in question. The Asia-Pacific region has a huge variety of armies, resulting in no 'one size fits all' regarding how they are trained.

by **Claire Apthorp**

The variation across these forces can be seen in those that are fully professional, such as the Australian Army; those that rely in part on conscripts, such as the Republic of Korea Army; those that need to understand combined arms manoeuvre in open terrain, such as the Indian Army, and those that need to focus on urban or jungle warfare, such as the Indonesian Army. Basic infantry training tends not to diverge much from that you would expect in any country, with an emphasis on skills such as drill and marksmanship. However, the demands of countries like Singapore, which operate a conscription based model, place an emphasis on rapidly attaining core skills before moving on to more advanced role specific training.

Basic training

Open sources regarding military training in Singapore note that basic training is role specific with army and marine recruits nearly always being trained in basic marksmanship with individually assigned weapons, field maintenance of weapons, physical fitness training, first aid and basic survival techniques as the initial level of proficiency. The Singaporean armed forces have acknowledged that basic infantry training has become more complex as contemporary warfare has moved away from mass formations of infantry to the need for smaller group

tactics. This is perhaps best exemplified by the counter-insurgency operations being performed by the US-led coalition against the Islamic State of Iraq and Syria insurgent organisation where military actions in both these countries tend to focus on small unit actions, as opposed to large scale combined arms manoeuvre.

However, on passing out of their Basic Military Training Centre all Singaporean conscripts are expected to meet a minimum level of proficiency across a number of core competencies including: executing basic drills; passing the Individual Physical Proficiency Test; operating and firing an ST Kinetics SAR-21 5.56mm assault rifle; throwing both practice and live SFG-87 hand grenades; completing a Standard Obstacle Course and Battle Inoculation Course and going through a field camp.

Typically the basic courses last around nine weeks depending on the conscripts being able to meet the basic physical requirements. Once these courses are completed a number of individuals who show aptitude will be selected to attend the Specialist Cadet School, which trains selected soldiers with leadership potential from all formations in the army to be commanders. This is where more advanced infantry combat skills are taught ensuring that the armed forces have a cadre of better trained and more experienced specialists (Singapore no longer uses the term Non-Commissioned Officer/NCO) to form the backbone of its formations.

Singapore has had to overcome the constraints of being a country with very little spare space in order to conduct larger training exercises; the country has a land area of a mere 719.1 square kilometres (277.6 square miles), according to the country's official statistics. It has approached this constraint from two different directions: The first has been to cultivate close ties with other militaries in the region that have much more space to operate. To this end, the country's low key military cooperation with the Republic of China (ROC) was recently highlighted when nine ST Engineering Terrex eight-wheel drive armoured fighting vehicles on their way back from being used for a training exercise in the ROC were impounded in Hong Kong on 23rd November 2016. As of 24th January, the Hong Kong government has said that it will allow these vehicles to return to Singapore.

The other way in which Singapore has looked to overcome its lack of live training facilities has been to embrace constructive and virtual training. Although the country does not talk openly about its training techniques the Singapore armed forces are believed to have adopted elements of virtual training for close quarter battle instruction, for example.

Singapore's new Armour Driving Simulator can mimic the movement of a real armoured vehicle on a rough terrain to provide a realistic setting for training.

Innovative Approaches

The Singapore armed forces were one of the first militaries in the region to introduce gaming and Personal Computer (PC) based simulation to hone the skills of its soldiers. As far back as 2003 a training initiative was introduced at the Army Officers' Advanced School at the SAFTI (Singapore Armed Forces Training Institute) to use the Joint Conflict and Tactical Simulation (JCATS), originally developed in the US by the Lawrence Livermore National Laboratory in California and now managed by the US Joint Forces Command in Virginia, and Quicksilver Software's Full Spectrum Command (FSC) tools. The JCATS, a PC-based wargame simulation, is designed to train commanders in various ground combat scenarios and joint operations while the FSC is a PC game that models the command and control of an infantry company in an urban environment, open sources note. The early adoption of these system, from circa 2003 according to local press reports, showed a commitment by the Singapore armed forces to explore new and innovative ways to train its soldiers in realistic and dynamic environments, and the army continues to work closely with the Defence Science and Technology Agency, part of the Singapore Ministry of Defence (MINDEF), in the implementation of this training initiative to meet the Singapore Army's training requirements.

Certainly 'Live-Virtual-Constructive' (LVC) training is employed for the army's bilateral training exercises with the US Army. In July 2015 the US Army's 29th Infantry Brigade Combat Team, Hawaii Army National Guard and 3rd Brigade Combat Team, and the Singapore Army's 9th Singapore Infantry Brigade participated in Exercise TIGER BALM on the Hawaiian island of Oahu. Information released regarding the exercise noted that live aspects comprised a Combined Arms Live Fire Exercise between the two armies, whilst the virtual aspect involved the employment of the Bohemia Interactive Simulations' (BISIM) Virtual Battlespace Simulator-2 (VBS2) for surveillance tasks. The constructive aspect saw the linking of the US' JCATS with the SAF's Army War-game Simulation System (AWSS) to allow the exchange of ground tactical information. According to an announcement by the MINDEF: "the employment of the LVC approach in Hawaii and Singapore stretched the participants in the conduct of large-scale operations in a realistic training environment and enhanced the interoperability between the two armies."

In December 2016 the MINDEF also announced that a new driving simulator had entered into service at the Singapore armed forces newly opened Armour


BISIM

VBS-3 also includes a new close air support system that allows users to select aircraft types and customise loadouts before unleashing them on a target.

Simulation Centre at Sungei Gedong Camp. The Armour Driving Simulator (ADS) has been designed for all armoured vehicles in the Singapore Army, and can support training for the Rheinmetall Leopard-2SG main battle tank, ST Kinetics Bronco all-terrain tracked vehicle and ST Kinetics Bionix tracked infantry fighting vehicle; replacing an older system that could only support Leopard-2SG driver training. The ADS allows soldiers to train as they fight, with each vehicle's steering wheel, seat and components replicated, along with a simulated jolting experience of driving over rough terrain. At the same time, the MINDEF added, a new Armour Gunnery and Manoeuvre Simulator (AGMS) entered into service, allowing trainees to conduct large-scale tactical combat training up to the company level. The official announcement continued that AGMS is built around a mock-up of a vehicle, giving trainees a 360 degree view of the terrain from within the vehicle to train in detecting targets, aiming and firing from within. Reality is enhanced by the ability to add in simulated enemy fire, poor visibility and bad weather conditions.

Local Developments

Singapore's training relationship with the ROC has been ongoing since the 1970s and it should not be a surprise as the two countries face several of the same challenges. Like Singapore, Taiwan operates conscription-based armed forces and has the same issues when it comes to training civilians as soldiers. However, unlike in Singapore there has been far more criticism in recent years about how the country treats its basic recruits, which has led the armed forces to reassess how they train the latest generation of Taiwanese conscripts while also looking to pivot towards an all-volunteer service. Protests erupted in the ROC in August 2013 after Hung Chung-chiu, who was three days short of completing his compulsory military service, died after being subjected to an arduous punishment drill which caused severe heatstroke.

The research and development institution of the country's Ministry of National Defence (MND), called the National Chung-Shan Institute of Science and Technology (NCSIST), has developed a number of simulation systems for training purposes. In 2004 two high fidelity Artillery/Mortar Observer Simulator systems were delivered to the Republic of China Army (ROCA). NCSIST's information notes that this system provides training for forward observers under various types of fire and ammunition expenditure, with different light, weather and noise conditions. A Multiple Arms Training System has also been developed by the NCSIST which the organisation articulates, allows 15 students to undertake training simultaneously on direct fire weapon simulators, and six teams to train on indirect fire simulators; all using different types of fire and ammunition. The system can be networked to support joint exercise with the direct and indirect fire and forward observer simulators. The weapon simulators are the same size and weight, with the same operation and recall as the real thing; with different weather/lighting/sound simulations possible. A Small Arms Training Simulator has also been developed that allows up to twelve trainees to undertake training on a simulator that mimics the ROC's 205th Armoury's T-91 5.56mm assault rifle. Although information is sparse regarding this simulator, it is entirely possible that, given Singapore's links with the ROC, and the use of the T-91 by the ROC's armed forces, this system could have been developed with the ROC market in mind.

New Developments

In 2013, BISIM released the latest version of its Virtual Battlespace game-based military simulation training tool known as VBS-3. This latter marque expands on the previous VBS-2 version by improving the system's open architecture, providing comparatively faster performance with the BISIM multicast system, and adding a new user interface. According to the company, the multicast system improves the performance of servers running the firm's software allowing several players to interact with scenarios with less impact on the visual


BISIM

Performance improvements to the VBS-3 include scenarios with hundreds of externally controlled vehicles.

ADF personnel participate in a computer-simulated battle scenario at the Weapon Training Simulation System virtual range during Exercise EXECUTIVE STRETCH at Singleton in New South Wales.

frame rate seen by the participants. This, the firm continued, can allow hundreds of players to be hosted using VBS-3.

The Australian Defence Force (ADF, which includes the country's army, navy and air force) procured its enterprise license for VBS-3 in June 2012, and according to a company spokesperson, the main ADF users, rolled out the VBS-3 V.3.9.2, the latest version of the software, at the end of 2016. Media reports note that the ADF is using VBS-3 to support 'part task' training, where parts of an entire task are practiced, at the Australian Defence College (ADC) Simulation Centre, which provides simulation services and advice across the ADC to support joint individual education and training.

Within the part task training domain, VBS-3 provides an immersive three-dimensional world for individual training, BISIM states. It uses typical gaming controls, such as joysticks and steering wheels, that most students are familiar with and contains a large library of accurately modelled military equipment. The software's scripting language can be used to trigger and control events as trainees progress through the virtual environment and the simulation can be paused to allow time for discussion of teaching points: "Since its release VBS-3 has undergone regular version updates including new features, capabilities and enhancements," a BISIM spokesperson told *AMR*. "This includes performance improvements so that VBS-3 can connect 200 clients to a single dedicated server, optimisations for VBS-3 scenarios with hundreds of externally-controlled vehicles, optimised performance for destructible buildings for multiplayer scenarios, and increased performance for scenarios."

