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May 2022 Vol. 45, No.5

JED

Journal of Electromagnetic Dominance

Layered Protection for Armor Survivability

- Feature: Long-Range Strike
- EW 101: Electromagnetic Protection
- News: DARPA Issues Microelectronics BAA

JED
Journal of Electromagnetic Dominance

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IDF

COVER PHOTO COURTESY OF ROK ARMED FORCES

Pennsylvania National Guardsmen hold an after action review following their March training at Fort Indiantown Gap, PA, on the new Tactical Dismounted Electronic Warfare and Signals Intelligence (TDEWS) system. The TDEWS fills a major training gap for soldiers in the intelligence Military Occupational Specialties (MOS), and the Pennsylvania Guard is the first guard unit in country to field the system. The training helped the guard unit prepare for the upcoming 56th Stryker Brigade Combat Team, 28th Infantry Division National Training Center (NTC) rotation.

US ARMY NATIONAL GUARD PHOTO BY SSGT ZANE CRAIG

Departments

ELECTROMAGNETIC PROTECTION

This month's *JED* features a the 300th installment of Dave Adamy's "EW 101" column, which is a remarkable achievement. Dave was already a well-known EW instructor when he began writing "EW 101" for *JED* in 1995. Since then, his column has been a favorite *JED* section for tens of thousands of EW professionals around the globe.

This month, Dave begins a new "EW 101" series on Electromagnetic Protection (EP). It's a timely topic, as western nations face countries like China, Russia and Iran that are investing heavily in advanced electromagnetic support (ES) systems that can detect, locate and identify emissions from radars and radios, as well as electromagnetic attack (EA) systems that can jam them.

During the Cold War, EP (then known as electronic counter-countermeasures – ECCM) was extremely important to NATO forces and was thoroughly integrated into western military EW concepts. Shortly after the Cold War ended, however, many western military forces lost their focus on EP. This was not simply a slow-down in in EP technology development. The atrophy also spilled into training, where exercises lacked congested and contested EMS environments that forced participants to operate in the presence of enemy SIGINT and jamming, as well as friendly interference.

Fortunately, NATO's complacent attitude toward EP has started change, and it is being replaced by a growing sense of urgency. In the US for example, the Services seem to be placing more emphasis on EP. In March, the Army issued a Request for Information (RFI) for an effort titled, Artificial Intelligence Radar Enhancement (AIRE), which aims to explore how AI and Machine Learning can be applied to a radar system to increase the number of waveforms and vary the schedule of those waveforms in order to counter enemy EA.

Last month, the US Navy announced an upcoming program named "Antenna Apertures for Resilient Communications" (2ARCS) that will look at using directional antennas for VHF and UHF communications. In its RFI, Naval Information Warfare Center - Atlantic noted that many of the radios used by US Navy and US Marine Corps forces rely on omnidirectional antennas for what are mostly point-to-point communications. Their plan is to significantly reduce friendly interference by using directional antennas on these systems. The RFI noted, "Ideal solutions will have modes for point-to-point, point-to-multipoint, and omnidirectional."

These are just two examples of recent and upcoming EP efforts.

I don't want to create the impression that the DOD has suddenly "rediscovered" EP. This is not the case. It's more apt to say that the DOD is increasing its attention on EP. Ten years ago, there was far less EP activity in the DOD, and much of this work was buried in larger weapons programs where it might or might not be widely shared with other programs.

By investing more resources in EP technology and training, western military forces can get a lot more operational benefit for their money. While there are many new and emerging technologies that can be exploited for EP, these will succeed only if we sustain our interest in EP over the long-term. – *J. Knowles*

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Calendar *Conferences & Trade Shows*

MAY

Cyber Electrometric Activities (CEMA) 2022
May 3-4
Aberdeen, MD www.crows.org

AOC Europe
May 10-12
Montpellier, France
www.aoceurope.org

Electronic Warfare Capability Gaps and Emerging Technologies
May 10-12
Crane, IN
www.crows.org

Special Operations Forces Industry Conference (SOFIC)
May 16-19
Tampa, FL
www.sofic.org

JUNE

Eurosatory
June 13-17
Paris, France
www.eurosatory.com

AOC Kittyhawk Week
June 14-16
Dayton, OH
https://kittyhawkaoc.org

Electronic Warfare Technical Conference
June 14-16
Shrivenham, Swindon, UK
www.cranfield.ac.uk

International Microwave Symposium
June 19-24
Denver, CO
https://ims-ieee.org

JULY

Farnborough International Air Show
July 18-22
Farnborough, Hampshire, UK
www.farnboroughairshow.com

