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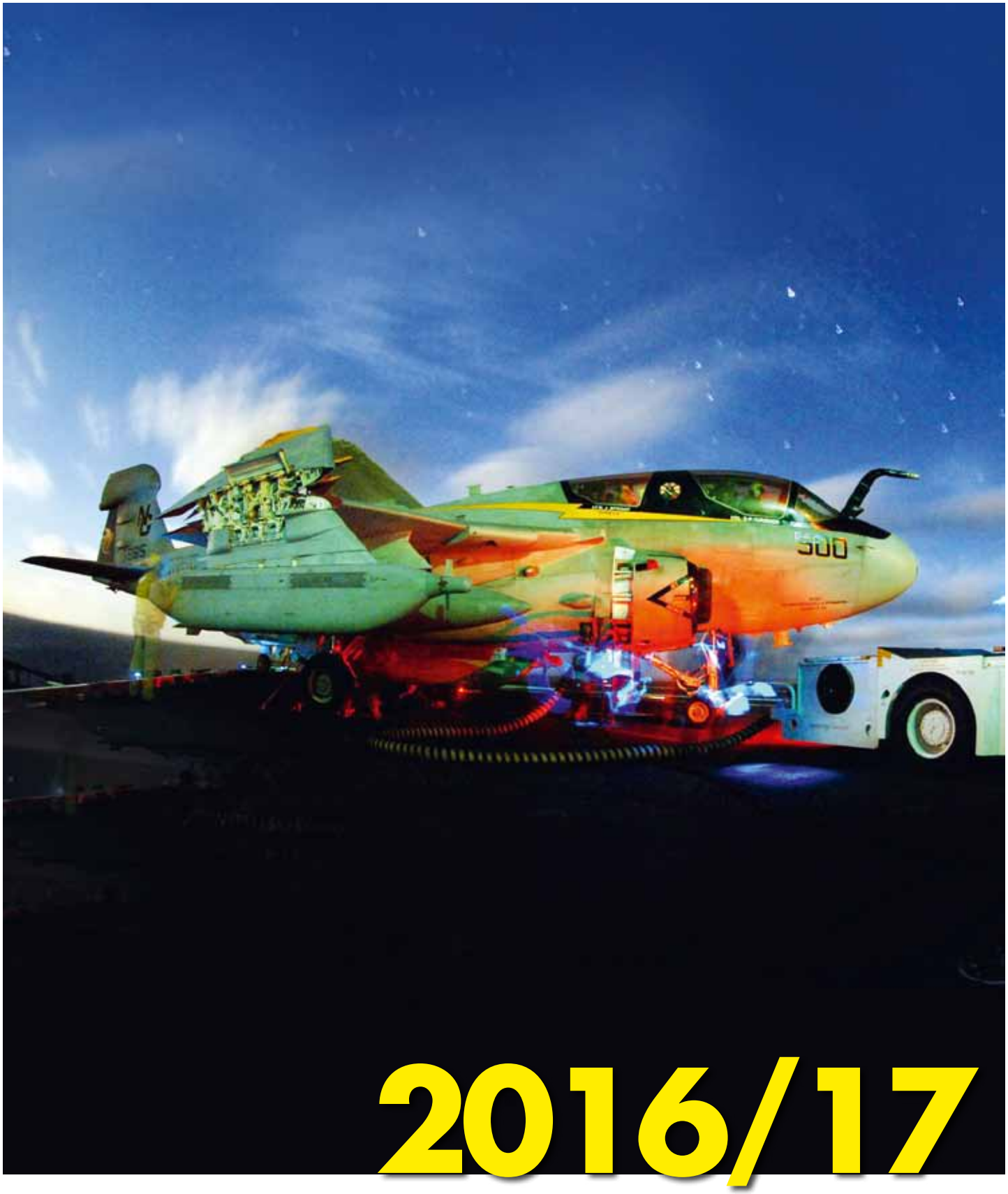

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An Iraqi radar lies destroyed in the desert sand. The ability of the West to prevail against surface-to-air threats has been taken for granted for decades, but is now under threat.

WAR IN THE ETHER

***Armada* is proud to present its first ever airborne Electronic Warfare (EW) compendium supplement. This publication will chronicle the current threats to air operations which EW must counter, leading airborne EW products and programmes, and how airborne EW may develop in the future.**

Thomas Withington

In 1947, the United Kingdom's Air Ministry, which had overarching responsibility for the Royal Air Force (RAF) during the Second World War, and the procurement of military aircraft and supporting equipment, published a document entitled *War in the Ether*. This fascinating publication chronicled the first application *en masse* of EW by the RAF's Bomber Command against the *Luftwaffe* (German Air Force) during the former's execution of the strategic air campaign against Nazi Germany. In the almost seventy intervening years since its publication, airborne EW has changed dramatically, yet it still applies the core principles of electronic warfare that were forged in the furnace of the Second World War; chiefly Electronic Attack (EA), Electronic Protection (EP) and Electronic Warfare Support (EWS).

Put simply, EA can use Radio Frequency (RF) energy to deceive, degrade, damage and/or destroy hostile military

platforms (ships, vehicles and aircraft) or subsystems. EP uses the Electro-Magnetic Spectrum (EMS) to protect these platforms from detection and attack. It employs active and passive techniques. Active techniques use electronic attack to protect these platforms, while the passive techniques employed in EP work to detect hostile electronic systems, such as fighter radars or surface-to-air missile guidance radars, to alert a platform that it may be under attack. EA can then be brought to bear, sometimes in combination with kinetic effects, to neutralise this threat. Finally, EWS focuses on the gathering of Electronic Intelligence (ELINT). ELINT is information regarding enemy systems which emit RF energy for offensive purposes. For the purpose of this discussion, in the airborne domain, this principally relates to RF emissions from hostile radars. Gathering ELINT enables EW practitioners to understand the characteristics of an adversary's radar systems, and hence what EA and EP techniques, tactics and systems need to be employed to neutralise these. Readers are advised that this is only a very broad and simple summary of the *modus vivendi* and *modus operandi* of airborne electronic warfare. They would be recommended to consult the myriad of specialist texts which discuss these subjects to gain a full comprehension of this fascinating discipline.

The first section of this supplement, entitled *Danger on the Edge of Town*, examines the threat posed by medium-range/medium-altitude and long-range/high-altitude Surface-to-Air Missile (SAM) systems, and shorter-range Man-Portable Air Defence Systems (MANPADS). Through the prism of the ongoing Syrian and Ukrainian civil wars, this article discusses the threat posed to air operations by existing Russian/Soviet Union origin mobile SAM systems. It argues that, since the end of the Cold War, the North Atlantic Treaty Organisation (NATO) has faced a progressively diminishing threat from SAMs, but that recent experiences in the Syrian and Ukrainian conflicts indicate that this trend may be coming to a close. Of particular concern is the Russian Almaz-Antey S-400 *Triumf* long-range/high-altitude SAM system which, as of November 2015, has been deployed to Syria to support the Russian air campaign in that country's civil war, and which could potentially pose a threat to US and allied air operations against Islamic State of Iraq and Syria (ISIS) insurgents operating in both these countries. Allied to the threat posed by systems such as the S-400 is the continuing threat posed by MANPADS.

US DoD

Chaff and flare countermeasures remain a highly reliable method of neutralising air-to-air and surface-to-air threats.

The discussion of the threat posed to air operations by SAM systems and MANPADS is followed by the *Electric Avenue* article reviewing the steps being taken by industry to help meet these threats. Industry officials approached by *Armada* argue that the Russian involvement in the Ukrainian civil war has underscored the value which Russia places on the use of EW, and the effect that this can have on military operations both contemporary and future. The article then chronicles some of the world's leading airborne EW systems and programmes in North America, Europe and Israel. This is not intended to be an exhaustive list, merely to give the reader a comprehensive overview of the systems and capabilities in the marketplace.

Following on from the discussion of industry's response to the threat which airborne EW must counter, the supplement's *The Need for SEAD* article will study possible future developments in this domain. In particular, it will examine how NATO will develop its Suppression of Enemy Air Defence (SEAD) posture in the coming years, and how NATO's European membership plans to absorb an increasing amount of the SEAD burden from the United States.

Industry is stepping up to this call, through the examination of concepts such as cognitive EW while arguing that airborne electronic warfare systems can no longer be considered as 'luxury' items onboard military aircraft. Other design imperatives for the next generation of airborne EW systems include the ability to constantly adapt to the threat as it occurs, and as it changes, alongside ensuring that such systems can detect discreet hostile RF transmissions in an increasing crowded electromagnetic spectrum. Regarding hardware, open architecture and the use of commercial-off-the-shelf technology continues to offer promise, while an ever-pressing need is observed by industry to continually reduce the size, weight and power consumption of EW payloads.