A new in-game communications system called VBS Radio also allows users to record in-game voice communications for replay in VBS-3's After Action Review, enabling the review of specific users' audio events or to cycle through all recorded channels for playback. Hundreds of new weapons, vehicles, civilian units, and other cultural objects have been added to the VBS-3 software, compared to previous marques, along with improved vehicle physics, a new weapon customisation system, and a new close air support system that allows users to select aircraft types and customise weapons loads.

The Australian Army has also ordered new 81mm simulated mortars from Meggitt Training Systems. Under an August 2016 contract the ADF ordered additional 81mm mortar systems for its regular army infantry battalions and army reserve light batteries. According to the company, it has installed, maintained and operated such Weapon Training Simulation Systems in Australia since 1999 and expanded this with the installation of 81mm mortar simulators at four sites during 2016. The simulators are used to train and test mortar troops, command post operators, fire controllers and commanders in their duties with regard to mortar operations, tactics, techniques and procedures.

Elsewhere, Cubic's Australia subsidiary continues to provide simulation support services for the Australian Defence Simulation and Training Centre (ADSTC) which streamlines and coordinates the defence synthetic environment governance, development and delivery to provide greater effectiveness in supporting joint, collective and individual training, as a key enabler of the ADF's future simulation capability goals. The company was awarded the four-year contract in July 2015 to provide ADSTC synergies and the ability to improve integration between single-service collective training and joint collective training for the Australian army and air force. The: "ADSTC is developing and supporting a comprehensive suite of simulations and network connectivity to support distributed joint collective training and distributed mission training," a company spokesperson told *AMR*: "The ADSTC is continuing to evolve its simulation services to offer more capacity and enhanced quality to meet growing demand from the ADF."

Meeting Requirements

At the Defence Services Asia (DSA) exhibition held in July 2016 in Kuala Lumpur, Saab was keen to highlight how its advanced solutions for training and simulation can benefit the Malaysian armed forces, positioning a number of its solutions as "highly relevant to the Malaysian environment," according to literature the firm published prior to the exhibition. The Malaysian armed forces have traditionally focused on very high levels of Counter-Insurgency (COIN) training for both their regular and reservist forces. During the exhibition, Saab highlighted a number of products suited to Malaysian requirements including its Small Arms Virtual Indoor Trainer, a highly realistic virtual shooting simulator that enables personnel to practice and hone shooting skills on a simulated live firing range or an operational area, using replica or appended weapons that accurately simulate ballistic performance and recoil.

From the individual soldier to the joint force, simulation is transforming the way infantry troops are trained and prepared for their role in battle. Simulation provides a cost-effective, efficient and flexible way for personnel to train for the scope of missions that they will undertake in their real-world operations. While there is no one-size-fits-all solution, the use of simulation is only set to grow as technology advances and the demands placed on infantry forces increases as their role expands into new areas on the future battlefield. AMR

UAC

Delivered in a variety of capability levels, the Indian Su-30MKI fleet is poised to be upgraded to the so-called 'Super 30' standard.

AIR SUPERIORITY COMPLEX

The Asia-Pacific remains one of the key battlegrounds for manufacturers of fighter aircraft. With diverse operational requirements and complex political considerations to take into account, the region's frontline fighters include international and indigenous offerings.

by **Thomas Newdick**

This report excludes lightweight fighters and light combat aircraft as well as carrier-based fighters and future fifth-generation projects so as to focus on the in-service multirole fighters that invariably represent the 'sharp end' of their respective operating air forces. Among the current fighter products from European manufacturers, the Eurofighter Typhoon is yet to win orders from customers in the Asia-Pacific. Its close rival, the Dassault Aviation Rafale family has been ordered by India, but not in the numbers originally envisaged, with New Delhi committing to 36 Rafale-F3B/C aircraft, with further batches likely to be contracted at a later stage, according to local media reports. Contract signature for the Rafale deal took place on 23rd September 2016 during a visit to New Delhi by the French minister of defence and veterans affairs Jean-Yves Le Drian. The government-to-government deal covers 36 Rafales; 28 single seat Rafale-F3A and eight two-seat Rafale-F3Bs that will be provided to the Indian Air Force in a 'flyaway' condition and is understood to be worth around $8.4 billion, reports continue, around half of which comprises offsets for Indian industry. The fighters will be delivered from September 2019 and the deal also includes weapons, such as the MBDA Meteor Active-Radar Homing (ARH) guided Air-to-Air Missile (AAM).

The Rafale family's predecessor, the Dassault Mirage-2000 series is now out of production but won export orders in the Asia-Pacific from India and the Republic of China (ROC). A $2.4 billion contract for the upgrade of the Indian Air Force Mirage-2000H/TH fleet was signed in July 2011. The first two upgraded fighters were accepted on 25th March 2015.


Dassault Aviation

An artist's impression of a Rafale-F3A in IAF service. As well as 36 aircraft (28 single-seat and eight two-seat versions) in 'flyaway' condition, the contract will provide weapons from MBDA.

India's Hindustan Aeronautics Limited (HAL) will upgrade another 47 of the aircraft in India. The upgraded fighters have received the revised designation Mirage-2000I/TI. Thales provides most of the new equipment in the upgraded aircraft, including the RDY-2 X-band (8.5-10.68 gigahertz/GHz) radar, a helmet-mounted display, new avionics including a mission computer and a new electronic warfare suite.

The ROC's fleet of Mirage 2000-5EI/DI fighters, delivered from 1997, are receiving a more modest upgrade. The local National Chung Shan Institute of Science and Technology is embarking on a programme to extend the shelf life of the MBDA MICA ARH/Infrared guided AAMs that arm the 56 of the surviving aircraft, from a total of 60 delivered. Reports state that the balance of four aircraft may have been mothballed due to a lack of spare parts.

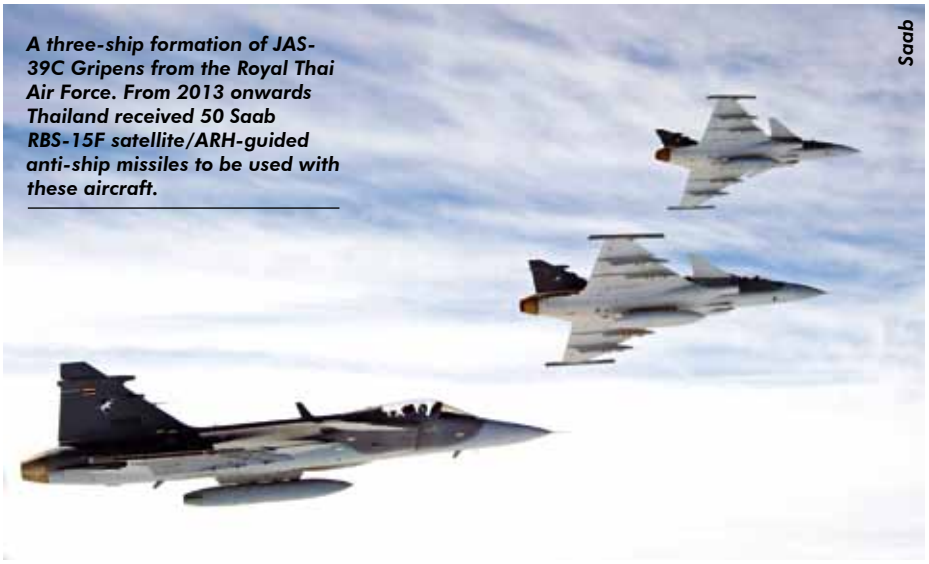
An unsuccessful candidate in India's original MMRCA (Medium Multirole Combat Aircraft) competition launched in 2001, and eventually won by the Rafale-F3B/C (*see above*) to replace a significant portion of the IAF's legacy Soviet/Russian supplied fighter fleet such as the MiG-21 fighter family, the Saab JAS-39C/D Gripen fighter currently serves in the Asia-Pacific with Thailand. Bangkok acquired twelve JAS-39C/Ds as part of an air defence package that also includes two Saab 340 Erieye airborne early warning aircraft. The final batch of six JAS-39C/Ds was delivered to Thailand in September 2013. Since then, one aircraft has been lost in an accident.

Russian Offerings

Away from Europe, the Sukhoi Su-30 fighter family is well represented in the region, with different variants produced by two separate production facilities in Russia, as well as under licence in India, and in the form of unlicensed copies in the People's Republic of China. The success of the aircraft began with an order from the IAF for the Su-30MKI version manufactured by the Irkut Corporation, part of Russia's United Aircraft Corporation (UAC). An initial contract was signed for the acquisition on 30th November 1996 and the most recent on 24th December 2012. In total, New Delhi has purchased 272 Su-30MKIs. By early 2016, the IAF had received around 225 aircraft, including 50 delivered in a 'flyaway' condition from Russia and 175 built locally by HAL. The Su-30MKI is being brought up to the so-called 'Super 30' standard with the addition of a new fire control radar, thought to be KRET's Zhuk-A X-band Active Electronically Scanned Array (AESA) system. The Indian Su-30MKIs are also to receive new avionics and a KRET Khibiny electronic warfare system, plus BrahMos Aerospace BrahMos satellite/ARH guided air-to-surface missiles and the indigenous Defence Research and Development Organisation Astra ARH-guided AAM, according to open sources. A derivative of the Indian Su-30MKI, the Su-30MKM was produced for Malaysia, which received 18 examples between 2007 and 2009.

The Komsomolsk-on-Amur Aircraft Production Association (KNAAPO), also part of UAC, produces the Su-30MK for export, with the initial foreign client being the PRC. The country purchased 76 Su-30MKK fighters between 2000 and 2003 followed by 24 improved Su-30MK2 fighters in 2004. Thereafter, Beijing switched to the local development of its own Shenyang Aircraft Corporation (SAC) J-16/D fighter, as an indigenous counterpart to the Su-30MK2. The J-16 first flew in October 2011 and reportedly entered service in May 2015.

Other KNAPPO Su-30MK customers in the region include Indonesia, which acquired two Su-30MKK fighters in 2003, and nine Su-30MK2 fighters between 2008 and 2013. Vietnam received 24 Su-30MK2V fighters between 2004 and 2012,


Saab

A three-ship formation of JAS-39C Gripens from the Royal Thai Air Force. From 2013 onwards Thailand received 50 Saab RBS-15F satellite/ARH-guided anti-ship missiles to be used with these aircraft.