AUGUST

TechNet Augusta
Aug. 15-18
Augusta, GA
www.afcea.org

Defence & Security 2022
Aug. 29 – Sept. 1
Bangkok, Thailand
www.asiandefense.com

SEPTEMBER

29th International Defence Industry Exhibition MSPO
Sept. 6-9
Kielce, Poland
www.targikielce.pl

AFA Air, Space and Cyber Conference
Sept. 19-21
National Harbor, MD
www.afa.org

Africa Aerospace and Defense (AAD2020)
Sept. 21-25
Air Force Base Waterkloof, Gauteng, South Africa
www.aadexpo.co.za

OCTOBER

AUSA Annual Meeting
Oct. 10-12
Washington, DC
www.ausa.org

59th Annual AOC International Symposium and Convention
Oct. 25-27
Washington, DC
www.crows.org

*AOC conferences are noted in **red**. For more info or to register, visit crows.org. Items in **blue** denote AOC Chapter events.*

Calendar *Courses & Seminars*

MAY

AOC Live Virtual Professional Development Course: EW Against a New Generation of Threats
May 2-25
8 Sessions, 3hrs. each
www.crows.org

AOC Virtual Series Webinar: Solutions for Quantum Computing and Communications
May 5
2-3 p.m. EST
www.crows.org

Electromagnetic Warfare Data Analysis
May 10-11
Atlanta, GA
www.pe.gatech.edu

Military Electronic Warfare
May 16-20
Shrivenham, Swindon, UK
www.cranfield.ac.uk

Modeling and Simulation of Phased Array Antennas
May 17-19
Online
www.pe.gatech.edu

Adaptive Arrays: Algorithms, Architectures and Applications
May 17-20
Atlanta, GA
www.pe.gatech.edu

AOC Virtual Series Webinar: Rotary-Blade Modulation and the Convergence of Next-Generation Communications
May 19
2-3 p.m. EST
www.crows.org

JUNE

AOC Virtual Series Webinar: Millimeter-Wave (mmW) Propagation
June 6
2-3 p.m. EST
www.crows.org

AOC Virtual Series Webinar: Development of Cognitive EW Datasets
June 16
2-3 p.m. EDT
www.crows.org

Basic RF EW Concepts
June 28-30
Las Vegas, NV
www.pe.gatech.edu

Cyber Warfare/EW Convergence
June 28-30
Las Vegas, NV
www.pe.gatech.edu

AOC Virtual Series Webinar: Electromagnetic Battle Management
June 30
2-3 p.m. EDT
www.crows.org

JULY

AOC Virtual Series Webinar: Low SWAP Multifunctional Electronic Warfare System Development
July 14
2-3 p.m. EDT
www.crows.org

AOC Virtual Series Webinar: Cognitive Eelectronic Warfare, an Artificial Intelligence Approach
July 28
2-3 p.m. EDT
www.crows.org

SEPTEMBER

AOC Virtual Series Webinar: Cognitive Electronic Warfare and Reinforcement Learning
Sept. 8
2-3 p.m. EDT
www.crows.org

AOC Live Virtual Professional Development Course: Cognitive Electronic Warfare, an Artificial Intelligence Approach
September 12-28
6 Sessions, 3hrs. each
www.crows.org

AOC courses and webinars are noted in ***red****. For more info or to register, visit crows.org.*

STRATEGIC AIR COMMAND (SAC) AND THE EMS

As this month's issue looks at USAF Global Strike Command (AFGSC) and EMSO, I thought I would take us on a quick trip back in time to when I served in SAC, AFGSC's predecessor, and share my views and experience of how SAC viewed the EMS.

SAC was well aware of the importance of the EMS and the need to operate and communicate across it. SAC controlled two-thirds of our nation's nuclear triad and accurate communications was imperative for command and control of those forces, which included missiles, bombers, tankers and reconnaissance assets. The Command was also aware of needing to operate across the EMS with both radar and EW. Bombers that were expected to penetrate deep into an adversary's airspace had EMSO capabilities that covered most bands of the spectrum. The B-52 was one of the aircraft that had vast receive and transmit capabilities. The desire was for us to be able to exploit the Electromagnetic Environment (EME) while negatively impacting an adversary's ability to use the EME.