At the market level, the demand for airborne electronic warfare systems is expected to remain strong in the Asia-Pacific and Middle East regions, with ongoing global tensions involving Russia, the People's Republic of China, the West and its allies helping to drive the market. Nevertheless, pressure on defence budgets around the world could act as a restraint on this demand, while the ever-present challenge remains ensuring that an awareness of what airborne electronic warfare can achieve is at the forefront of the minds of policy makers and practitioners alike.

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DANGER ON THE EDGE OF TOWN

Conflicts in Ukraine, and in Syria and Iraq, illustrate the threat posed to current, and future air operations exemplified by medium-range/medium-altitude and long-range/high-altitude SAM systems and MANPADS.

Adrian Pingstone

An example of a Turkish Air Force RF-4E Phantom reconnaissance aircraft, of a similar type to that which was shot down over the Mediterranean on 22 June 2012.

On 22 June 2012, Flight Lieutenant (Flt. Lt.) Gökhan Ertan and Flying Officer (F/O) Hasan Hüseyin Aksoy climbed aboard their *Türk Hava Kuvvetleri* (Turkish Air Force/TAF) McDonnell Douglas/Boeing RF-4E Phantom reconnaissance aircraft and departed the TAF's Erhaç airbase in the eastern central region of Turkey. The aircraft disappeared from TAF radar screens at 1202 local time. On 4 July, the bodies of Flt. Lt. Ertan and F/O Aksoy were recovered from the depths of the Mediterranean by remotely operated vehicles from the EV *Nautilus* research vessel operated by the Ocean Exploration Trust.

The crew of the RF-4E had been briefed to help test the radars operated as part of the TAF's integrated air defence system. After departing from Erhaç airbase, they had flown their jet between the southern Turkish province of Hatay and the island of Cyprus. At around 1142 local time, the aircraft reportedly violated Syrian air space, remaining in that airspace for five minutes before being warned by TAF air traffic controllers to immediately leave the area, which the RF-4E did at 1147 local time. Much of what happened to the

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Vitaly Kuzmin

Several theories as to which system downed the TAF RF-4E abound, with the Pantsir-S1E/S2 (pictured) being a possible culprit.

RF-4E between 1147 and 1202 local time remains shrouded in mystery and is a matter of conjecture. It is known that at some point the aircraft was shot out of the sky by the Syrian military. It has not been possible to determine precisely which SAM system was responsible for downing the jet, but the rumoured culprits, according to authoritative open sources, are either the Russian-origin Pantsir-S1E/S2 short-to-medium range air defence system which has an engagement range of circa 10.2 nautical miles/nm (19 kilometres/km), using its 57E6 SAMs, or possibly the Russian Almaz-Antey Buk-M2E SAM system, which has an engagement range of 22.6nm (42km). Both of these systems are operated by the Syrian armed forces, either with the Syrian Army, the Syrian Air Defence Force, or both.

The shoot down of the TAF RF-4E shows that the airspace above Syria is becoming more dangerous. NATO and United States allies in general have enjoyed an increasingly more benign environment for air operations regarding the surface-to-air threat since the Persian Gulf War of 1991 when circa 44 coalition aircraft were destroyed by surface-to-air threats, principally Anti-Aircraft Artillery (AAA). This reduced to three NATO aircraft losses from surface-to-air threats during NATO's Operation DELIBERATE FORCE, mounted in 1995 to degrade the Bosnian-Serb armed forces so as to prevent further attacks against United Nations-mandated safe areas in Bosnia-Herzegovina in the Balkans. These loss rates fell to two airframes during Operation ALLIED FORCE, mounted to stop the ethnic cleansing of Kosovar Albanians by Serbian Army and special police units in the Balkans province of Kosovo in 1998. A single coalition aircraft was lost to surface-to-air attack during the US-led Operation IRAQI FREEDOM in 2003, with no coalition aircraft lost to such threats during Operation UNIFIED PROTECTOR/ODYSSEY DAWN over Libya in 2011. Thus, one trend which can be observed is that, with the exception of the threat which MANPADS (Man-Portable Air Defence Systems) continue to pose at relatively low altitudes and short ranges, air operations involving US and Allied powers are facing progressively less of a threat from medium-range/medium-altitude and long-range/high-altitude SAM (Surface-to-Air Missile) systems.

Yet such a conclusion would be dangerous. The downing of the TAF RF-4E discussed above indicates that the skies above current and potential future conflicts are far from sanitised. For example, Torez in eastern Ukraine became a scene of horror on 17 July 2014 when Malaysian Airlines Flight MH17, a Boeing 777-200ER airliner with 298 passengers and crew aboard, was shot down by what is strongly believed to have been a Russian 9K37 *Buk* SAM system believed to have been supplied to Russian separatists fighting the Ukrainian government in that country's civil war, with the loss of all souls. Independent investigators from the *Bellingcat* citizen journalist website claimed that the 9K37 system belonged to the 53rd Anti-Aircraft Rocket Brigade of the Russian Army. Although the Malaysian Airlines 777-300ER was a civilian aircraft and hence bereft of the Integrated Self-Defence Systems (ISDSs) usually found on military aircraft, this was not thought to be the case for the RF-

Vitaly Kuzmin

An example of the Russian 9K37/317 Buk surface-to-air missile system. This weapon is thought to have destroyed Malaysian Airlines Flight MH17 over Ukraine on 17 July 2014.

4E which may have been shot down by the same system. Presumably, the RF-4E was outfitted with an ISDS? One would expect that an aircraft operating so close to a war zone, in this case Syria, which was known to possess robust air defences, would have been equipped with a functioning ISDS. This has raised questions as to whether the ISDS was functioning on the RF-4E, or whether it was unable to defeat the threat posed by the 9K37 system or whichever SAM system may have attacked the aircraft.

Beyond the loss of the TAF RF-4E and flight MH17, other air operations have been threatened by systems such as the 9K37. For example, on 7 December 2015, the Israeli Air Force (IAF) performed several air strikes against *Hezbollah* Palestinian insurgent weapons storage facilities using McDonnell Douglas/Boeing F-15 family fighters. Open source reports state that, despite heavy electronic jamming being deployed by the IAF aircraft, a Syrian Army/Air Defence Force 9K317 *Buk*-M2 SAM system that was deployed at Mezzeh airbase, southwest of the Syrian capital Damascus, was able to fire two missiles at the first formation of two F-15 aircraft, which avoided being shot down by using evasive action. The second F-15 formation was attacked by two Syrian Almaz-Antey S-125 *Neva/Pechora* SAMs. Although these two jets avoided being shot down, one of the Rafael Advanced Defence Systems Popeye INS (Inertial Navigation System)/Television guided air-to-surface stand-off missiles fired by the aircraft was reportedly destroyed by one of the SAMs fired from the S-125 battery. The IAF's targets had reportedly been arms storage sites at Damascus International Airport, to the southeast of the city, and similar facilities in the town of Al-Dimas, to the northwest of the city, close to the Syrian-Lebanon border.

S-400

Systems such as the 9K37/9K317 family clearly remain a cause for worry, yet US and allied militaries are also increasingly concerned by the Almaz-Antey S-400 *Triumf* long-range/high-altitude SAM system. The S-400 has yet to be used in anger against the US or any of her allies, yet the system is being treated with considerable respect by these actors.

Having entered service in 2007 with the Russian Army, the S-400 has an operational range of up to 215.9nm (400km) with its integral 40N6 SAM. Although the S-400 has been deployed in Russia for almost a decade, it made its operational debut in the Syrian theatre of operations when it reportedly completed its deployment on 26 November 2015. The Russian government, which had commenced its air campaign against Syrian rebel groups opposing the government of President Bashir al-Assad on 30 September 2015, deployed the S-400 in response to a shoot down of a Russian Air Force Sukhoi Su-24M fighter bomber on 24 November by two TAF General Dynamics/Lockheed Martin F-16C/D Fighting Falcon fighters employing Raytheon AIM-9X infrared/Semi-Active Radar Homing (SARH) air-to-air missiles. The attack followed a reported violation by the Su-24M of Turkish airspace.

The S-400, and its deployment to Syria, is a major concern for the US and her allies. As noted above, the key threat posed by the system is its reach, with the operational range of the 40N6 missile being an example of the radius of territory which it can protect. In addition to the 40N6, the S-400 can deploy the 48N6E2 SAM

Part of Russia's S-400 Triumf. This sophisticated surface-to-air missile system represents a potential threat to current and future air operations.