Two-seat PLAAF J-10AS fighters taxi for take-off. Production of the basic J-10A/AS was completed in early 2014, after seven production blocks.

and another batch of twelve Su-30MK2Vs were ordered by Hanoi in August 2013, deliveries of these beginning in 2014.

While two-seat variants of the Su-30MK are built by both Irkut and KNAAPO, the single-seat Sukhoi Su-35 family was developed and manufactured by the Komsomolsk-on-Amur Aircraft Production Association (KAAPA), also part of the UAC. In a surprising development, the launch export customer for the Su-35 was the PRC. Reportedly worth $2 billion, Beijing's order for 24 Su-35Ss was signed on 19th November 2015, and the first Chinese Su-35S arrived in the PRC on 25th December 2016. The reasoning behind the Chinese order remains obscure. PRC aerospace analyst Andreas Rupprecht noted that the Chinese side has never officially confirmed the deal: 'Most previous estimations suggested that the fighters were intended not for an operational regiment, but more likely a dedicated flight-test regiment to explore the aircraft's thrust-vectoring engines and for dissimilar air combat training against other PLAAF (People's Liberation Army Air Force) assets," Mr. Rupprecht said. Another alternative is deployment in the Southern Theatre Command (one of the Chinese armed force's geographical commands in the south of the PRC) in which the Su-35S could be used as a long-range fighter escort in the South China Sea, he continued

In 1991 China became the first export customer for the KNAAPO Su-27SK. A contract for 46 aircraft was signed in 1991 and was complemented by an additional 28 aircraft delivered between 2000 and 2002. Included in these agreements was a $1.2 billion contract for SAC to licence-build 200 Su-27SKs under the Chinese designation J-11. In the event, KNAAPO delivered only 95 kits before production shifted to the J-11B, an upgraded indigenous version. The J-11B was first to add an element of multirole capability, with an undisclosed Chinese multi-mode pulse Doppler X-band radar and an updated 'glass' cockpit.

The PRC's 'legacy' fleet of Sukhoi Su-27 family and SAC J-11A/B fighters are not strictly multirole in the modern sense, lacking a genuine precision attack capability in their basic form. However, the J-11D first flown on 29th April 2015, represents the next-generation of the aircraft. The fighter reportedly incorporates new AESA radar, a greater proportion of composite materials, radar-absorbent coating and a modernised fly-by-wire control system. Most observers assume the J-11D will be introduced in the form of a mid-life upgrade for existing J-11B fighters. As well as the 'all-up' J-11D, the basic J-11A is also receiving upgrades, including a infrared missile approach warning system and Vympel R-77 ARH-guided AAMs.

'Legacy' Su-27 family aircraft are also operated by Indonesia and Vietnam. Indonesia acquired two Su-27SKs in 2003, and became the only customer for the improved Su-27SKM, three of which were delivered in September 2010. Vietnam ordered a first batch of six Su-27SK/UBK aircraft, valued at $150 million delivered in 1995, while the second batch of six, priced at $120 million, was delivered in 1998. The fortunes of Sukhoi's fifth-generation T-50 fighter rest heavily upon India. The joint Russian-Indian Fifth-Generation Fighter Aircraft (FGFA) programme is being pursued jointly by Sukhoi and HAL on the basis of the T-50, however, its future is far from certain: Media reports have noted that India is yet to determine the quantity of fighters it plans to acquire and there is little clarity on Indian industrial participation in the project. Furthermore, the aircraft which is eventually developed as a result of the FGFA undertaking will have to compete for funding against further Su-30MKI upgrades (*see above*), the acquisition of a new single-engine fighter planned for licence production and HAL's future Advanced Medium Combat Aircraft (AMCA) project: "The Indian Air Force doesn't believe in the (FGFA) aircraft," contended Angad Singh, a New Delhi-based aerospace analyst. Air Chief Marshal Arup Raha, the IAF's chief of staff, who held the post until 31st December 2016 went on the record to say "there are certain issues involving technical features, cost and delivery timelines, which are being addressed at the highest level," concerning the project.

Chinese Developments

Elsewhere in the PRC, the Chengdu Aerospace Corporation (CAC) J-10 has followed a trajectory of successive improvements and expanded multirole capabilities similar to that of the J-11 family. The first frontline unit was established in June 2004 and the last of the initial J-10A models was completed in early 2014: "At first, the J-10A was fielded with a limited air-to-air armament" observed Mr. Rupprecht: "In recent years its weapons options have been steadily expanded. For example, a new twin-rail launcher has been developed to carry four rather than two Leihua Electronic Technology Research Institute PL-12 ARH-guided AAMs. Luoyang Electro-Optics Technology Development Centre LS-500J precision-guided munitions have also been seen more regularly," he continued. The next series-production model, the J-10B, was revealed in March 2009. This featured a new fixed diverter-less supersonic inlet for the aircraft's Saturn-Lyuika AL-31FN turbofan, a passive electronically scanned array X-band radar; an infrared search and track and laser rangefinder system plus a wide-angle head-up display. The latest J-10C represents a fully multirole fighter with an unknown AESA radar. Although it first appeared in December 2013, it was 22nd September 2015 before a J-10C prototype completed a first flight powered by an indigenous Shenyang WS-10 turbofan.

Lockheed Martin test pilot Paul 'Bear' Randall flying the first upgraded F-16A/B for the Republic of China Air Force at Lockheed Martin's Fort Worth, Texas facility in October 2015.

Lockheed Martin

Pakistan has been linked with a possible J-10 purchase, but until now has relied upon the JF-17/B Thunder to meets its multirole fighter needs. A joint programme developed by the Pakistan Aeronautical Complex (PAC) and CAC of China, the JF-17 has introduced incremental improvements in multirole capability via the form of production block upgrades. The initial Block-2 version took to the air from PAC's Kamra facility in northern Pakistan on 9th February 2015. It features changes, compared to previous *marques*, including a refuelling probe, improved oxygen system and enhanced electronic countermeasures. Pakistan has 50 JF-17 Block-2 aircraft under contract, which will join the 50 JF-17 Block-1 aircraft previously delivered. More information and news regarding Pakistan's JF-17/B aircraft can be found online at *asianmilitaryreview.com*.

Falcons and Eagles

Pakistan ultimately plans to acquire 150 JF-17/Bs, which will complement the Pakistan Air Force's General Dynamics/Lockheed Martin F-16 family fighters deliveries of which have periodically been held up by the US government. In total, Islamabad placed orders for 111 F-16A/B Block-15 fighters, but only received 40 between 1983 and 1987 due to a US embargo imposed as a response to Pakistan's nuclear weapons programme. These were supplanted from 2010 by 18 new F-16C/D Block-50/52 fighters and in late 2013 Pakistan acquired 13 second-hand Royal Jordanian Air Force F-16A/Bs. Outside Pakistan, the F-16 family remains the most numerous US fighter in the Asia-Pacific, with over 400 examples serving with Indonesia, the ROC, the Republic of Korea, Singapore and Thailand.

The ROC was the first Asia-Pacific F-16 operator to choose to upgrade its aircraft with an AESA radar. In 2011 the ROC government decided to put 145 surviving F-16A/B Block-20 aircraft through a capabilities upgrade. In October 2012 Lockheed Martin received a $1.8 billion contract for the work and in October 2015, the first upgraded F-16A/B flew in the US equipped with the Northrop Grumman AN/APG-83 Scalable Agile Beam Radar X-band system installed. In January 2017, upgrade work began at Aerospace Industrial Development Corporation (AIDC) facilities in the ROC. While two aircraft are being upgraded in the US, work on the remaining 142 fighters will be completed in the ROC, where AIDC will complete between 25 and 28 upgrades annually until 2023, according to reports. Singapore, meanwhile, operates a fleet of 60 F-16 Block-52/52+ fighters delivered between 1998 and 2003. They will be upgraded with new data links, AESA radars and satellite-guided weapons. In December 2015 Lockheed Martin received a $914 million contract to perform the Singaporean F-16 upgrade. Work began in 2016 and will last up to six years. There appears to be no official comment regarding the radar which will equip these upgraded F-16C/D aircraft, although it appears likely that the Republic of Singapore Air Force may opt for the AN/APG-83, given Lockheed Martin's work upgrading the ROC's F-16A/B aircraft.

Elsewhere in the Asia-Pacific, the ROK originally selected the Raytheon Advanced Combat Radar (RACR) X-band system for its AESA upgrade, which would extend to 134 of its F-16C/D Block-32/52 aircraft. After the collapse of an upgrade deal with BAE Systems, Seoul turned to Lockheed Martin, and outlined a revised $2.5-billion upgrade package. A first upgraded aircraft will be ready in 2018 and the entire upgrade is valued at $1.5 billion, media reports note. Thailand, meanwhile, has launched a modest upgrade programme for its fleet of 61 F-16A/B Block-15 aircraft. Initial upgrade work is valued at $700 million and covers 18 aircraft, which are receiving Northrop Grumman's AN/APG-68(V)9 X-band radar, together with BAE Systems' AN/APX-113 combined interrogator and transponder and AN/ALE-47 countermeasures dispenser system. Diehl BGT Defence's IRIS-T infrared guided AAMs have also been added to the aircraft's armoury.

Joining the F-15 family in the Asia-Pacific is the McDonnell Douglas/Boeing F-15 family which serves with Japan, the ROK and Singapore. Japan has launched upgrade programmes for both its F-15J/DJ fleet and for its indigenous Mitsubishi F-2A/B fighter. In 2014 twelve F-15Js received upgrades at a cost of $12.5 million each. The upgrades addressed the F-15J's Mitsubishi Integrated Electronic Warfare System, forward looking infrared and infrared search and track capability and added night vision goggle compatibility to the cockpit. The F-2A/Bs are receiving the Mitsubishi J/APG-2 AESA X-band radar as well as new Mitsubishi AAM-4B ARH-guided AAMs and Boeing Joint Direct Attack Munition family weapons. Currently, Japan operates 153 F-15J/DJs, and 94 F-2A/Bs.