SAC also had outstanding intelligence, surveillance and reconnaissance (ISR) assets: U-2, SR-71 and the RC-135. One time, when we were looking for receiver displays for the bombers, I was fortunate to get one sortie in an RC-135 when I was stationed with the 513 Engineering and Test Squadron – back when it was the bomber reprogramming center, at Offutt AFB. Those ISR platforms provided critical information that SAC, Tactical Air Command (TAC) and others would use to execute operational missions around the globe.

The USAF and SAC not only invested in heavily across all platforms to ensure their ability to operate across the spectrum, but they also invested in training capabilities. We had various types of EW simulators that we used to augment flight training. The flight training piece included various low-level routes around the United States, as well as some overseas. The routes and ranges had a multitude of threat emitters, and one of the best threat simulators during the 1980s and 1990s was the Multiple Threat Emitter System (MUTES), which could emulate/simulate various radar signals at the same time.

AFGSC faces a number of EMS challenges, in part because the EME is more congested and contested than during my time in SAC. Today, however, we have a number of digital capabilities that provide advantages in the EME, and the US and its allies continue to develop new EMSO technologies. The world is also much more integrated than in the past; operations are joint and coalition based, and we are still growing Space capabilities that must be integrated across EMSO. So, while the future has challenges, it is also going to be exciting to see what it holds for us.

As I mentioned last month, May will be very busy for the AOC, with CEMA and Crane conferences, as well as AOC Europe – all in-person. Please stay safe out there, spread the news, welcome new Crows, mentor young Crows and look to help the AOC grow and improve. – *Glenn "Powder" Carlson*

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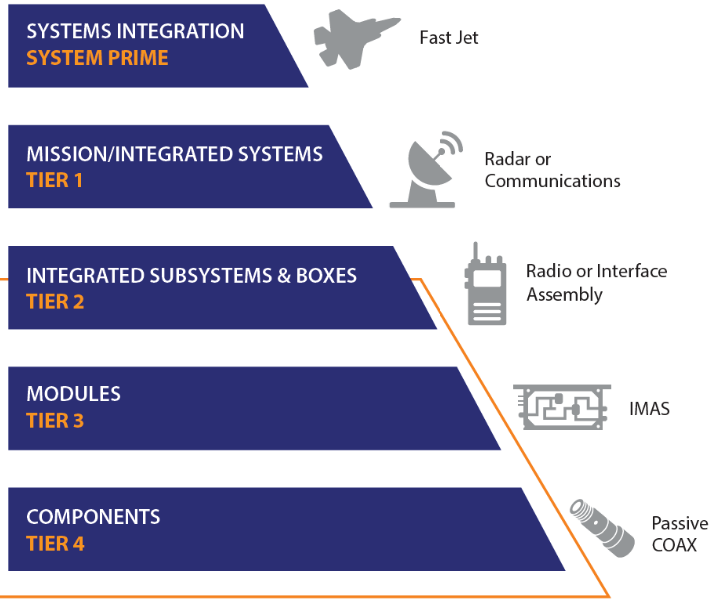

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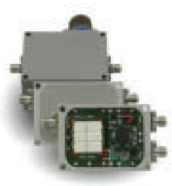

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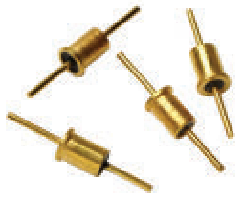

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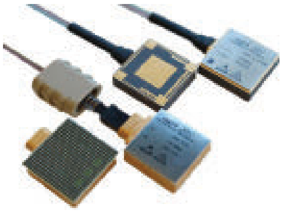

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DARPA ISSUES MICROELECTRONICS SOLICITATION

The Defense Advanced Research Projects Agency (Arlington, VA), Microsystems Technology Office (MTO) has issued a Broad Agency Announcement (BAA HR001122S0030) that seeks to develop a wide range of innovative microelectronics technologies. Under this BAA, which covers technology development efforts that are not typically covered in other DARPA programs, MTO plans to award multiple early stage research contracts that address four "thrust areas."

The first of these is " Embedded Microsystem Intelligence and Localized Processing." In this area, according to the BAA, "Creating the capability to rapidly assess and make decisions at the tactical edge will fundamentally alter the future battlespace. Intelligent microsystems – self-tuning, self-optimizing, and mission reconfigurable, at an acceptable size, weight, power, and cost (SWaP-C) – have been a longtime focus of MTO research investments. However, past attempts to realize this goal were constrained by limitations in the available local processing capability. Advances in artificial intelligence and machine learning-specific processors, graphic processing units (GPUs), and other special purpose computation technologies offer a new path to overcome such limitations. MTO seeks to explore the development of sensors and systems that enable specialized computation at the tactical edge and microsystems capable of learning, moving beyond those with pre-set functions. One area of particular interest within this topic is technologies to achieve improved cognitive electronic warfare (EW)."