Vitaly Kuzmin

which uses SARH guidance (like the 40N6 which can also use Active Radar Homing/ ARH) with a range of 107.9nm (200km), the 48N6DM/E3 employing SARH with a range of 134.9nm (250km), the 9M96E SAM with a range of 21.5nm (40km), and the 9M96/E2 with a 64nm (120km) range. Also of concern is the 91N6E S-band (2.3-2.5/2.7-3.7 Gigahertz/GHz) ground-based air surveillance radar which has a reported instrumented range of 323.9nm (600km) and is capable of tracking 300 targets, plus the S-400's 92N6E target engagement radar. This latter system has an instrumented range of 215.9nm and the capability of tracking 100 targets, while engaging six of those targets simultaneously.

Alongside its capabilities in terms of missile engagement and instrumented radar ranges, the S-400 has been designed to be mobile greatly easing its deployment. As the deployment to Syria in 2015 illustrated, it was declared deployed and ready by the Russian Ministry of Defence two days after the Su-24M shoot down. Mobile systems tend to be harder to detect and destroy compared to fixed SAM systems such as the S-125 *Neva/ Pechora*, the Almaz-Antey S-200 *Angara/ Vega/Dubna* and the S-75 *Dvina* weapons which NATO faced during its intervention in Libya in 2011 (*see above*).

The S-400 is a cause for concern in the Middle East. Since June 2014, the US-led Operation INHERENT RESOLVE has been targeting the presence of the ISIS insurgent organisation which has occupied significant parts of north-western Iraq and eastern Syria. Alongside the US, Australia, Belgium, Bahrain, Canada, Denmark, France, Germany, Jordan, Morocco, the Netherlands, Qatar, Saudi Arabia, Turkey, the United Arab Emirates and the United Kingdom have all contributed air forces and in some cases ground forces (mainly Special Forces) to the anti-ISIS effort. The S-400 unit deployed at Khemeimim airbase, collocated at Bassel Al-Assad International Airport on Syria's northern Mediterranean coast, has sufficient range to place any aircraft flying over much of Syria, particularly the western and central parts of the country in danger. In tandem, a significant part of southern Turkey falls under the weapon's coverage along with all of Cyprus and Lebanon, plus a significant part of northern Israel and Jordan.

The deployment of the S-400 is no coincidence given that it was performed shortly after the Su-24M shoot down discussed above. Meanwhile, relations between Russia, the United States and NATO remain frosty. During the NATO summit held in Warsaw, Poland on 8 July, involving the alliance's heads of government, it agreed to deploy 4000 troops to Poland, and to the Baltic states of Latvia, Lithuania and Estonia to deter any Russian aggression against these nations. The deployment indicates that tensions between Russia and NATO remain high,

US DoD

The threat from MANPADS has not diminished in recent years, and has in fact witnessed renewed use in the Ukrainian, Syrian and Iraqi theatres of conflict.

particularly since Russia's annexation of Crimea on 18 March 2014, and the country's continued involvement in the Ukrainian Civil War supporting pro-Russian separatists. The existence of the S-400 in Syria means that a potent weapon could potentially be used against US and allied warplanes in the future, should relations deteriorate from their current tense characteristic into a shooting war.

MANPADS

However, military aviation does not only face a re-energised surface-to-air threat in the form of new systems such as the S-400 and existing platforms like the 9K37/9K317. MANPADS continue to pose a clear and present danger, particularly to aircraft operating at altitudes of below circa 20000 feet/ft (6096 metres/m). Ongoing conflicts have witnessed several notable uses of MANPADS. For example, on 13 May, a Bell AH-1W Super Cobra helicopter gunship of the *Türk Kara Kuvvetleri* (Turkish Army) was shot down by *guerrillas from the Kurdish Worker's Party* in south-eastern Turkey using a KBP 9K38 *Igla* infrared-guided MANPADS. Meanwhile, on 12 March, a Syrian Air Force MiG-21bis fighter was reportedly shot down by a MANPADS of an unknown type, although it has also been reported that the aircraft was shot down using AAA. Just under one month later on 5 April, the *Al-Nusra* Front, a militant Islamist insurgent organisation fighting the regime of Mr. Assad, reportedly shot down a Syrian Air Force Sukhoi Su-22 fighter using a MANPADS of an unknown type close to the city of Aleppo in northern Syria.

The Ukrainian civil war has seen its share of aircraft shoot downs beyond the loss of flight MH17. To this end, a Ukrainian Air Force (UAF) Sukhoi Su-25M1 ground attack aircraft was shot down by pro-Russian separatists using a SAM of an unknown type on 29 August 2014 in eastern Ukraine. Nine days previously, a Mil Mi-24 helicopter gunship, also belonging to the UAF, was shot down near the city of Horlivka, in eastern Ukraine, with a UAF Su-24M ground attack aircraft shot down by pro-Russian separatists near the city of Luhansk in eastern Ukraine. It has not been reported which weapon was responsible for downing either the Su-24M and Mi-24 on 20 August, or the Su25M1 on 29 August.

Thus the ongoing conflicts in Syria and Iraq, and the ongoing Ukrainian civil war are illustrative of the threat posed to air operations from MANPADS and from advanced medium-range/medium-altitude and long-range/high altitude SAMs. Although it is impossible to completely eliminate the danger that such systems pose, electronic warfare, and in particular electronic countermeasures are helping to not only reduce the risk posed by these current threats, but also potential future threats.

The cyber domain will be increasingly important to the execution of electronic warfare in the future, given the importance that air command and control systems place on computerisation.

ELECTRIC AVENUE

The events of the last twelve months in Iraqi, Ukrainian and Syrian theatres underscore the reality that the electromagnetic spectrum, in which friendly and hostile radars and communications operate, is a domain of warfare in its own right, as much as the oceans, the ground and the skies.

Increasingly, this branch of warfare also includes the cyber domain, highly reliant as it is on digital communications. Larry Rexford, electronic warfare strategic development and marketing manager at Rockwell Collins, and an electronic warfare practitioner with over three decades of experience, sees EW in a holistic fashion: "While EW is often associated with the air, land and maritime domains and is tightly coupled to specific platforms, it actually operates within a distinct/different warfighting domain, the electromagnetic spectrum." What this means for air operations is that controlling and dominating the EMS (Electromagnetic Spectrum) is essential for both air superiority, via the degradation, damage and destruction ('jamming') of opposing radar and communications, and also to support air power's capability to influence the battle on the ground or at sea. "My view is that the EMS is the warfighting domain, EW is a means to conduct warfare within the EMS, signals within the EMS (both friendly and hostile) are potential targets,"


USAF

says Mr. Rexford. "To achieve effects within the EMS you need capabilities to detect, degrade, deny, disrupt, destroy and exploit signals of interest, while, at the same time, protecting the spectrum for your use."

Reflecting on recent operations, Mr. Rexford argues that during the ongoing Ukrainian civil war, the Russian armed forces were able to deny the use of the EMS to the Ukrainian armed forces, during the latter's military operations supporting pro-Russian separatists fighting the Kiev government, while ensuring that Russia's use of the EMS remained largely protected. "As a result, the pace of Russian decision making and military operations was far superior to the Ukrainian ability to respond, similar to the effect achieved during the German *blitzkrieg* (Lightning War) through the Low Countries into France during the Second World War, through the combination of *auftrakstaktik* (mission tactics) and mechanized warfare … It is clear that the Russians not only integrated EW into their offensive planning, but that they trained in an EW environment. Conversely, the Ukrainian military forces did not possess robust EW capabilities, nor were they ready to operate in an EMS-denied environment."


Raytheon

One of the flagship US airborne EW programmes is the EA-18G Growler electronic warfare aircraft which is to furnish the RAAF as well as the USN.

Petter Bedoire, head of marketing at Saab's EW business unit makes similar observations. He states that, for "the last ten years, there has been a lot of focus (within the air power community) on international operations and asymmetrical warfare (notably US-led military operations in Afghanistan and Iraq). In those environments air superiority has been a pre-requisite, the focus being on protection against MANPADS (Man Portable Air Defence Systems) and other types of rather unsophisticated ground-based threats." However, the situation regarding Ukraine, and the Iraq/Syria theatres discussed in the previous article, illustrate "a clear trend that the focus is shifting back to Cold War era scenarios with BVR (Beyond Visual Range) warfare and much more sophisticated threats", the S-400 *Triumf* deployment to Syria in late-November 2015, mentioned in the previous discussion being a prime illustration. These lessons are no doubt being digested not only within the Russian and Ukrainian armed forces, but also within NATO and across the world. This article will examine some of the leading programmes ongoing which are seeking to ensure that air platforms, and air operations in general, continue to remain able to protect their own use of the EMS, while denying its use to adversaries.