Looking to the future, the first two customers for the Lockheed Martin F-35A/B/C Lightning-II in the region are Japan and the ROK. Japan's first four F-35As are being built in the US, while Mitsubishi Heavy Industries will assemble the remaining 38. The ROK, meanwhile, has selected the F-35A and in September 2014 announced its plan to acquire 40 for delivery between 2018 and 2021. The presence of the F-35A/B/C in the Asia-Pacific allied with the emergence of at least two fifth-generation fighter designs from China (the CAC J-20 and SAC J-31) looks set to fuel continued activity in the multirole fighter market. At the more ambitious end, Japan and the ROK are both pursuing indigenous fighter programmes (the F-3 and KF-X, respectively), while countries including Indonesia and Malaysia are due to embark on long-delayed fighter acquisition programmes which may commence within the next five years. Alongside these efforts, a continued demand for 'fighter mass' in the form of robust fighter fleets, will ensure that existing fighter inventories continue to be upgraded to keep pace with technological developments. AMR

STRANGER ON THE SHORE

India has the eighteenth longest coastline in the world, according to the Central Intelligence Agency's *World Fact Book*. Stretching for a total of 3779.7 nautical miles/ nm (7000 kilometres/km), it is little wonder that the country's government wishes this to be as secure as possible.

by **Thomas Withington**

Yet the nation is making strides in this regard. On 27th February, local media reports stated that the country's Ministry of Defence had given the green light for the procurement of up to 38 coastal surveillance radars, alongside four mobile surveillance stations and two vessel traffic management systems, the latter of which are to be located in Kutch and Kambatch, both in the western Indian state of Gujarat. The value of the contract is expected to be $148.1 million. Reports continued that Bharat Electronics Limited (BEL) will be the prime contractor for the initiative.

This latest initiative forms the second phase of an overarching programme to reinforce the coastal surveillance radar coverage of India's coastline in the wake of the attacks perpetrated by the Lashkar-e-Taiba insurgency organisation in the western Indian city of Mumbai which caused the deaths of 164 people between 28th November and 29th November 2008. Prior to the attacks, the insurgents had arrived using inflatable boats in the district of Colaba, in the extreme south of the conurbation. The subsequent attacks triggered a reinforcement of Indian coastal security, with an initial procurement of 46 coastal surveillance radars from BEL in 2011 for a cost of $89.6 million, according to media reports. Details on the exact type of radar which BEL supplied to the Indian government as part of the 2011 procurement are hard to find. Tantalisingly, BEL makes no reference to any coastal surveillance radar products in its catalogue although some reports have stated that the systems transmit in X-band (8.5-10.68 gigahertz/

Terma

Terma provides a number of coastal surveillance radars in its portfolio, such as the SCANTER-4000 and SCANTER-5000 products.

GHz). It is likely that the new radars to be procured as part of the February deal may be of a similar design to those procured in 2011, although there are no details as to when these new radars will commence and complete delivery, and when they maybe declared operational.

Band Choices

X-band is a popular choice for coastal surveillance radar. As Paul Mariner, sales manager at Kelvin Hughes, explained in a paper entitled *Advanced VTS (Vessel Traffic Service) and Coastal Surveillance Radar Technology*, the: "X-band frequency is best suited to providing an acceptable level of range and bearing" information for a target at sea. Essentially, the comparatively narrow frequencies of X-band enable the radar operator to discern small targets such as jet skis or small boats clearly in the 'clutter' of the undulating sea surface which risks swamping coastal surveillance radars operating in lower frequencies.

Nevertheless, as with so many aspects of radar engineering, trade-offs are inherent in coastal surveillance radar design. While X-band radars are good at discerning small targets, they are susceptible to degradation from rain and moisture in the air and, as Mr. Mariner articulated, X-band radar "performance in rain cannot match S-band (2.3-2.5/2.7-3.7GHz)." Thus, X-band radar can detect small targets amidst sea clutter but can suffer performance degradation in rain. Meanwhile S-band radars are better at penetrating rain, but might not be able to match X-band radar performance regarding small targets. This vexing compromise causes users to often procure both S-band and X-band radars to exploit the performance advantages offered by both bands: "This enables X-band to provide excellent range and bearing discrimination in good weather while providing the option to switch to the S-band when prevailing conditions seriously degrade X-band performance," continued Mr. Mariner. It will be of little surprise for readers to learn that Kelvin Hughes offers both S-band and X-band systems as part of its Shore Based Sensor (SBS) coastal surveillance radar series, which uses the firm's SharpEye radar family at its core. It is worth noting that X-band is also used by airborne maritime surveillance radars, such as Telephonics' RDR-1700B. However, this article will focus chiefly on land-based coastal surveillance radar.

Air Targets

Like Kelvin Hughes, other coastal surveillance radar suppliers have opted for either X-band or S-band offerings. For example, Airbus' defence and space subsidiary's SPEXER-2000 coastal surveillance radar provides a range of circa ten nautical miles (18km) using X-band, as does Thales' CoastWatcher-100 which has a 100nm (185km) instrumented range: five SPEXER-2000 radars were acquired by Malaysia in December 2015. The 'odd one out' concerning coastal surveillance radars in this regard is Harris' LCR-2020 system. Transmitting in the C-band (5.25-5.925GHz), this radar exploits a further compromise in radar engineering: C-band sits between S-band and X-band in the radio frequency portion of the electromagnetic spectrum. The result is that this band can provide good target and clutter discrimination, while avoiding the interference caused by precipitation. Moreover, C-band radars will not cause interference with other S-band and X-band radars which could be located close to the coastline to provide air traffic management services, for example. According to George Yakimovicz, business development capture director at Harris, the firm has

Kelvin Hughes employs both X-band and S-band technology in its SBS coastal surveillance radar family so as to exploit the advantages offered by these two distinct radar bands.

Kelvin Hughes


Airbus

Airbus has made a significant leap forward in coastal surveillance radar design by adopting AESA technology in its SPEXER-2000 product.

been involved in the provision of coastal surveillance radars for Sweden for the past two decades, adding that the company currently has 53 of its 54nm (100km) range radars in service around the world. One remarkable aspect of the LCR-2020 design is its high and low beam concept. This permits the simultaneous detection of air targets, at a range of circa 81nm (150km) using the high beam, and surface targets using the low beam.

The evolution of this radar is continuing, and Mr. Yakimovicz shared that Harris is currently performing studies regarding enhancements of the radars' software, and its front end, to improve its ability to detect targets with a low radar cross section, such as low-flying light aircraft which risk being lost in the radar clutter generated by the sea's surface. This is an important consideration: According to a 2014 report published by the US Department for Homeland Security's Science and Technology Directorate entitled *Small Dark Aircraft: The Hunt for Drug Smuggling Aircraft at our Borders*: "a number of small aircraft, including ultra-lights, small fixed-wing general aviation and helicopters, are still able to slip through (US) airspace undetected." The report went on to note that: "these planes have become ideal drug-smuggling vehicles." That the Asia-Pacific is home to the so-called 'Golden Triangle', an opium-producing area encompassing parts of Burma, Laos and Thailand, underscores the importance not only of ensuring coastlines are robustly protected against vessels which maybe performing illegal actions, but also that small aircraft, possibly engaged in similarly nefarious tasks can be detected.

Spectrum

Another consideration noted by Harris *vis-à-vis* coastal surveillance radar is spectrum management. The electromagnetic spectrum is a crowded place. For example, the number of cellphone users is expected to rise from circa four billion globally, according to the online research service Statistica, to over five billion by 2019. Similarly, figures published by technology firm Cisco in June 2016 predicted that there will be over four billion internet users globally by 2020, compared to three billion in 2015. The company's figures continued that the number of networked devices in use around the world will climb to 26.3 billion by 2020, compared to 14.3 billion in 2015, while broadband connection speeds will increase to 47.7 megabits-per-second (mbps) in 2020, compared to 24.7mbps in 2015. Such requirements will translate into an increasing demand on the areas of the spectrum inhabited by coastal surveillance radar. For example, in Canada and Ireland, X-band is already used for terrestrial broadband communications. Mr. Yakimovicz argued that such demands are forcing radar engineers to: "use radar bands more efficiently, and to employ advanced next-generation waveforms," which promise to occupy as little of the RF spectrum as possible.


Harris

The need to detect aircraft as well as surface vessels is a growing requirement for coastal surveillance radars, as illustrated by the use of air and sea surveillance techniques in Harris' LCR-2020 radar.

Coastal surveillance radar architecture is also changing. According to a statement supplied to *AMR* from Blighter, which produces a number of coastal surveillance radars in its B400 and C400 families: "The majority of existing coastal surveillance radars use cheap and unreliable valve based transmitters." At the core of these radars, the statement continued, is the magnetron. Put simply, a magnetron has a heated cathode in the form of a solid metal rod at its centre. This cathode is surrounded by a ring-shaped anode. Cut into the anode are a series of hollows, known as cavities. The anode, with its accompanying cavities, and cathode at its centre are all enclosed in a tube which has a powerful magnet at one end with the intention of generating a magnetic field parallel to the cathode. An electric current is passed through the cathode which produces electrons. This produces an electrical field between the cathode and anode, and also a magnetic field, thanks to the magnet. This causes the electrons to move in a rotational fashion zooming past the cavities and causing them to resonate and emit microwave radiation. This radiation is then channelled to a radar's antenna by means of a waveguide and transmitted from the antenna so at to collide with a target and produce a radar echo, which is then depicted on the radar operator's screen as a target and track. Yet magnetron technology is becoming antiquated, perfected as it was in 1940 by British physicists John Randall and Harry Boot at the University of Birmingham in the UK.

Architecture

The radar industry as a whole has migrated towards solid state electronics which dispense with the magnetron and which can operate at lower power levels compared to their magnetron-equipped counterparts, while also enjoying higher levels of reliability and lower maintenance

Blighter provides a number of coastal surveillance radars in both its B400 and C400 radar families.

Blighter

burdens. The industry is now changing once again with the adoption of Active Electronically Scanned Array (AESA) technology. This technology is slowly migrating to the coastal surveillance radar domain, having proliferated through the military radar domain since the introduction into service of the Multi-Function Array Radar-I (MAR-I) system in US Army service as a ground-based air surveillance radar to support the force's LIM-49 Nike Zeus anti-ballistic missile system in the early 1960s.