The second thrust area is "Next Generation Front-End Component Technologies for Electromagnetic (EM) Spectrum Dominance." The BAA describes this work as follows: "For many DoD command, control, communications, computing, intelligence, surveillance, and reconnaissance (C4ISR) and EW systems, the analog and mixed-signal front-end fundamentally determines key performance characteristics, such as bandwidth, tuning range, dynamic range, etc. Often these requirements greatly exceed the needs of the commercial sector. Thus, these technologies tend to be niche and largely ignored by the commercial electronics industry, but they hold extraordinary value for the DoD. To maintain dominance in the EM battlespace, MTO is investing in a new set of emerging material, device, and circuit approaches that provide leap-ahead performance in the sensing and modulation for radio frequency (RF), active and passive photonic, electro-optical/infrared (EO/IR), and magnetic-field applications. The office is also pursuing alternatives to large, costly optical/RF systems, exploring highly integrated microsystems, and new fabrication technologies to enable the proliferation of compact optical/RF systems in a variety of SWaP-C constrained platforms. Finally, MTO is exploring compact next-generation positioning, navigation, and timing technologies."

The third area is "Microsystem Integration for Increased Functional Density and Security," which the BAA describes as follows: "Over the past decades, microelectronics advancement has proceeded through several waves – the first wave was controlled by device scaling, the second by the introduction of new materials and architectures, and the third through the creation of 3D devices. MTO has assumed a leadership role in the ongoing "Fourth Wave" revolution that will be dominated by 3D heterogeneous integration at multiple length scales. Fine-scale integration will bridge the technical gap between traditional assembly technology and the lithography-defined back-end-of-the-line dense interconnects. A key part of this vision is that fine-scale integration can serve as a means to tie together the incredibly powerful but widely available commercial capabilities with DoD-specific discriminators. In addition to the tools and methods to realize fine-scale integration, MTO aims to address its associated challenges for these increasingly complex circuits and systems-on-chip (SoC). These include next- generation of electronic design automation (EDA) tools, new approaches ensure secure and trusted microsystems, and microsystem thermal management technologies."

Finally, the fourth thrust area is "Disruptive Defense Microsystem Applications." Here, "MTO seeks to increase the pace of innovation by identifying and rapidly demonstrating disruptive applications of innovative microsystems component technologies, including those developed under the prior three thrusts. MTO aims to explore high-risk/high-reward technologies in their infancy to identify disruptive potential well in advance of operational use. If successful, activities under this thrust should hasten adoption of advanced microsystem technologies and enable future DoD C4ISR, EW, and directed energy (DE) systems."

Across these four thrust areas, the BAA lists 27 technology areas of interest, including:

- Advanced RF and EO/IR filters and related front-end components,
- Cognitive and other advanced EW technologies,
- Directed energy component technologies, physics of effects, and protection techniques,
- High energy lasers,
- High power microwave technologies,
- Low power electronics,
- Microsystems for position, navigation & timing, and
- Microsystems for RF/optical transceivers.

DARPA plans to award multiple short term (less than 12 months) study contracts valued under $1 million each, some of which could lead to further hardware and software development work. However, companies may also propose multi-phase efforts in excess of $1 million and longer than 12 months.

The BAA point of contact is Dr. Mark Rosker, Director, Microsystems Technology Office and BAA Coordinator, e-mail HR001122S0030@darpa.mil. MTO is accepting proposals on a rolling basis through January 6, 2024. – *JED Staff*

OSD TO HOLD TECH DEMO FOR BATTLESPACE MANAGEMENT IN CONTESTED ENVIRONMENTS

The Office of the Secretary of Defense (OSD) is seeking industry inputs to help it identify Electromagnetic Spectrum Operations (EMSO)-related solutions for an upcoming demonstration it plans to hold later this year.

The Under Secretary of Defense for Research and Engineering, Defense Modernization & Prototyping (DM&P) program, issued a Request for Information (RFI) last month soliciting proposed solutions to be evaluated at its Thunderstorm Technology Demonstration & Experimentation 22-2 event, which focuses on battlespace management in contested environments. According to the RFI, "Thunderstorm provides an opportunity for technology developers to demonstrate and experiment with new and evolving technological capabilities in an operationally relevant environment, as well as to obtain insight into federal technology gaps and emerging needs. The demonstration and experimentation environment enables a collaborative working relationship between government organizations, academia and industry." Furthermore, the event offers a "realistic demonstration environment" for technology developers from industry and academia to interact with operational personnel.