GROWLER

The United States is particularly aware of the SAM and radar threats it faces in to-

Although it has been retired from US Navy service, the EA-6B is expected to remain in service with the US Marine Corps until the end of the decade.

day's and tomorrow's conflicts. One of its flagship programmes in this regard is the Boeing EA-18G Growler electronic warfare aircraft which is being delivered to the United States Navy (USN). Entering service in September 2009, the aircraft is also equipping the Royal Australian Air Force (RAAF), with the USN acquiring a total of 114 airframes, and the RAAF receiving twelve, the first of which was delivered to the RAAF in late July 2015. In USN service, the EA-18G has been procured to replace the venerable Northrop Grumman EA-6B Prowler electronic warfare aircraft which was withdrawn from US Navy service in 2015, with the United States' Marine Corps expected to retire their EA-6B aircraft from 2019.

The EA-6B is a potent electronic attack platform thanks to its Harris AN/ALQ-99 airborne integrated jamming system (*see below*), and Northrop Grumman AN/ALQ-218 airborne ELINT gathering system, which detects, analyses and geo-locates RF emissions to identify and locate hostile RF threats, particularly radar systems, which can then be jammed using the AN/ALQ-99.

Although it remains in service on the EA-18G, the AN/ALQ-99 is expected to be eventually replaced by Raytheon's Next Generation Jammer (NGJ). There is little publicly-available information regarding the performance particulars of the NGJ. This is not surprising as the system is still under development. The USN specified in their requirement for the NGJ that it must incorporate AESA (Active Electronically Scanned Array) technology. Such technology incorporates a multitude of Transmit/Receive (T/R) modules mounted on a specific antenna. In the context of an EW jammer, each T/R module would be able to interpret potentially hostile RF signals that they detect, and initiate an appropriate jamming response. The advantage for EW, particularly during air operations, is that several potentially hostile threats could be detected simultaneously including ground-based air surveillance radars, fighter radars,

US Navy

US Navy

For many years, the AN/ALQ-99 has played an important role in helping to jam hostile RF threats. It will continue in service for some years yet before its expected replacement by the NGJ.

or SAM (Surface-to-Air Missile) target engagement radars and jammed at the same time, using different power outputs and waveforms, a waveform being an RF (Radio Frequency)transmission which has a particular power output, propagation characteristics and programming to achieve a particular task.

In terms of development status, in early April, the US Naval Air Systems Command, which is overseeing the NGJ effort, announced that the NGJ Increment-1 stage of the programme has transitioned into its Engineering and Manufacturing Development phase. According to publicly available reports, the USN plans to field the NGJ with different frequency bands, with Increment-1 covering mid-band radars (typically between 18-27 Gigahertz/GHz) from 2021, with low-band frequency coverage (between 0.5GHz to 18GHz) following in Increment-2 and Increment-3 taking care of high band coverage (from 18GHz to 40GHz). It was announced in April that Raytheon would deliver 15 NGJ prototype pods to the USN during the next four years as part of a $1 billion contract ahead of an expected NGJ Increment-1 design freeze in 2017. Raytheon told *Armada* in a written statement that, "the threat continues to drive the evolution of airborne EW and it's evolving more than ever." It added that the NGJ "is a new product that will deliver (a) transformational stand off jamming capability for the US Navy's EA-18G."

Alongside the work that the company is performing on the NGJ, it has developed the ADM-160C MALD-J (Miniature Air-Launched Decoy-Jammer). On 11 July, the firm was awarded a contract worth $118.5 million to provide the ADM-160C to the United States Air Force (USAF). The ADM-160C is an evolution of the ADM-160A/B, the former of which was designed to mimic the electromagnetic signature of the aircraft from which it was launched. This was intended to confuse radar operators as to which track on their screens represented their target: Both the Alpha and Bravo ADM-160 variants are similar, although the Bravo uses a more powerful engine, and a redesigned airframe, with the ADM-160C having the wherewithal to perform RF transmissions to jam hostile radars. The ADM-160C is used by the USAF's General Dynamics/Lockheed Martin F-16C/D fighters, which can carry four, and the Boeing B-52H Stratofortress strategic bomber which can accommodate 16.

As well as accommodating the ADM-160C, F-16 family aircraft can employ Harris' AN/ALQ-211(V)9 Advanced Integrated Defensive Electronic Warfare Suite which can detect, classify, geolocate and jam radar threats, while providing infrared and laser threat warning. While the AN/ALQ-211(V)9 is a podded system, the other eight AN/ALQ-211 versions can internally equip rotorcraft and fixed-wing aircraft. Recent deliveries of the AN/ALQ-211(V)9 have been made to the Pakistan Air Force and the Turkish Air Force, to equip their respective F-16A/B and F-16C/D aircraft. The AN/ALQ-211 family is not the only airborne EW system available from Harris. This March, the firm won a $88.3 million US Navy contract for 48 AN/ALQ-214(V)4/5 radio frequency jamming systems, which follows an earlier July 2015 award for 46 examples. The March order is expected to be completed in December 2017.

These 48 new systems will be used to protect existing US Navy McDonnell Douglas/Boeing F/A-18C/D/E/F Hornet and Super Hornet fighters. The AN/ALQ-214(V)4/5 forms part of the compa-

Raytheon's Next Generation Jammer could revolutionise how airborne EW is performed. The system is thought to incorporate AESA technology.

ny's AN/ALQ-214 Integrated Defensive Electronic Countermeasures (IDECM) product family. In terms of the two AN/ALQ-214(V)4/5 variants, the AN/ALQ-214(V)4 outfits the F/A-18E/F while the AN/ALQ-214(V)5 equips the legacy F/A-18C/D, the principal differences between these being the mounting equipment used to affix the system within the aircraft. The architecture of the AN/ALQ-214 combines an RF generator, onboard RF transmitters and a towed decoy. The generator produces an RF signal designed to spoof or disrupt potentially hostile radar and radar-guided SAMs and air-to-air missiles. The AN/ALQ-214 also has a modular and programmable design to counter emerging RF threats. Compared to earlier versions of the AN/ALQ-214 which commenced delivery in 1997, the AN/ALQ-214(V)4/5 has a weight saving of 100 pounds/lbs (45 kilograms/kgs) and has important updates to its hardware and software architecture. This will allow the AN/ALQ-214(V)4/5 to take emerging radar threats into account as and when they appear.

Despite the eventual replacement of the AN/ALQ-99, it is expected to remain in US Navy service for some time yet, prior to the first NGJ systems being made available for the EA-18G (*see above*). For example, Harris continues to perform sustainment work on the AN/ALQ-99E airborne jamming system. The AN/ALQ-99E is carried onboard the US Navy's EF-18Gs. The work, which is expected to be completed by 2017, covers the redesign of the components equipping the AN/ALQ-99E's universal exciter. Principally, existing parts will be replaced with field-programmable components to make it easier to configure the AN/ALQ-99E for its specific missions. The AN/ALQ-99E can perform spot and barrage jamming and can operate in automatic, semi-automatic and manual modes. Using the former mode, the AN/ALQ-99E detects electromagnetic threats, prioritises and then jams them. In its semi-automatic mode, the AN/ALQ-99E continues to prioritise the threats, although the operator selects which threats to jam and performs the jamming action, while in manual mode, the operator identifies and prioritises the threats, and initiates the jamming.

The AN/ALQ-99E is reportedly able to generate almost eleven kilowatts of jamming power. There are no publicly-available details regarding the AN/ALQ-99's capabilities as a jammer, although it is thought to at least cover the two to 18 gigahertz segment of the electromagnetic spectrum; yet this may have been increased to 0.5-40GHz to allow the jammer to engage a higher number of radar threats, particularly millimetric wave radars inhabiting the 8.5-36GHz range used by naval fire control radars and radars employed by Anti-Ship Missiles. In addition, Harris will complete deliveries of an undisclosed number of AN/ALQ-


Raytheon

99 electronic warfare pods for the Royal Australian Air Force (RAAF) by June 2017, according to a company press release issued in late-January. The RAAF is procuring the pods to equip its EA-18Gs.