AESA radars have several benefits but, put simply, an AESA radar includes an antenna that mounts a multitude of miniature radars, known as Transmit/Receive (T/R) modules on its antenna. The T/R modules enable the radar to perform several tasks such as air and surface search simultaneously, thanks to the ability of each of these T/R modules to perform a large part of the radar's RF transmission and processing, and to be tasked independently. Moreover, AESA antennae benefit from so-called 'graceful degradation' in that the failure of one T/R module will not cause the entire radar to become unserviceable. Furthermore, T/R modules can transmit on different frequencies within the radar's transmission band, increasingly the frequency agility of the radar, and hence making its transmissions harder to detect and jam.

Since the advent of the MAR-I radar, AESA radars have progressively proliferated throughout the military domain. AESA technology is now standard equipment on fighter aircraft, as illustrated by the Thales RDY-2 X-band fire control radar which equips the Dassault Rafale-F3B/C/M fighter, or Northrop Grumman's AN/APG-83 Scalable Agile Beam Radar X-band product which is designed to equip the Lockheed Martin F-16 Fighting Falcon fighter family, and the Rockwell International/Boeing B-1B Lancer strategic bomber of the United States Air Force. Two factors have assisted this proliferation of AESA technology. The first is the introduction of Gallium Arsenide throughout the 1980s to equip an AESA's T/R modules helping to reduce them to the size of a cigarette packet in some cases. The second factor is the overall reduction of the physical size of electronics as a result of 'Moore's Law'; the observation of Gordon Moore, a co-founder of the Intel Corporation, whom argued that the number of transistors on a single chip doubles every circa two years. This dictum, and the advent of Gallium Arsenide, enabled AESA radars to be housed in progressively smaller installations.

Cost

A written statement supplied to *AMR* by Leonardo, which provides the ARGOS-30VS X-band coastal surveillance radar, articulated an expectation that AESA technology may increasingly migrate to the coastal surveillance radar world. This has already begun with the employment of an AESA architecture in Airbus' SPEXER-2000 radar. Yet costs will need to reduce if the technology is to be widely adapted by coast guards, navies and other government departments charged with securing coastlines. For example, Thales' GroundMaster-400 S-band ground-based air surveillance radar, which employs AESA technology, has a reported unit price of $19 million. As a contrast, India's acquisition of 46 coastal surveillance radars in 2011 for $89.6 million (worth $96.7 million in 2017 values), gives available acquisition funds of $2.1 million per radar, while its planned February acquisition potentially gives a per-radar acquisition budget of $3.8 million. However, these figures do not take into account other items which maybe purchased as part of the acquisition such as maintenance, repair and overhaul services, installation, training and logistics costs. It is noteworthy that the February acquisition includes plans to acquire four mobile surveillance stations and two vessel traffic management systems, potentially further lowering the available funding for the acquisition of the radars. AESA technology clearly offers promise to address the challenges facing coastal surveillance radar engineers, but costs will need to reduce further if this technology is to be increasingly adopted in the future. AMR

Coastal surveillance radars are also available from Israel Aerospace Industries in the form of the company's EL/M-2266 X-band product.

IAI

While Malaysia will only receive its Starstreak-NG launchers and missiles in 2018, a small quantity of both have been provided to Malaysia for training purposes.

Dzirhan Mahadzir

MALAYSIA TIGHTENS ITS BELT

Given Malaysia's ongoing fiscal limitations and the continuing depreciation of the national currency, it is expected that the Malaysian armed forces will not make any major procurements in 2017, particularly given the ongoing purchases that need to be paid for.

by **Dzirhan Mahadzir**

According to the Malaysian ringgit forecast published on the *tradingeconomics.com* website, the national currency was worth just over MYR4.4 for $1 in January 2016, ending the year being worth circa MYR4.5 for $1 this January. Similarly, reports in October 2016 predicted that Malaysia's defence budget would fall by twelve percent to $3.6 billion in 2017. For now, the author expects the Malaysian government to concentrate on continuing payments for ongoing procurement programmes such as the Airbus A400M turboprop airlifter for the Royal Malaysian Air Force (RMAF), the Littoral Combat Ship/Second Generation Patrol Vessel (LCS/SGPV) for the Royal Malaysian Navy (RMN) and the DefTech AV-8 *Gempita* eight-wheel drive armoured vehicle family for the Malaysian Army. In addition, the slight possibility remains that one or two programmes such as the agreement with the United States on the purchase of United Defence/BAE Systems' M-109A5 Paladin self-propelled howitzers may continue. In March 2016, the army stated that it would acquire 24 M-109A5s under the US government's Excess Defence Articles programme which transfers excess US defence equipment to foreign governments. Similarly, despite fiscal and budgetary strictures, the army's upgrade of its Rheinmetall Condor four-wheel drive Armoured Personnel Carriers (APCs) may continue, but other major purchases are unlikely save for the formalisation of the Littoral Mission Ship agreement between Malaysia and the People's Republic of China (PRC). In

Dzirhan Mahadzir

The RMAF currently has three of the four A400Ms ordered with the final aircraft to be delivered in 2017. These aircraft are being upgraded to perform tactical missions.

November 2016 it was reported that the RMN planned to acquire four so-called Littoral Mission Ships (LMSs) from the PRC (*see below*).

Strategic Picture

Strategically little has changed for the Malaysian armed forces over the past three years, the newly appointed chief of the armed forces General Raja Mohamed Affandi, who assumed the post in December 2016, will oversee a military focused upon ensuring security in the Eastern Sabah area of Malaysia's territory on the island of Borneo, and preventing a repeat of the 2013 Lahad Datu standoff. using a military grappling with the issues of restricted finances (*see above*). The 2013 Lahad Datu standoff saw insurgents from the Royal Security Forces of the Sultanate of Sulu and North Borneo infiltrate the town and surrounding area of Lahad Datu in Eastern Sabah from the southern Philippines island of Tawi-Tawi.

Meanwhile, Malaysia is involved in the dispute with the PRC over the sovereignty of the Spratly Islands in the South China Sea, alongside Brunei-Darussalam, the Philippines, the Republic of China and Vietnam. Malaysia claims part of the Spratly archipelago which falls within the country's Exclusive Economic Zone, and has occupied Swallow Reef, Ardasier Reef and Mariveles Reef. Given the Malaysian government's pursuit of closer economic and trade links with the PRC, it seems unlikely that in the near future the two countries will be in direct confrontation over territorial claims there. Aside from an 850-strong battalion which comprises part of UNIFIL (United Nations Interim Force in Lebanon) which aims to enhance the authority of the Lebanese government in the south of the country, the Malaysian armed forces have no significant foreign commitments. As stated earlier, the security of the Eastern Sabah area is the primary focus and a number of measures have been undertaken in this regard, including the establishment of a forward operating base for helicopters at Lahad Datu, a permanent sea base, the *Tun Sharifah Rodziah*, a converted oil platform, off the Eastern Sabah coastline along with two ships, the *Bunga Mas Lima* and the *Tun Azizan*, both converted container ships, acting as mobile sea bases in the area. The RMAF also deploys a BAE Systems Hawk Mk.108/208 trainer/light attack aircraft squadron possibly either 6 Squadron or 15 Squadron, thought to be based at Labuan airbase located off the coast of Sahah. Future government plans include the reorganization of naval commands in East Malaysia and the establishment of an additional army division in East Malaysia which are detailed in the paragraphs below. The timeframe in regard to the army plan is uncertain despite the then Malaysian Army chief Gen. Affandi announcing the army plan in 2014. Gen. Affandi told the author that the nucleus of the division, a command element called Task Force 450 had been set up but an expansion to the division which would require a mix of active duty and reservist infantry battalions to be formed, would depend on the government's approval to recruit the additional personnel for the units required for such an expansion as the new division would largely not be drawing upon existing manpower strengths. RMN chief Admiral Ahmad Kamarulzaman announced the RMN's reorganization in December 2016, stating that this reorganization is expected to be completed sometime in 2017.

Army

The army's key ongoing procurement programme is the delivery of 257 AV-8 vehicles. A combination of financial limitations and running changes to the vehicle based on the force's experience of operations with vehicles already delivered has slowed down delivery, which was originally scheduled to be completed by 2018. No official figures have been released so far on the number of vehicles delivered but it is estimated that around 50 had been delivered by the end of 2016. The vehicles have primarily gone to the 19th (mechanised) battalion of the Royal Malay Regiment (19th RMR) based in Peninsular Malaysia. The battalion currently maintains a detachment of AV-8s in Sabah as part of the efforts to maintain security in Eastern Sabah. The 19th RMR operates the IFV-25 version of the AV-8 equipped with a BAE Systems Sharpshooter turret and Orbital ATK M-242 Bushmaster 25mm autocannon along with a small number of three other variants, the ATGM (Anti-Tank Guided Missile) variant equipped with Denel's LCT-30 turret outfitted with the firm's GI30 30mm autocannon and four Denel ZT3 Ingwe laser-guided surface-to-surface missiles, the turret-less command variant and the turret-less signals variant. An initial delivery of five AFV-30 variants carrying the Denel LCT-30 *sans* the G130 weapon, has also been made to the 1st regiment of the army's Royal Armour Corps. Gen. Affandi told the author that the army plans for the AV-8 to replace the Condor and GKN Snakey/BAE Systems Sibmas APCs in some units, but other units will continue to use the Condors due to the cost of the AV-8s and the financial challenges being currently experienced across the Malaysian armed forces.