The RFI also states, "Specific technologies areas of interest to add capacity and capability at all levels of the Department of Defense (DoD) include, but are not strictly limited to, Electromagnetic Spectrum Situational Awareness, Information Operations, Free Space Optical Communications (FSOC), and Spectrum Maneuverability solutions." The RFI is somewhat vague about the specific areas of interest, however. It calls for "electromagnetic spectrum solutions" that "leverage custom RF, microelectronic, and photonic components," "enable wideband RF operations" and "demonstrate free-space optical communications systems and associated atmospheric mitigation and signal processing techniques." It further requests "Spectrum Maneuverability Solutions" that "provide visualization and signal processing tools," "quantify provenance and pedigree of signals and optimize situations awareness and communications."

The RFI also seeks "Information Operations Solutions" that "acquire, process, distribute, and employ data to enhance combat power;" "change or maintain observations, perceptions, and other elements to influence desired behaviors of relevant actors" and "inform decision making and/or exploitation of signals through AI/ML."

Finally, the RFI calls for "Logistics Under Attack Solutions" that "enhance movement, camouflage, concealment, and physical security of materiel through innovative packaging, storage, and distribution;" "predict requirements and expeditiously identify, mitigate, respond to supply chain disruptions;" and "augment or conduct urgent resupply/sustainment missions with multi-capable distribution platforms for a disaggregated force."

US NAVY ISSUES RFP FOR COUNTER-UAS AND COUNTER-RCIED SYSTEMS

Naval Sea Systems Command (NAVSEA) (Washington, DC) has issued a Request for Proposals (RFP) for production and delivery of up to 1,150 counter-remote-control improvised explosive device (RCIED) and counter-unmanned aerial system (C-UAS) jamming systems. The Navy will supply a comprehensive technical data package to the contractor under a build-to-print acquisition scheme.

NAVSEA's Program Executive Office Unmanned and Small Combatants (PEO USC), Expeditionary Missions Program Office (PMS 408) is managing to acquisition, which covers Joint CREW Increment 1 Block 1 (JCREW I1B1) counter-RCIED systems and Drone Restricted Access Using Known EW (DRAKE) C-UAS variants. Users will include US Navy and US Marine Corps afloat and ashore units, as well as potential Foreign Military Sales (FMS) customers.

The JCREW I1B1 systems will be manufactured in three variants: a manpack dismounted configuration, a vehicle-mounted configuration and a fixed-site configuration. DRAKE systems will be manufactured in a man-pack configuration. If all contract options are exercised, NAVSEA will by up to 385 JCREW I1B1 dismounted systems, 656 vehicle mounted systems and 29 fixed-site systems, as well as 41 "jammer core" spares. It would also buy up to 80 DRAKE systems and 10 "jammer core" spares. The RFP also includes optional provisions for spare parts, sustainment and engineering services and FMS support.

Northrop Grumman is the original developer and manufacturer of the JCREW I1B1 and DRAKE systems. However, the Navy acquired the technical data package for these systems and is able to conduct the upcoming procurement as a full and open competition for a "build to print" contract.

The solicitation number is N00024-22-R-6427. Bids are due by May 4. The contracting point of contact is Roy Williams, roy.williams22.civ@us.navy.mil. – *J. Knowles*

Last year, the US Navy and US Marine Corps began deploying DRAKE systems to protect Navy ships from unmanned aerial systems. Above, Interior Communications Electrician Seaman Londel Coles, assigned to the Wasp-class amphibious assault ship USS Iwo Jima (LHD 7), stands watch with a DRAKE system during a sea and anchor evolution in May 2021.

US NAVY PHOTO BY MASS COMMUNICATION SPECIALIST 3RD CLASS JESSICA KIBENA

Proposed solutions should be at Technology Readiness Level 4 or higher.

As this issue of *JED* went to press, DM&P officials had not set a specific date for the Thunderstorm 22-2 event. However, the RFI states that it will likely be a two-week event sometime in July, August or September.