EPAWSS

With significant business in both the United States and throughout the rest of the world, BAE Systems was selected earlier in 2016 to fulfil the United States Air Force (USAF) EPAWSS (Eagle Passive/Active Warning Survivability System) self-protection suite for the USAF's McDonnell Douglas/Boeing F-15C/E Eagle fighter. Boeing was selected as the prime contractor for the EPAWSS programme by the USAF in early October 2015. Boeing in turn selected BAE Systems to provide assistance for the EPAWSS as a subcontractor. The EPAWSS replaces the Northrop Grumman AN/ALQ-135D/M Tactical Electronic Warfare System currently equipping the F-15C/E. It is thought that the system is capable of detecting and jamming multiple radar threats from air-to-air and surface-to-air missiles, and from air-to-air and ground-based air/naval surveillance radars. In service with these aircraft since the 1970s, the AN/ALQ-135D/M has been continually upgraded throughout its service life. The total value of the EPAWSS programme is $4 billion, according to a press release issued by Boeing on 1 October 2015, with the new self-protection system expected to be installed on circa 412 F-15C/E aircraft operated by the USAF. Deliveries of the EPAWSS to furnish the USAF F-15C/Es should commence in 2020, with the retrofit of these aircraft continuing until 2029.

One of BAE Systems' flagship programmes in the airborne EW domain is the AN/ASQ-239 electronic warfare/countermeasures system which equips the Lockheed Martin F-35A/B/C Lightning-II fighter. Few details have emerged


USAF

The RC-135V/W (the interior of a USAF version is picture here), continues to play an important role in COMINT and ELINT collection in the Iraqi and Syrian theatres.

US Navy

Orbital ATK is augmenting its AAR-47 missile approach warning system with new acoustic and short-wave infrared sensors to enhance its responsiveness.

regarding the exact design of the AN/ASQ-239, although the firms' official literature stresses that it provides RF and IR (infrared) protection, and can operate in a 'signals dense' environment. Perhaps the most interesting hint that the defence community has had regarding the design of the AN/ASQ-239 is its apparent use of so-called 'cognitive' electronic warfare techniques. Cognitive EW intends to increase the amount of processing which an aircraft EW system can perform as soon as it detects a potentially-hostile RF signal. Traditional electronic intelligence required RF transmissions to be detected, recorded and then analyzed. Once the signals had been analyzed as hostile, an RF jamming response could be devised to be applied against this threat. Yet this process was understandably time consuming.

Cognitive EW employs software programmes inside the EW system to identify an RF transmission and its waveform, even if this has not been encountered by the system before, and then to devise an appropriate jamming response. Ultimately, such an approach promises to greatly accelerate the speed with which hostile signals can be detected and then jammed. This will help to protect combat aircraft carrying such EW systems, and also other aircraft in a strike package which may not possess cognitive EW capabilities.

ELINT

While much of this supplement has focused on the electronic attack element of electronic warfare, that is the tools used to transmit RF energy for the purposes of degrading, damaging and destroying an adversary's use of the EMS, the other part of the EW triad (see this supplement's *War in the Ether* introduction) is electronic warfare support which encompasses Electronic Intelligence (ELINT) gathering. Much of the EW world is shadowy, but ELINT gathering is perhaps the most covert domain of all. Significant ELINT-gathering is continuing, using airborne platforms above Syria and Iraq. This is to monitor and pinpoint the use of telecommunications by ISIS and maybe also gather information regarding the electronic order-of-battle of the Syrian Air Defence Force which commands Syria's ground-based air defences, including its radars, SAMs and AAA (Anti-Aircraft Artillery). The aircraft may also be collecting information regarding Russian ground-based air defences, particularly since the S-400 system was deployed in November 2015 (see this supplement's *Danger on the Edge of Town* article). Such information is no doubt essential for the safe performance of US-led air operations above the country against ISIS, particularly in the light of the loss of the Turkish Air Force McDonnell Douglas/Boeing RF-4E reconnaissance aircraft on 22 June 2012 (see this supplement's *Danger on the Edge of Town* article).

Since October 2014, the Royal Air Force has deployed at least one of its three new Boeing RC-135W Airseeker ELINT platforms to the Iraq/Syria theatre,

from the RAF Akrotiri airbase in Cyprus. The aircraft is based on the Boeing RC-135V/W Rivet Joint ELINT-gathering aircraft which is operated by the United States Air Force. However, one key difference between the British and the American aircraft is that the former is thought to be optimized to detect Communications Intelligence (COMINT), while having a slightly reduced capability to collect ELINT (radar information). The aircraft are thought to be able to detect and geolocate ground tactical radio traffic using BAE Systems' Low Band Sub System (LBSS) equipment.

The successful exploitation of the EMS depends upon understanding the electromagnetic environment in which operations are being performed. Products such as Rockwell Collins' IFMR-6070 receiver greatly assist in this regard. This offers instantaneous frequency coverage from 0.5GHz to 18GHz, performing precise radar signal measurement and analysis with growth potential to cover a frequency range of 0.5 to 40GHz. In addition, Mr. Rexford states that the company recently "just introduced the RC-8800 multi-channel microwave tuner, designed to support signal detection in the 0.5 to 20 GHz range." He adds that both of these products are currently under evaluation with the US armed forces and several unnamed NATO countries. Alongside detecting potentially hostile RF signals, the ability to detect other non-RF threats against aircraft forms an important part of airborne EW. Orbital ATK's AAR-47 Missile Warning System provides missile detection via the infrared detection of the missile's exhaust heat, while acoustic sensors which the company is integrating onto the AAR-47 allow the detection of rocket-propelled grenade launchers and small arms fire, which is a particular hazard to low-flying military aircraft such as helicopters. Company officials told the author that the firm is examining the integration of a Short Wave IR (SWIR) camera within the AAR-47 architecture to heighten the system's visual detection of incoming threats, particularly when some threats have a low heat signature. The firm added that, when used in conjunction with the AAR-47's integral sensors, this can reduce the threat false alarm rate. Orbital ATK added that it is currently testing the SWIR and acoustic augmented AAR-47 prototypes in a live fire environment. It hopes to have this new version of the AAR-47 ready for delivery in 2019, and the AAR-47 thus equipped can either be supplied as a new-build product, or these additional capabilities can be retrofitted onto existing systems.

EUROPEAN EFFORTS

Away from US suppliers, Leonardo is to equip the BAE Systems Hawk Mk.209 light attack aircraft of the *Tentara Nasional Indonesia-Angkatan Udara* (TNI-AU/Indonesian Air Force) with its SEER advanced Radar Warning Receiver. Deliveries are expected to commence this September and conclude by the end of the year. SEER collects information on potential threats and displays this to aircrew either on a dedicated threat warning indicator or on cockpit multi-function displays. In addition, it can record and replay RF threat information gathered by the equipment during a mission for debriefing purposes. Capable of recording up to 20 hours of operations, SEER can detect and analyze signals from S-band (2.3-2.5/2.7-3.7GHz) to the low K-band (24.05-24.25GHz), with the option to extend this downwards to mid-range Ultra High Frequency (420-450/890-942MHz) and upwards to Ka-band (33.4-36GHz) levels. Capable of detecting frequency-agile radar emissions under 50 nanoseconds in duration, the equipment can detect pulsed, pulse Doppler and continuous wave radar emissions, and imposes a weight penalty of 24.2 pounds (eleven kilograms) on the aircraft.

It is not only light attack aircraft which are geting new EW systems. The *Aeronautica Militaire* (Italian Air Force) is receiving Elettronica's ELT/572 Directional Infra-Red Counter-Measure (DIRCM) for their fleet of Lockheed Martin C-130J Hercules turboprop freighters with the ELT/572 being factory-installed by Lockheed Martin in the United States. The installation of the ELT/572 on the Italian C-130Js is expected to conclude by the end of 2016. The ELT/572 is designed to protect wide-bodied aircraft and helicopters and defeats IR-guided SAMs and air-to-air missiles by shining laser light into their seekers to blind the weapon. During the Farnborough air show in the UK held in July, the company announced that it will collaborate with Thales on the development of the Cybele Integrated Self Defence System which will equip both rotary and fixed-wing aircraft. For the development of Cybele, Thales will provide a missile warning system, radar warning receiver and a chaff/flare dispenser, with Elettronica providing the electronic support measure (which contains the RF threat libraries enabling the system to recognise hostile RF threats), a directional IR countermeasure to disrupt IR-guided missiles, electronic countermeasures and the Sparc active decoy, the development of which Elettronica expects to conclude by the end of 2017. In addition, a laser warning system, to alert the crew to

Leonardo

Leonardo's BriteCloud expendable RF decoy is expected to equip a number of airframes including the JAS-39E.