Deftech is working on an upgrade programme for the Condors with a prototype upgrade unveiled during the 2016 Defence Services Asia exhibition held in Kuala Lumpur. The Condor upgrade involves the replacement of the vehicle's Mercedes Benz OM352A engine and axles, and improving the vehicle's automatic transmission, hydraulic system, engine cooling, air conditioning, steering and vision. The vehicle is also to be

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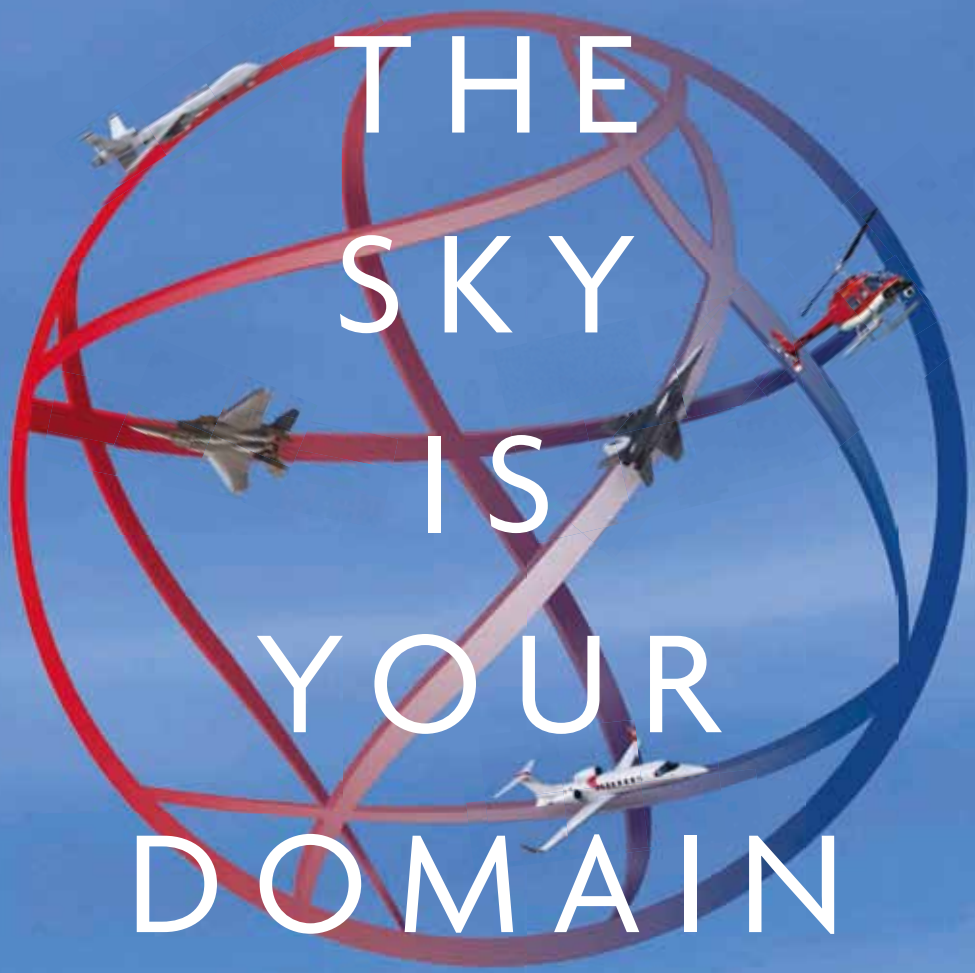

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Deftech's prototype Condor upgrade for the Malaysian Army as seen at the 2016 Defence Services Asia exhibition. A total of 300 vehicles could be upgraded if the programme goes ahead.

outfitted to allow it to accept modern digital equipment with a rewiring of its electrical harness to this end. A new electrical open-topped turret with shields has also been installed with the preferred weapon to be mounted being the Dillon Aero M-134DH 7.62mm minigun. No contract for addition guns has been signed yet though the army has the M-134DH weapons on other platforms. Trials on the prototype are currently being conducted, and the army is expected to commence the upgrade programme if the prototype passes its trials and if funding is available. There is no information as to when this might occur. With around 300 Condors still in service, it is expected that any upgrade will be done in batches based on available funding rather than via a contract for the upgrade of the whole fleet. The army is also in the midst of receiving 20 Deftech AV-4 Lipanbara MRAP (Mine-Resistant/Ambush Protected) vehicles for use in Eastern Sabah (*see above*).

Meanwhile, the Malaysian government on 15th September 2015 signed a contract for an undisclosed number of Thales Starstreak-NG semi-automatic command-to-line-of-sight surface-to-air missile systems at the Defence and Security Exhibition International event in London. The value of the contract was announced by Thales to be in the region of $122 million. Deliveries will be made in 2018, the author has learned, though the Malaysian armed forces have received a small quantity of current Starstreak systems to conduct training and live firing the system will used by all three services but it is expected that the army's 401 Ground Based Air Defence (GBAD) squadron will be given the priority for deployment of the Starstreak-NG.

Organisationally, the army plans to form a fifth division to add to the four existing ones with the planned 5th Division to be deployed in East Malaysia joining the 1st Infantry Division there. Currently, the 1st Infantry Division holds the responsibility for the entirety of East Malaysia, namely the states of Sabah and Sarawak but the establishment of the 5th Division will allow the 1st Division to be responsible for Sarawak while the 5th Division would then be responsible for Sabah, the author was told by army sources. The planned establishment of the 5th Division, the reports continued, is to enable the army to better command and organise its operations in Sabah and increase troop strength in the area.

Maritime

Adm. Kamarulzaman is currently in the midst of recapitalising the RMN fleet under his so-called '15 to Five' plan. His plan is to pare down the number of ship classes operating in the navy from 15 to five classes, which would include the LCS/SGPV, the 'Kedah' class Offshore Patrol Vessels (OPVs), the LMS, the conceptual Multi-Role Support Ship (MRSS) and the 'Scorpene' class conventional hunter-killer submarines (SSKs). Six LCS/SGPV ships, based on the DCNS 'Gowind' class corvette design, are on order with construction of the first ongoing and the first ship scheduled to commission in 2019. The 15 to Five plan calls for an additional six of this class to be built once the initial six are completed. The six 'Kedah' class OPVs are already in service and the plan calls for another twelve, though these would likely be versions armed with surface-to-surface and surface-to-air missiles and anti-submarine weapons, according to navy sources, although such a move would also depend on available finances. The MRSS programme has been a navy aspiration since 2006 but has never materialized owing to budgetary restrictions. Despite this, the 15 to Five plan calls for a total of three such ships. Two 'Scorpene' class submarines are already in service but the navy would like two more to make the submarine fleet more operationally viable given the fact that having only two submarines has resulted in time gaps where neither submarine is available for operations, however the costs of additional submarines and alleged controversies surrounding the purchase to the two 'Scorpene' class SSKs means it is highly unlikely that such will be realised in the near future.

On 1st November 2016, in conjunction with Malaysian Prime Minister Najib Tun Razak's official visit to the PRC, an agreement was reached for the construction of four LMSs for the navy within 24 months of the signing of a formal contract with two to be built in the PRC by China Shipbuilding and Offshore International and two in Malaysia by Boustead Heavy Industries, builders of the LCS/SGPV. Little information is available on the actual design and specifications of the ship so far save that navy sources told the author that the LMS would be configured for, but not with, anti-ship missiles. Official statements during the signing of the agreement said that the final design, specifications and cost of the ships were currently being discussed and would be finalised later at an undisclosed date. On 8th November 2016 the minister of defence Hishammuddin Tun Hussein was reported by the Malaysian media as stating that the total cost of the four ships would be capped at $220 million. As of the time of writing no official announcement

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The RMN's 15 to Five fleet recapitalisation programme calls for the RMN to lower its number of ship classes from 15 to five classes.

No replacement has emerged yet to for the RMAF's fleet of MiG-29N/UB fighters due to budgetary restrictions.

has been yet made on a formal contract for the programme and the cost and specifications of the ship. However, the procurement of the LMS vessels, together with the purchase of additional vessels in the future, such as a revival of the MRSS programme, are likely to be dependent on the navy's available budget.

Organisationally the navy plans to establish an additional naval regional command (COMNAV) to add to the three currently in existence as announced by Adm. Kamarulzaman to the media in December 2016. Currently, COMNAV-1 at Kuantan naval base oversees much of Peninsular Malaysia, and the southern half of the Malacca Strait. COMNAV-2 at Kota Kinabalu naval base oversees East Malaysia and COMNAV-3 at Langkawi naval base on the eponymous island in the Andaman Sea oversees the northern half of the Malacca Strait and the Andaman Sea bordering it. The new COMNAV-4 will be based at the planned Bintulu naval base, Sarawak on the island of Borneo, and will assume the responsibilities of the waters off the state of Sarawak which is currently under COMNAV-2. The move is to allow the navy to better monitor the waters surrounding Sarawak with the command scheduled to be activated sometime in 2017, as stated by the RMN chief in December 2016. Unstated is that the move is due to the concerns regarding the area around James Shoal and Luconia Breakers which have been claimed by the PRC with Malaysian fishermen in the area claiming, in June 2015, that Chinese Coast Guard vessels had prevented them from fishing there.

Aviation

Gen. Affendi Buang, who recently took over as the RMAF chief in December 2016 faces a considerable challenge in dealing with the air force's lack of funding for new and additional aircraft along with significant cuts to the service's operational budget for 2017, the RMAF's deputy chief Lieutenant General Ackbal Samad told the author that the air force had to rework its plans for activities in 2017 when the government officially announced the budget for 2017 which cut the air force operational budget from $607 million in 2016 to $404 million for 2017. Malaysia's multirole fighter aircraft requirement to replace the MiG-29N/NUB continues to be outstanding with no funding or clear candidate in sight. With Mr. Hussein stating in 2016 that the aircraft selection would likely be as late as 2020, the Saab JAS-39E Gripen fighter has been mooted by some in the Malaysian air power community as an affordable option for Malaysia. In the meantime, the air force's MiG-29N/NUB aircraft continues in service, although the numbers of aircraft flying are said to be between four and six of the twelve-strong fleet, according to RMAF sources. The bright spot for the RMAF has been the A400M programme with three aircraft already delivered and in service without any significant issues, and the final aircraft to be delivered in 2017. However the first three aircraft will have to return to Seville, Spain to be fully outfitted to the tactical transport configuration. The first aircraft is already in Spain, having left Malaysia in January. The outfitting will allow the aircraft to perform tactical operations with the addition of self-protection systems and equipment for parachute drops, short-runway operations and the ability to conduct and receive mid-air refuelling.