Responses are due by June 1. The solicitation number is DMP-22-2-RFI-01. Georgia Tech Research Institute is supporting RM&P in this effort and will lead the Thunderstorm 22-2 event. Questions can be sent to GTRI organizers at thunderstorm@gtri.gatech.edu. – *J. Knowles*

IN BRIEF

Last month, the US Air Force demonstrated that an E-3G AWACS could collect and record radar signals with its onboard ESM system, transmit those recorded signals to a ground-based reprogramming center via its beyond line-of-site satellite communications system and then quickly receive updated emitter data back from the reprogramming center and update its mission files during flight. The process, which would have previously taken days or even weeks, was conducted within an hour, marking an important milestone on EW battle management and network connectivity. The E-3G was flown by the **605th Test and Evaluation Squadron, Detachment 1** (Tinker AFB, OK), and it communicated ESM data to the **36th EW Squadron** (Eglin AFB, FL), which "processed and analyzed the E-3G's data, corrected deficiencies observed in the data, and transmitted the updated file back to the E-3G for immediate loading during the mission," according to an Air Force news release. The demonstration was conducted by the AWACS Combined Test Force, which includes the 96th Operations Group, Det 2, and 605th TES, Det 1 – both are responsible for the developmental and operational testing of new hardware and software on the E-3G.

India's Defence Research and Development Organisation (DRDO) (New Delhi) has named **Nuthi Srinivas Rao,** Outstanding Scientist, as the new Director of the Defence Electronics Research Laboratory (DLRL) in Hyderabad. DLRL is the DRDO's primary electronic warfare research and development establishment. Rao joined DLRL in 1987 and has worked on shipboard EW programs during his long tenure with the lab. He obtained a degree in Electronics and Telecommunications Engineering from IETE (New Delhi) in 1986 and earned an M.Tech in Digital Systems & Computer Electronics from JNTU (Hyderabad) in 2001.

India's Ministry of Defence (MOD) has awarded **Bharat Electronics Limited** (BEL) a Rs 1,993 crore (US$262.7 million) contract to supply electronic warfare equipment for the Indian Air Force. The EW suite, originally designed and developed by the Defence Avionics Research Establishment (DARE), part of DRDO, is designed to provide self-protection for Indian Air Force fighter aircraft. Specific aircraft types have not been identified. Separately, the MOD has concluded a Rs 1,109 crore (US$145.6 million) contract with BEL for the development of an Instrumented Electronic Warfare Range (IEWR). The IEWR facility will be used to test and evaluate airborne EW equipment in a realistic electromagnetic environment.

Japan's Ground Self-Defense Force, in March, established a new electronic warfare headquarters to centralize management of its growing number of EW units spread across the country, according to Japanese news reports. The new unit, headquartered at Camp Asaka near Tokyo, is commanded by **Col Hiromitsu Kadota,** who will lead 180 personnel across 10 new EW units established in 2021 and 2022. The JGSDF had previously relied a single EW unit based at Camp Higashi-Chitose on the northern island of Hokkaido. As Japan faces rising tensions with China and Russia, it is investing more resources into its EW capabilities, such as the JGSDF's Network EW System (NEWS), a family of vehicle-based electronic support and electronic attack systems developed between 2010 and 2016.

Spectranetix, Inc. (Sunnyvale, CA) has won a $9.2 million cost-plus-fixedfee contract from the Office of Naval Research (Arlington, VA) for its "Modular Open Suite of Standards/Sensor Open Systems Architecture Node Based Resilient Networking and Electronics Warfare Orchestration at the Edge" effort. The company will develop, integrate and demonstrate the C4ISR Modular Open Suite of Standards (CMOSS) / Sensor Open Systems Architecture (SOSA)-aligned implementation of the Navy's Enabling Dynamic Operational Radio Frequency (ENDOR) architecture. ENDOR will provide a secure tactical computing infrastructure that can be rapidly and dynamically updated with new tasking and applications. The company is slated to complete the work by March 2024.

Bird Aerosystems (Herzliya, Israel) was selected by the Israeli MOD's Directorate of Research and Development (MAFAT) to develop and demonstrate a variant of its SPREOS directed infrared countermeasures (DIRCM) system in a new role against anti-tank guided munitions (ATGMs). According to the company, the prototype will include a small innovative radar, which is based on the confirmation and tracking radar implemented in the company's SPREOS. Small and lightweight, the new radar will conduct detection and verification of incoming ATGM threats, and then deploy and guide the system countermeasures to intercept the threat. The company expects to conduct a demonstration of the complete APS system, which is currently in an advanced stage of development, by the end of 2022.