Saab

A JAS-39C/D fighter is seen here dispersing flares. Saab will outfit the newest version of this aircraft, the JAS-39E, with its BOL-700 countermeasures dispenser.

incoming laser-guided missiles will be acquired from a third party.

Much like the RC-135W aircraft of the Royal Air Force discussed above, the *Armée de l'Air* (AdlA/French Air Force) TransAllianz C-160G2 Gabriel Signals Intelligence (SIGINT) gathering aircraft may be assisting in anti-ISIS efforts while also 'hoovering up' general ELINT, potentially related to Syrian air defences. The C-160G2, of which the AdlA operates two, are thought to be equipped with Thales' ASTAC ELINT collection system for ground and surface-based, and airborne, radar threats across frequencies from circa 250MHz up to 24.25 gigahertz/GHz, according to company literature. COMINT, meanwhile, is collected by the aircraft's EPICEA (*Ensemble Pilotant un Centre d'Ecoutes Automatisé*/Automatic Listening Centre) subsystem, also thought to be provided by Thales.

Other major European suppliers of airborne EW systems have been active during the past twelve months, including Airbus which will deliver its AN/AAR-60(V)2 MILDS-F fighter missile launch detection system to the *Koninklijke Luchtmacht* (Royal Netherlands Air Force/RNAF) throughout 2016. In March, the company announced that it will equip the force's General Dynamics/Lockheed Martin F-16AM/BM fighters with the same payload. The number of systems to be delivered remains classified, although the RNAF operates 61 of these aircraft. The AN/AAR-60(V)2 uses IR imagery to detect the hot exhaust plume of an incoming surface-to-air/air-to-air missile. Once the AN/AAR-60(V)2 detects the incoming missile and its trajectory, it initiates the launch of countermeasures to protect the aircraft, and alerts the crew to the threat so that they can commence evasive action. The system can handle multiple threats, prioritizing the most dangerous, using a number of sensors, each of which has a 120 degree field-of-view mounted around the airframe to provide 360 degree coverage.

While the RNAF is modernizing its F-16AM/BM fighters with new self-protection systems, Saab will be equipping its new JAS-39E Gripen fighter, which was rolled out on 18 May, with the firms' BOL-700 self-protection system. This product has been designed to help keep the aircraft's Radar Cross Section (RCS) as low as possible. This is achieved by installing the BOL-700 either completely inside the airframe, or in a pylon mount. The JAS-39E will begin to equip the Brazilian and Swedish air forces early next decade. This chaff and flare dispenser will be controlled by the Saab multifunction fighter EW system which also equips the JAS-39E. In terms of the BOL-700's payload, it is expected to deploy Leonardo (Selex) BriteCloud expendable Digital

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Rafael

Rafael's Sky Shield self-protection system is designed as a comprehensive jamming package which can equip a number of platforms, including the AMX International AMX family light combat aircraft.

Radio Frequency Memory (DRFM) decoys. There are designed to be launched from an aircraft's standard 55mm flare cartridge. Once in the air, it detects and prioritizes hostile RF transmissions which it then retransmits in such a fashion as to lure these RF threats away from the aircraft.

Fellow Scandinavian company Terma are forging ahead with their AN/ALQ-213 electronic warfare management system. In a nutshell, the AN/ALQ-213 integrates all of a combat aircraft's self-protection systems and allows them to be managed from a single cockpit controller. According to Dan Ulrich, senior vice president of airborne systems at the firm, it has supplied over 3000 AN/ALQ-213s for fixed-wing and rotary military aircraft around the world to date. Mr. Ulrich adds that Terma is currently under contract to deliver the AN/ALQ-213 for installation onboard the NH Industries NH-90NFH/TTH naval support and medium-lift utility helicopters equipping the Dutch Air

Elbit

Elbit's Light SPEAR product is designed to provide self-protection to UAVs. The protection of such assets is a trend increasingly being witnessed within the air power community, particularly for strategic UAVs.

IAI

IAI's EL/L-8212 (circled) makes an ideal fit for F-16-sized fighter aircraft and can be accommodated on the aircraft's weapons stations which are capable of carrying AIM-7, AIM-9 and AIM-120 weapons.

Force and navy. Mr. Ulrich adds that the first AN/ALQ-213s to equip these machines have been delivered, with deliveries expected to be completed by the end of next year. The AN/ALQ-213 is already in service onboard the McDonnell Douglas/Boeing AH-64D Apache helicopter gunships operated by the RNAF, and is equipping the Boeing P-8A/I Poseidon maritime patrol aircraft furnishing the Indian Navy, RAAF, Republic of Korea Air Force and the US Navy.

ISRAEL

Alongside the industrial efforts of European and North American suppliers, Israel is a known centre of excellence for airborne electronic warfare products, with leading suppliers Elbit Systems and Rafael Advanced Defence Systems very active in this domain alongside Israel Aerospace Industries (IAI). This latter company is thought to supply airborne EW systems for the three Gulfstream G-550 *Shavit* business jets operated by the Israeli Air Force (IAF) which perform ELINT gathering. Details regarding the precise equipment fit of these three aircraft are sparse, although they are reportedly furnished with IAI ELTA Systems division's mission fit thought to comprise ELINT and COMINT systems. IAI's official literature discussing its EL/I-3001 AISIS (Airborne Integrated Signals Intelligence System) product depicts a G-550 with a strong resemblance to the G-550 *Shavit* on its cover, although bereft of IAF markings, the inference being that the G-550 *Shavit* either carries the EL/I-3001 AISIS, or is outfitted with an ELINT package based on this product.

Away from strategic and operational level systems such as the G-550 *Shavit*, IAI provides systems to protect individual combat aircraft such as the modular EL/L-8260 product which possesses either a Radar Warning Receiver (RWR) or a Radar Warning and Locating (RWL) device as standard plus an EW controller. These basic sensors can be combined with a MAWS (Missile Approach Warning System) and a third-party laser warning system, plus chaff and flare dispensers, a towed RF decoy for countering SAMs and air-to-air missiles and a third party directional infrared countermeasure. IAI's EL/L-8265 includes an RWR and RWL. According to Rami Navon, the firms' EW systems marketing and projects manager, one essential design prerequisite for modern airborne EW systems is for them to be able to detect Low Probability of Interception (LPI) radars. This means that any RWR which is accommodated on a military aircraft must be capable of detecting the weak RF transmissions associated with LPI radars.

Mr. Navon continues that it is imperative for any modern RWR to be capable of geolocating where a specific radar threat is so that it can be safely avoided, accurately jammed, or so that kinetic effects, in the form of an anti-radiation missile, or conventional air-to-ground or surface-to-surface fires can be employed against this threat. One concept which Mr. Navon

IAI

IAI's EL/L-8222 self protection system is designed for comparatively large fighters of F-15 size. Like its smaller sibling, the EL/L-8222, it can be accommodated on the aircraft's weapons stations.

Elbit

Elbit's All-In-Small provides a single EW suite controller which can manage several of a combat aircraft's disparate self-protection systems, as this infographic demonstrates.

noted is a new technology called 'Spatial ELINT' developed by IAI. This approach is enhanced in order to be used by the company's electronic countermeasure systems which can examine simultaneously a wide swathe of airspace and detect hostile RF threats. Once these hostile threats are detected, they can be geolocated and jammed with accurate directional transmission, while the EW system continues to simultaneously watch the enemy's area for other threats.

Other systems in the IAI stable include the EL/L-8212 and EL/L-8222, the principal difference between these being their physical size, with the EL/L-8212 being designed for relatively small fighter aircraft such as the F-16 family, and the EL/L-8222 optimised for larger platforms such as the F-15 family. Both the EL/L-8212 and EL/L-8222 can be accommodated on weapons stations capable of carrying Raytheon's AIM-9 Sidewinder and AIM-120 AMRAAM (Advanced Medium-Range Air-to-Air Missile) AAM family, alongside Raytheon's AIM-7M Sparrow AAM, and still maintain the full flight envelope of the host aircraft as if the pod was another missile.