Conclusions

The outlook for the Malaysian armed forces in regard to capability procurement is not positive as the Malaysian government is facing fiscal difficulties with almost all ministries in the government taking funding cuts. At the time of writing the ringgit has been stable for the first two months of 2017 but uncertainty looms over the long-term prospects of the currency and economy. With a looming general election in 2018, the priority for the Malaysian government will be electorally friendly programmes and not defence programmes. The positive side for the Malaysian armed forces is that a number of key procurement programmes such as the AV-8, SGPV-LCS, Littoral Mission Ship, Starstreak-NG Missile and the A400M are all ongoing smoothly or will be carried out without being affected by the budget situation. The biggest issue is still in regard to the air force's fighter fleet, with a new fighter requirement remaining unsatisfied and no clear direction as to its outcome. Adm. Kamarulzaman though takes a more positive view on the budget constraints saying that the fiscal constraints now forces the navy to ensure that it is more efficient and cost effective, and the same could apply to the Malaysian armed forces as a whole: "We should not see these fiscal constraints as just a challenge but also an opportunity for us to change the way we do things and ensure that we are more cost efficient and receive value for money in our undertakings." AMR

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The events surrounding the loss of MH370 was only the first tragedy involving the 777-200ER in 2014, as another Malaysia Airline-owned example was shot down some months later by a surface-to-air missile.

Boeing

THE SAD SONG OF MH370

The loss of Malaysia Airlines' flight MH370 *en route* from Kuala Lumpur to Beijing on 8th March 2014 was an event that not only had rippling effects throughout the aviation industry, but also across the rest of the world.

***by* Beth Stevenson**

The seemingly inexplicable disappearance of a Boeing 777-200ER airliner and the 239 souls on-board quite rightly made the general public stand up and pay attention to the safety of air transport that is generally taken for granted. Not since the horror of the 11th September 2001 Al Qaeda attacks on New York and Washington DC had the public paid this much attention to the safety of aviation, and the crash of the airline's flight MH17, a second 777-200ER, this time *en route* from Amsterdam to Kuala Lumpur on 17th July 2014, some four months after MH370 went missing, did very little to help matters. Flight MH17 is widely believed to have been shot down by a Russian Army 9K37 Buk surface-to-air missile battery from the force's 53rd Anti-Aircraft Rocket Brigade while over Eastern Ukraine.

An international search for MH370 led by Australia commenced on 17th March 2014 launched over the Indian Ocean to try to locate the missing airliner and its passengers utilising a range of different technologies from satellite data down to Autonomous Underwater Vehicles (AUV). A number of nations offered maritime patrol aircraft and vessels for the search, which concentrated on a particular area of the Indian Ocean, chiefly its south-eastern part, where it was determined that the aircraft was most likely to be. Nevertheless, on 17th January, the decision was made to suspend the search by the governments of Australia, Malaysia and the People's Republic of China; the three nations leading the effort. The hunt had already been scaled down at that point, with one of the survey vessels, the MV *Fugro Discovery*, leaving the area in August 2016. This left the search responsibility to the MV *Fugro Equator* vessel, equipped with its Kongsberg Echo Surveyor-IV Hugin-3000 AUV, Kongsberg EM-2040 multibeam echo sounder, and an EdgeTech deep towed sonar to carry out the remaining part of the search.

A joint statement from the governments of Australia, Malaysia and the PRC said that despite using the best science and technology available, they had not been able to find the aircraft: "Whilst combined scientific studies have

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The MV Fugro Equator vessel was the last remaining asset coordinating underwater search activities up until the mission was suspended in January.

A number of underwater systems were deployed from search vessels during operations to locate MH370, which involved deep water surveillance using a different sensing technology, including an EdgeTech deep towed sonar.

continued to refine areas of probability, to date no new information has been discovered to determine the specific location of the aircraft," the statement said: "The decision to suspend the underwater search has not been taken lightly nor without sadness. We remain hopeful that new information will come to light and that at some point in the future the aircraft will be located."

Whilst significant resources were ploughed into finding flight MH370, family members of those on board were demonstrably frustrated with the lack of progress, and formed a group, known as Voice370, based in Kuala Lumpur, to campaign for more investigations to take place. The cancellation of the search understandably riled Voice370, which claims that an event so often referred to as unprecedented should not be so easily forgotten, and points to the admission by the Australian government in January 2016 that available funding was not the reason for the cancellation, so the search should continue: "In our view, extending the search to the new area defined by the experts is an inescapable duty owed to the flying public in the interest of aviation safety," Voice370 said in a statement it released after the search was cancelled: "Commercial planes cannot just be allowed to disappear without a trace … We appeal to Malaysia, China and Australia to reconsider the decision to suspend the search."

The 7th Arc

One thing that has caused much frustration among relatives and campaigners was the suggestion by researchers in Australia that the search zone that was being explored was in fact the wrong one, and the aircraft was likely to be in an area 25 nautical miles/nm (48.2 kilometres) away: "The experts confirmed their agreement that the analysis of the last two SATCOM (Satellite Communications from the airliner) transmissions, the likely housed position of the main flaps at impact, and results from the recent flight simulations indicate with high probability that the aircraft lies within 25nm of the 7th Arc that had been derived from analysis of the last satellite communications with the aircraft ... Given the high confidence in the search undertaken to date, the experts agreed that the previously defined indicative underwater area is unlikely to contain the missing aircraft between latitudes 36 degrees south and 39.3 degrees south along the 7th Arc." The 7th Arc refers to a section of the Indian Ocean positioned 20 degrees south to 39 degrees south.

A report issued by the Australian Transport Safety Bureau (ATSB) in December 2016 claims that drift modelling had concluded that the northern third of the initial search area remains prospective. This northern area was partially searched, close to the 7th Arc, in the latter half of 2014 and early 2015, while locations outside the searched area that are still within a likely distance from the Arc remain unsearched: "The region near 35 degrees south is particularly prospective because there is strong evidence (from Earth-observation satellite data) that this is where, at the time of the accident and for weeks after, the debris field would have been carried north-west for about 270nm (500km), away from where the March-April 2014 surface search was conducted and away from the shores of western Australia." This conclusion is consistent with the times and locations of the debris that has been found that has so far been confirmed as belonging to the airliner, as well as the lack of debris spotted during the initial aerial and surface searches: On 29th July 2015, debris in the form of one of the aircraft's flaperons was washed up on the Shore of Reunion Island in the Indian Ocean. This was confirmed by France's *Bureau d' Enquetes et d'Analyses pour la Securites de l'Aviation Civile* (BEA/Civil Aviation Security Enquiry and Analysis Bureau) as originating from flight MH370.

Voice370 has since called on experts in the fields of oceanography and air safety investigation, plus independent investigators and members of the public, to further appeal to the governments discussed above to repeal their decision, and start the search again. This included

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ATSB

A flaperon found on La Reunion island in the Indian ocean in July 2015 was proven to be from the missing airliner, which alongside a number of other fragments of the aircraft that have been swept to different shorelines, remain the only remnants of the missing airliner.

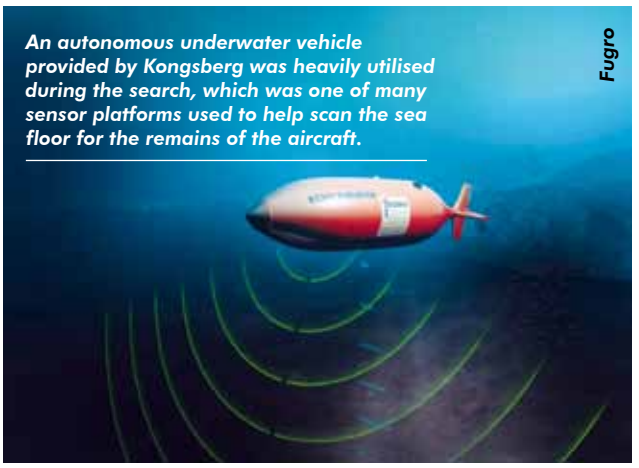
a response from Grant Brophy, a US-based air safety investigator, who on behalf of Voice370 wrote a letter to the Malaysian transport minister, Liow Tiong Lai, urging the search to continue: "Despite the massive underwater search zone, the only traces of the aircraft found to date have been pieces recovered from islands in the western Indian Ocean and Africa," Mr. Brophy said. "New analysis by the Australian government-funded Commonwealth Scientific and Industrial Research Organization (CSIRO) provides an impetus to continue the search somewhat longer … According to the CSIRO, an area near the intersection of the 7th Arc and 35 degrees south latitude offers the best potential for locating the aircraft." Additional debris was found washed up in Mozambique on 2nd March 2016 later confirmed as a horizontal stabiliser from the aircraft.

Mr. Brophy added that while the region of 36 degrees south to 32 degrees south identified by CSIRO remains prospective, the region nearest 35 degrees south appears to offer the most promise: "In saying that, I also recognise that there are significant limitations to our ability to successfully locate the aircraft and the remains of those on board," he noted: "If the official search must be brought to an end … I ask that it be extended so that the region highlighted at 35 degrees south can be searched." A petition has since been launched by Voice370 to keep the search going, which those involved claim needs to be acted on as soon as possible so that the equipment required to continue is not demobilised. Mr. Liow has since claimed that he would establish a response team to continue studying the possible whereabouts of the lost aircraft, which will include the ATSB, Malaysia Airlines, and Malaysia's civil aviation authority: "With the suspension of the underwater search, a response team led by the Malaysian department of civil aviation will be established to handle all matters relating to MH370," he said. "This includes information and debris that may be discovered in the near future with continued commitments from the governments of Australia, China and Malaysia."

The BEA has contributed its experience with investigating in the aftermath of Air France flight AF447, an Airbus A330-203 airliner that crashed in the Atlantic Ocean on 1st June 2009 when flying from Brazil to France, with the loss of all 228 souls. This accident involved a similar sized aircraft, and was recovered from depths similar to those found in MH370's search area. While the announcement by Mr. Liow means that more pieces of the aircraft may be positively identified, one of the main frustrations from the relatives of those on board is that the search equipment will be removed, and no active searching is going to continue. The last sensor carrying out the search was the Echo Surveyor-IV Hugin-3000 AUV, which carried out 23 hour missions on average, utilising sonar to scan for parts of the wreckage, plus towed sonar systems. Planning for the underwater search focused on selecting a system that could search a very large area of the seafloor, at that time up to 17493 square nautical miles (60000 square kilometres) in ultra-deep water in often poor weather conditions, and therefore 6000 metre (19683 feet) depth rated deep-tow AUVs were selected as the primary search system. Deep tow survey systems can perform deep ocean floor surveys using sonar or cameras.