Horizon Technologies (Reading, UK) announced that it will launch its Amber-1 ESM satellite aboard a Virgin Orbit LauncherOne rocket later this year. The announcement follows an agreement between the **Satellite Applications Catapult** and **Virgin Orbit** to launch the Amber-1 satellite as part of Catapult's In-Orbit Demonstration (IOD) program from Spaceport Cornwall at Cornwall Airport Newquay. This will also mark the first ever orbital launch from a UK spaceport. Amber-1 is the first of 20+ planned Amber satellites that will geolocate and demodulate radio frequency (RF) data from ships to provide Maritime Domain Awareness for customers, such as the UK's Joint Maritime Security Centre (JMSC).

The Naval Air Warfare Weapons Center (Point Mugu, CA) has awarded multiple contracts for its Aircrew Electronic Warfare Tactical Training Range (AEWTTR-II) Threat Radar Systems and Simulators Program. Awardees include **Scientific Research Corp.** (Atlanta, GA), **Saab Inc.** (East Syracuse, NY), **Leidos** (Ridgecrest, CA), **Amentum Services** (Germantown, MD) and **Huntington Ingalls Industries Mission Technologies** (formerly Alion Science and Technology Corp.) (McLean, VA). These contracts will provide pre-deployment aircrew warfighter training and EW weapon systems development at DOD and Allied test and training ranges. The estimated aggregate ceiling for all contracts is $250 million, with the companies having an opportunity to compete for individual orders.

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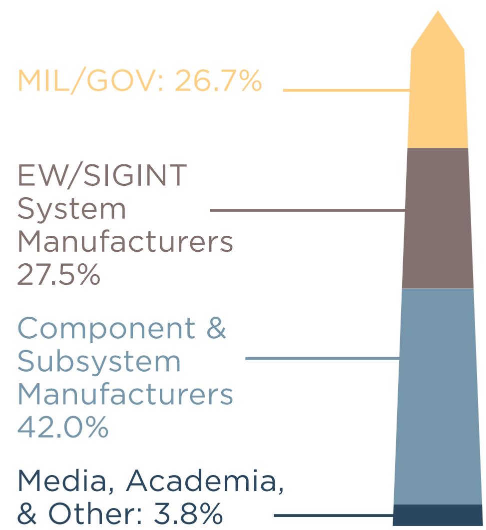
The 59th Annual AOC International Symposium & Convention will take place October 25-27, 2022, at the Walter E. Washington Convention Center, 801 Mount Vernon Place NW, Washington DC.

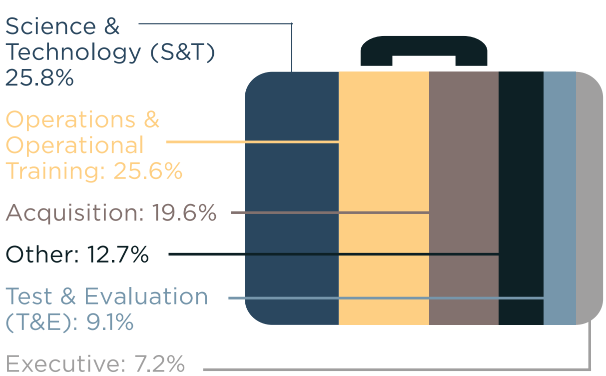
Who Attends:

33 countries
in attendance

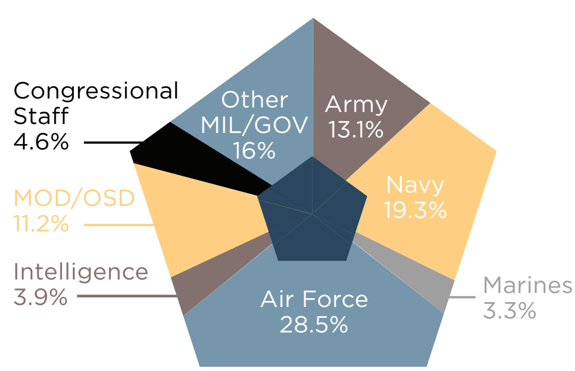
Attendance Profile



MIL/GOV Breakdown by Job Function



MIL/GOV Breakdown by Employer



**Data is representative of the 2019 iteration of this event.*

What exhibitors are saying...

"The AOC International symposium is a major event in the EW industry and provides us a unique opportunity to not only meet senior engineers and program leads from all of our major customers in this area, but it gives us the opportunity to showcase innovative products and solutions in this industry."

Franck Kolczak, TE Connectivity

EXHIBITOR INFORMATION

10′ x 10′ Exhibitor Booth Rates

	Before 3/1/22	After 3/1/22
Member fee*	$5,900	$6,200
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**Company must be a corporate member.*

To view the current floorplan, visit **crows.org/2022floorplan**.