Joining IAI as a leading supplier of airborne EW systems is Elbit's Elisra division which produces the United EW Suite equipped with "one central processing Line Replacement Unit (LRU) for all EW suite functions (such as radar, laser and missile approach warning, and chaff and flare dispensing. This approach enables simple platform installation and Integration (less LRUs means less power consumption and weight) and reduces maintenance and costs," the company revealed by a written statement. Allied to this, the firm provides; "mission support tools for threat libraries programing and mission debriefing. EW mission support tools allow rapid and constant updates of the threat parameters, to be performed independently by the end user." The firm has recognised that, alongside inhabited aircraft, Unmanned Aerial Vehicles (UAVs) also require self-protection and EW systems. This has resulted in the development of its Light SPEAR jammer for UAVs, which the firm states has been sold "to several customers," whose identity is preserved. In the inhabited domain, the firm has developed its All-In-Small EW suite housed in a single LRU (*see above*). Alongside controlling radar, laser and missile warning, plus countermeasures dispensing, the All-In-Small can be connected to a DIRCM to defeat incoming IR-guided missiles.

The Association of Old Crows international electronic warfare advocacy organisation defines electronic warfare as "the struggle for control of the electromagnetic spectrum … to assure that friendly forces can use the spectrum to their full potential in wartime, while denying that use to enemies." The products described above all play their important role in making this maxim a reality. With the present examined, we now turn our thoughts towards how airborne electronic warfare could develop in the future.

THE NEED FOR SEAD

Events in Syria notably the deployment of sophisticated Surface-to-Air Missile systems such as the Russian Almaz-Antey S-400 *Triumf* to support Russia's ongoing air campaign is giving NATO pause for thought.

US DoD

The AGM-88E/F HARM is the mainstay of NATO's kinetic anti-radar capabilities. The weapon is in use with the US armed forces, as well as Germany and Italy.

The area that systems such as the S-400 can cover, which has a reported interception range of 215.9 nautical miles/nm (400 kilometres/km) with its 40N6 SAMs, enables it to provide coverage across a significant swathe of territory, making it a powerful Anti-Access/Area Denial weapon. Speaking at this year's Electronic Warfare Europe conference and exhibition held in Rotterdam, the Netherlands, in early May, experts working closely with NATO (North Atlantic Treaty Organisation) provided an insight regarding how the alliance expects its Suppression of Enemy Air Defence (SEAD) capabilities to grow in the future.

The alliance's heads of government September 2014 summit held in Newport, Wales, stipulated that from 2025, NATO's European membership, and Canada, must provide 50 percent of the alliance's SEAD capability. At present, the vast majority of the kinetic and electronic aspects of NATO's SEAD posture is provided by the United States Air Force (USAF) and the US Navy (USN), via the Raytheon/Orbital ATK AGM-88E/F High Speed Anti-Radiation Missile, which is carried by the USAF's General Dynamics/Lockheed Martin F-16CJ Wild Weasel SEAD aircraft, and the USN's McDonnell Douglas/Boeing FA-18 family fighters and electronic warfare aircraft. Nevertheless, European NATO members do possess some SEAD capabilities in the form of the Panavia Tornado-ECR SEAD aircraft furnishing the German and Italian air forces.

The USAF and the US Navy continue to absorb the SEAD burden for NATO, using platforms such as this USAF F-16CJ Wild Weasel aircraft.

US DoD

MBDA's Meteor air-to-air missile has been mooted as a possible anti-radar weapon in the future, potentially arming several European fighter types to this end.

The presentation added that the alliance would have, in the future, to face an operating environment where radar could detect incoming aircraft at ranges of circa 539.9nm (1000km), with SAM ranges potentially increasing to 269.9nm (500km). In addition, radar detection frequencies are moving down the spectrum to Very High Frequency (VHF/30 to 300 Megahertz) ranges as such systems can make it easier to detect aircraft with a low Radar Cross Section (RCS). Comparatively low frequency radars can be difficult to detect and geolocate with existing airborne EW systems. Secondly, passive radars which detect the RF emissions from an aircraft's communications systems such as its radios, datalinks and emissions from its radar, can be detected using so-called 'passive radar' which detects these transmissions and then geolocates the aircraft.

The presentation continued that NATO foresees a trio of approaches as the optimum way to neutralise these threats, employing the tried and tested EW approach which uses destruction, disabling, deception, denial and degradation. NATO says that destruction can be achieved by using traditional kinetic means such as ARMs, conventional weapons, electronic warfare and Special Forces operations. Disabling the hostile electronic systems which an integrated air defence system relies on, namely radar, radio communications and computer systems, can be achieved using ARMs and electronic warfare, while cyber attack can be brought into play to deceive, deny and degrade these electronic elements.

NATO's approach is being met by working closely with industry and with military and civilian research institutes. For example, last year the author was told that MBDA had been asked to assess the feasibility of developing its Meteor beyond-visual-range air-to-air missile as a possible future ARM (Anti-Radiation Missile). While no further information has reached *Armada* regarding this initiative, should the weapon be developed into an ARM, it could potentially offer platforms able to carry this missile, such as the Eurofighter Typhoon, the Saab JAS-39C/D/E Gripen and the Dassault Rafale-F3B/C/D fighters with an ARM, and the wherewithal to perform true SEAD (as opposed to the destruction of enemy air defences using conventional weapons). With the exception of the Tornado-ECR aircraft operated by Germany and Italy, NATO's European membership possesses no dedicated SEAD weapons.

The alliance is currently drafting a roadmap regarding how to reach the

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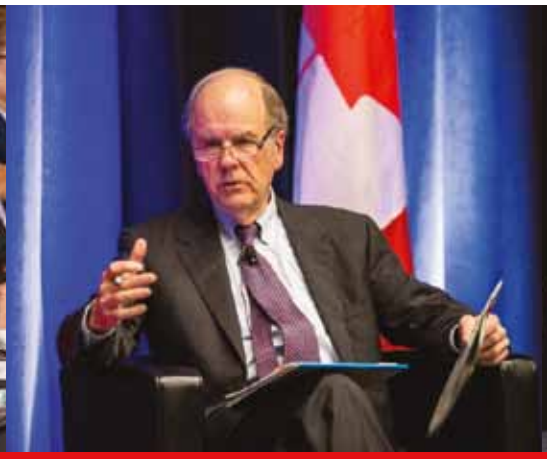


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US DoD

The Luftwaffe's Tornado-ECR aircraft are part of a handful of SEAD assets which NATO has at its disposal. The alliance is now contemplating how it can deepen its SEAD capabilities.

SEAD goals outlined at the Wales summit discussed above. Furthermore, the presentation emphasised the need for alliance members to ensure that the national SEAD capabilities that they currently possess, or which they could gain in the future, mesh with NATO's overall SEAD strategy, as well as serving national doctrines. The prevailing vision is for NATO's European membership to be ready to absorb this goal of 50 percent of the alliance's SEAD capability by circa 2030.

INDUSTRY PERSPECTIVES

Industry is certain to be called upon to help NATO to achieve the goals discussed above. Beyond the alliance's long-term requirements, companies involved in the airborne EW domain expect it to grow in the near future. Elettronica told *Armada*, via a written statement, that the "geopolitical situation boosts the need for EW capabilities" as events in Syria and Iraq discussed above have shown. Technology is also playing its role, with new techniques such as cognitive EW allowing the capabilities of current and future airborne EW systems to be increased, the company added. A written statement provided to *Armada* by Raytheon chimes with Elettronica's assessment noting that "the threat continues to drive the evolution of airborne EW, and it's evolving more rapidly than ever." Moreover, the company continues that airborne EW can no longer be considered a 'luxury' item in the military aviation domain. "There was a time when EW was thought of as an optional capability, but with this evolving threat, our customers are recognising the need for this capability across all platforms. For the purposes of situational awareness, and 'eyes' in the electromagnetic spectrum, don't leave home without it."

Raytheon has also recognised the need for airborne EW systems to become more responsive to the changing nature of the EW threat. "The threat evolution is happening on a timescale that makes traditional identification methods inadequate for the purposes of real-time or even near-real-time functions, such as self-protection. It's increasingly agile, constantly changing its appearance (and) adapting on the fly." This is where cognitive techniques come in, with the firm asking us to "imagine a threat identification system that doesn't require a Mission Data File (MDF, containing details on the Radio Frequency threats an aircraft may encounter during a specific mission) that can identify radar threats, and if those threats modify their behaviour, the system keeps up with it. An aircraft would no longer have to land and wait for a reprogrammed MDF before it can fly again."

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US DoD

The ability to ensure that radar threats can be destroyed in the future using electronic and kinetic means will remain a key occupation of the defence industry and EW practitioners.

The company is heavily involved in developing such techniques, telling *Armada* "that's what we're pursuing, better algorithms and faster electronics that respond in real-time or near-real-time."