Some 34986 square nautical miles (120,000 square kilometres) of seabed was ultimately scanned, using an array of different systems: "The underwater search required a phased approach given the unknown composition and topography of the seafloor in the search area," an ATSB report from November 2016 said: "Before the high-resolution sonar search commenced, a bathymetric survey was conducted to ensure that the deep tow vehicles to be used in the search could be navigated safely and efficiently close to the sea floor … The bathymetric survey work commenced in June 2014 using hull-mounted multibeam sonar systems on the vessels MV *Fugro Equator* and MV *Zhu Kezhen* (a Chinese hydrographic survey ship)." Once a sufficient area had been surveyed, deep tow operations began. These involved Malaysia's MV *Go Phoenix* vessel, and the ATSB contracted vessel the MV *Fugro Discovery*.

A deep tow search system was also integrated onto the MV *Fugro Equator* once the system had completed initial bathymetric survey work, and from late 2014 through to 2015, deep tow search operations focused on searching the areas adjacent to the 7th Arc between latitudes 32.8 degrees south and 39 degrees south,


Fugro

An autonomous underwater vehicle provided by Kongsberg was heavily utilised during the search, which was one of many sensor platforms used to help scan the sea floor for the remains of the aircraft.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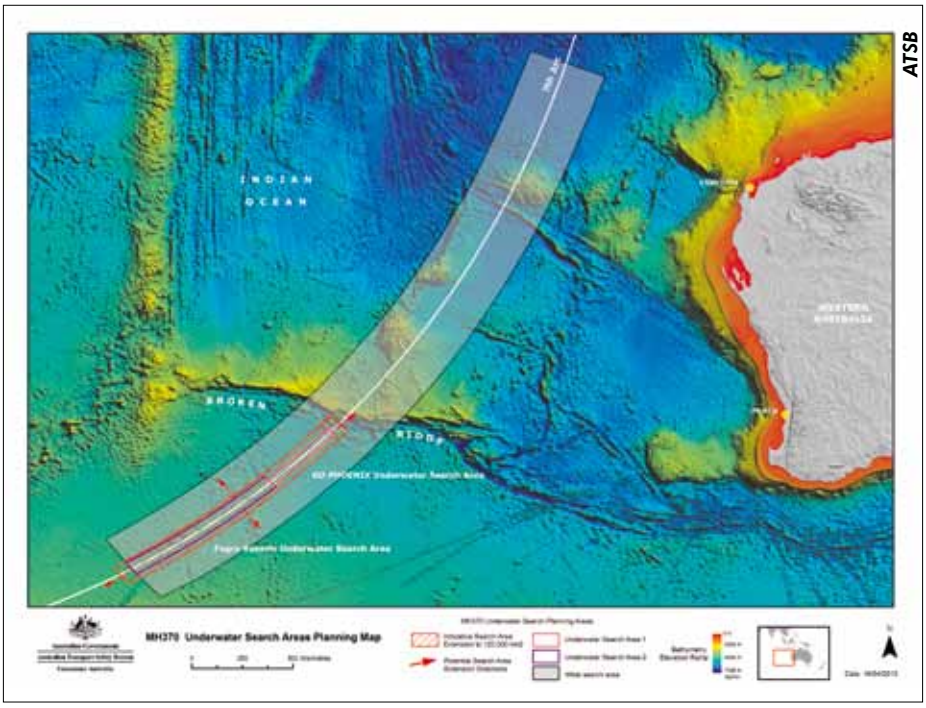

The search for MH370 was suspended in January, although evidence from the ATSB has determined that a different area some 25nm away from the original search zone is actually more likely to contain the aircraft.

the ATSB said. During this time, the MV *Go Phoenix* was tasked with searching from 32.8 degrees south to 34.5 degrees south in the northern section of the search area, while the two Fugro vessels were tasked to search from 34.5 degrees south to 39 degrees south. April 2015 saw the MV *Go Phoenix* complete its contract with the Malaysian government, at which point it left the search, and in parallel, the three governments decided to expand the search area to 34986 square nautical miles.

In November 2015, additional analysis of the SATCOM data and flight path modelling was completed by DST Group, an Australian governmental organisation which applies science and technology to support Australia's defence, and as a result, the area between 36 degrees south and 39.3 degrees south in the search area, and up to 40nm (74.1km) either side of the 7th Arc, was prioritised, and that remained so until operations ceased.

In February 2016, the Chinese vessel MV *Dong Hai Jiu 101* joined the search, initially equipped with the same deep tow system which was deployed on the MV *Go Phoenix*. A remotely operated vehicle was also deployed on the vessel some months later, and was used in the latter part of 2016 to investigate and discount a number of sonar contacts detected during deep tow and AUV search operations. While Australia has received criticism for having spent two years searching what has now turned out to be the wrong area, Malaysia and the PRC, as the two destinations that the aircraft was travelling between, have arguably not sufficiently carried out their search obligations.

Keep Looking

The potential continuation of the work, which has now determined that an area just out of the search area is more likely to contain the wreckage (*see above*), is in the hands of the Malaysian government, which is why Mr. Liow agreed to continue assessing wreckage after the search was suspended. Australia, meanwhile, had the search and rescue responsibility conferred upon it due to the point at which the aircraft was determined to have fallen in the Indian Ocean, around 970nm (1800km) southwest of Perth, Western Australia, and the PRC remains somewhat unvocal on developments.

While the pressure has been laid on all of the parties involved in finding the aircraft to answer all of the questions thrown at them, a lack of consistency, and a tendency to attribute a quick answer to the causes of the disappearance, has not helped. Malaysian Prime Minister Najib Razak claimed just after the event that the communications systems on board the aircraft had been intentionally disabled, and the 777-200ER could have been flying for a further seven hours after it last made a connection with the ground. Claiming these movements were consistent with deliberate action by somebody on the aircraft, the comments from Mr. Razak just added to the uncertainty already felt by relatives of the people on board, and no evidence has backed up his claim since.

Another revelation that provoked false theories on what caused the crash was the presence of two Iranian men on board the flight that had forged passports, leading to assumptions that they hijacked the aircraft. This was quickly quashed by Interpol, but the conspiracies surrounding the unprecedented disappearance of MH370 demonstrates that those involved have explored many avenues for a quick answer, yet three years later the search is only eliminatory in nature, and there are still no real answers for the families of the victims over what happened to the airliner and its passengers.

What has been confirmed by the ATSB, is that two wing flaps from the aircraft (*see above*) that were found were not in the landing position at the point of crash: "Additional analysis of the burst frequency offsets associated with the final satellite communications to and from the aircraft is consistent with the aircraft being in a high and increasing rate of descent at that time," the December 2016 report from the bureau said: "Additionally, the wing flap debris analysis reduced the likelihood of end-of-flight scenarios involving flap deployment." Satellite data also suggested the aircraft made a rapid descent, but how this relates to the loss of the aircraft, or the site of the crash, cannot be determined.

The three nations have claimed that new evidence would rejuvenate the search, but the approach from the governments seems to be that they have accepted that the aircraft and the bodies of those on board will not be found. While conspiracy theories on where the aircraft is and what happened on 8th March 2014 are bountiful, there are no clear indications of what actually happened, and if the search is called off, it seems there never will be. Although no new evidence has been found to support a continued search *per se*, the acknowledgement that the past three years have involved a search in the wrong area is likely to be enough to keep the relatives of those on board flight MH370 committed to continuing the search, but only time will tell if the governments involved will give the go ahead to make this happen. AMR


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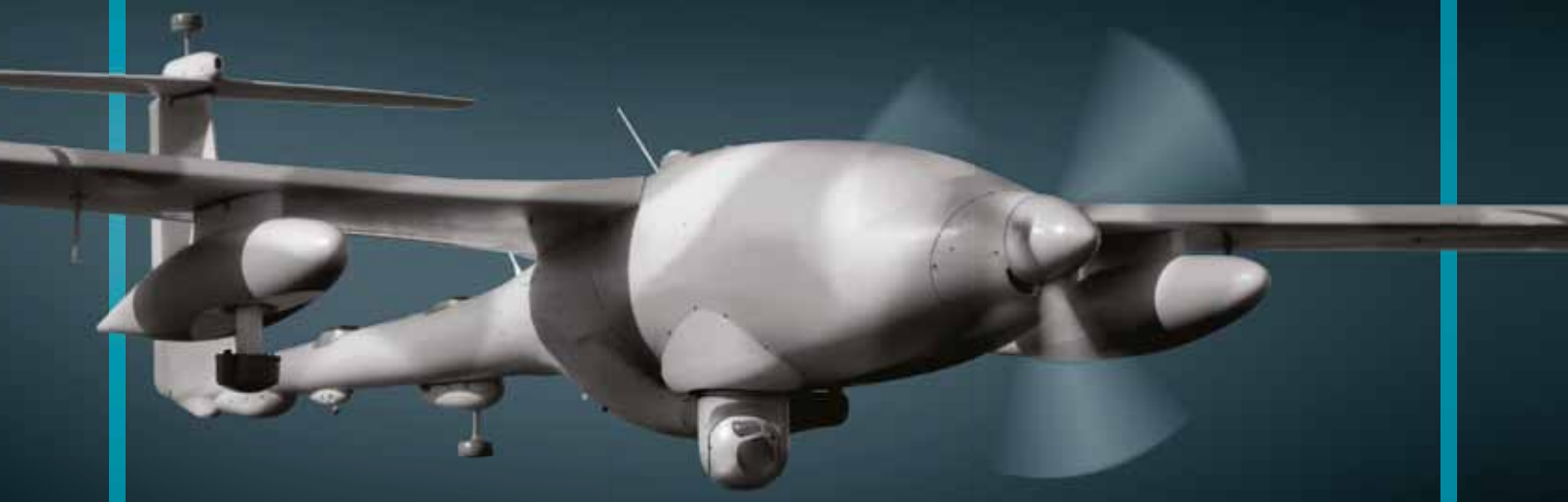

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