A written statement supplied to *Armada* by Harris also mooted the importance of cognitive EW architecture: "The nature of today's EW landscape requires technology with rapid response capabilities that can uncover cognitive insights about the environment in which it is operating in order to adapt to future threats in near-real time." Making the next generation of airborne EW systems agile and responsive to current and emerging threats is vital, as John Wojnar, director of business development and advanced project solutions at Lockheed Martin observes: "The hardware will need to incorporate advancements which enhance the frequency range of operations as well as system bandwidth coupled with leveraging high speed digital processing. Large amounts of digital data will be generated by these systems requiring advancements in processing as well as memory." Mr. Wojnar has also spotted the cognitive trend: "Advanced algorithms will move beyond brute characterisation using a small set of parameters to more agile, even cognitive processes which can assess the information being provided by the diverse set of potential threats, characterize them, identify them, and properly respond."

Interference is another challenge for airborne EW engineers. According to Petter Bedoire, head of marketing at Saab's EW business unit, civilian communication are increasingly creeping into frequency bands previously the preserve of radar. This is a result of the proliferation of cellphone communications worldwide, and the demands from the civilian world for increasing frequency bandwidth to ensure that this can be satisfied. The net effect of this is that the frequency spread in which radar can operate becomes reduced, and means that civilian communications can be 'mixed up' in the overall electromagnetic environment, along with military radar transmissions. Mr. Bedoire says that these challenges can be addressed "through (the use) of very selective ultra-wideband digital receivers that can discriminate between different types of signals without reduced performance."

Harris provided some additional thoughts to *Armada* regarding how they think airborne EW technology will develop, notably, the firm posits that open architecture in the design of EW systems will become increasingly important. "While open architecture has been on the radar for more than a decade, industry challenges still remain as it relates to acquisition strategy, despite industry solutions that are readily available to support mission needs." Allied to the benefits which open architecture potentially offers, software defined architecture (where a systems' capabilities can be enhanced through improving its software, with minimal or zero modifications to its hardware, saving costs), also offer promise. "Major platforms are too costly to continuously upgrade. As such, EW aircraft operators need access to systems that have the ability to navigate software intelligence for ongoing upgrades." Potential drivers expected by Harris *vis-à-vis* the future airborne EW market include the need to make in-

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Electronic intelligence gathering aircraft may reduce in size in the future enabling small turboprop aircraft to perform ELINT roles.

creasing use of commercial off-the-shelf technologies where possible in future EW systems to reduce design, production and acquisition costs. Allied to this is the ever-present need, Mr. Wojnar notes, to "reduce the size, weight and power needs of our next generation systems while developing the architectural capability for these systems to network to update and maintain effective situational awareness on the electronic battlefield."

Regarding markets, Elettronica see demand for airborne EW systems in the Middle East and the Asia-Pacific region remaining strong. Larry Rexford, Electronic Warfare (EW) strategic development and marketing manager at Rockwell Collins, sees the ongoing strategic posture of Russia and the People's Republic of China influencing the airborne EW market, with countries close to the borders of these nations re-examining their airborne EW posture, with the Ukrainian civil war, and Russia's role in that conflict being a significant 'wake up call' in this regard. Germany's Rhode and Schwarz, which is particularly active in the ELINT gathering domain believes that the airborne EW market will witness new entrants to the 'club' of militaries which have platforms capable to performing ELINT collection. "Emerging countries which have currently no airborne EW platforms in their portfolio are considering this capability as a necessity. For these countries a completely-equipped high performance airborne platform (such as the Boeing RC-135V/W Rivet Joint ELINT-gathering aircraft) will not be the best choice, but smaller, multi-role (reconnaissance) platforms" will be a more practical acquisition.

Yet while markets may have drivers, such as those mentioned above, they can also experience restraints. Elettronica continued that issues with defence budgets around the world to risk slowing down the acquisition of airborne EW systems, both for new aircraft, and for retrofit programmes. However, as Raytheon notes, money is not the only issue, EW awareness is another. "EW has become increasingly important, but it can be tough to wrap your head around something you can't see. There's a driving need to further people's understanding around what EW can actually bring to the fight and how to best implement its contribution; it's a modern and a prime-time capability." Ultimately, awareness, as much as finance and scientific ingenuity, will help to ensure airborne electronic warfare can continue to keep pace with today's and tomorrow's threats in a complex and changing world.

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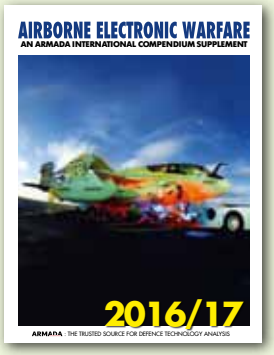

ON THE COVER: For many years the stalwart of US Navy and US Marine Corps airborne electronic warfare, the EQ-6B has now reached the end of its career © US DoD

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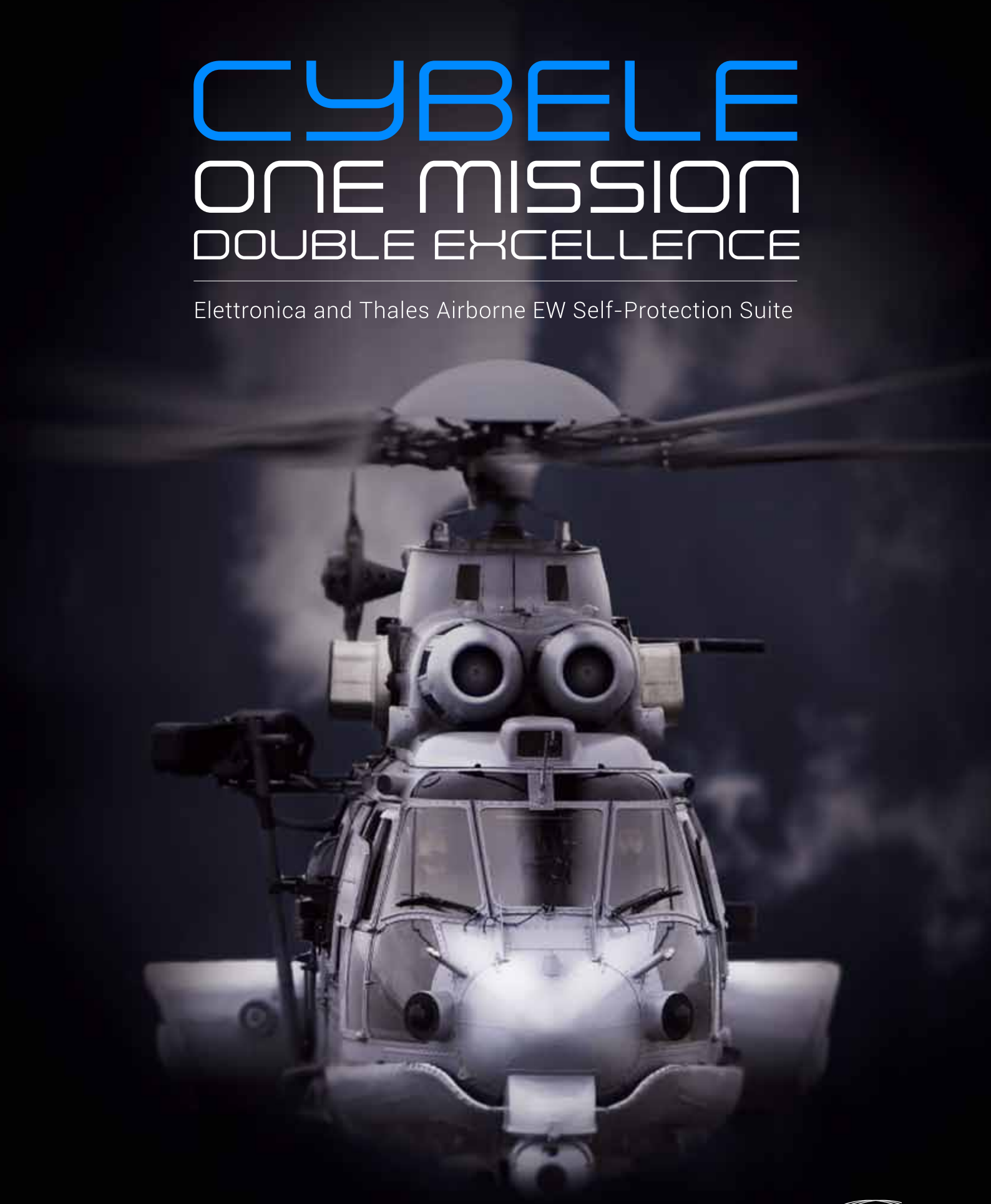

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