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Exhibitor Schedule

Exhibitor Move-In
Monday, October 24 — 8:00 AM - 5:00 PM

Exhibitor Registration
Monday, October 24 — 1:00 PM - 6:00 PM

Exhibit Hall Hours*
Tuesday, October 25 — 10:00 AM - 6:00 PM
Wednesday, October 26 — 9:45 AM - 6:00 PM
Thursday, October 27 — 9:45 AM - 2:00 PM

**Booth personnel have access to show floor one hour prior and after official show hours*

Exhibitor Move-Out
Thursday, October 27 — 2:00 - 7:00 PM

Schedule is subject to change

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- Company listed in official on-site program
- Company description in the pre-convention issue of the *JED* and in your company profile on the interactive floorplan
- Post-show attendee list, including name, company, and city/state
- Exhibitor Services Kit detailing fees and information on shipping, furniture rental, and booth set-up will be emailed to the main contact for each booth approximately three months prior to the event
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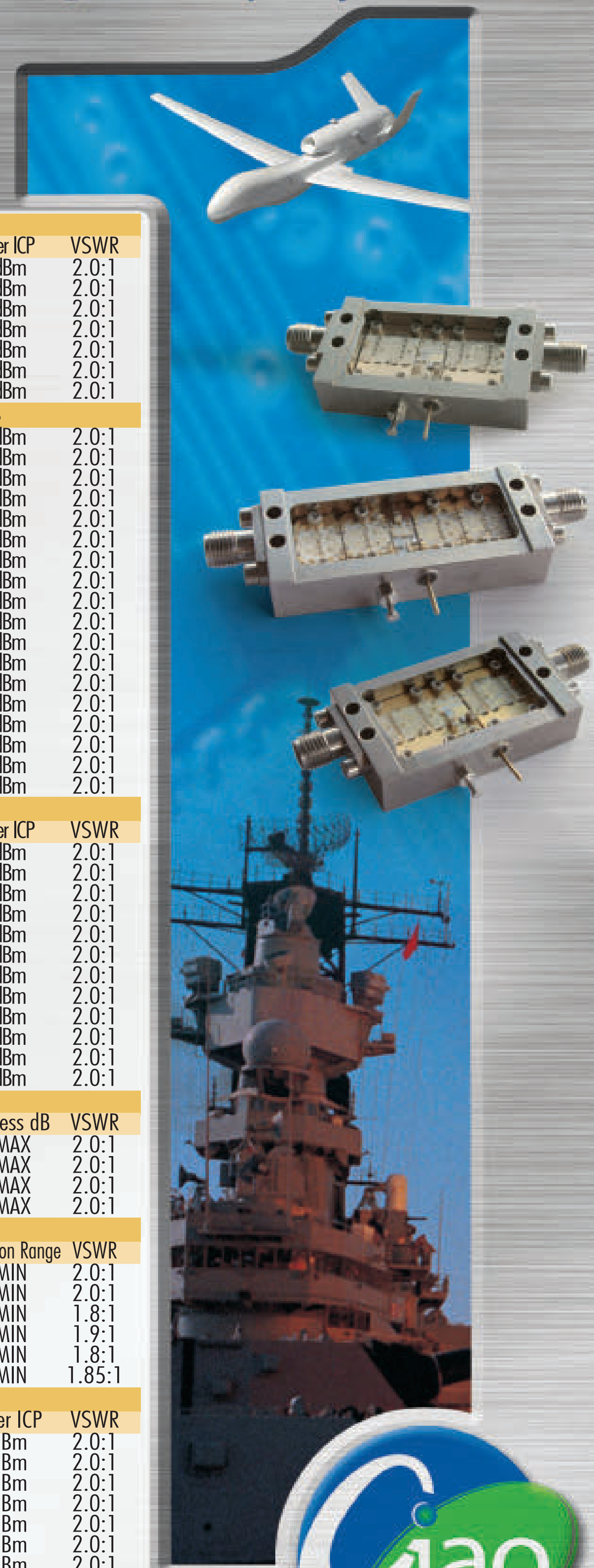

OCTAVE BAND LOW NOISE AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2110	0.5-1.0	28	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA12-2110	1.0-2.0	30	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
CA48-2111	4.0-8.0	29	1.3 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA812-3111	8.0-12.0	27	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA1218-4111	12.0-18.0	25	1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA0102-3111	0.1-2.0	28	1.6 Max, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA0106-3111	0.1-6.0	28	1.9 Max, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-3110	0.1-8.0	26	2.2 Max, 1.8 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-4112	0.1-8.0	32	3.0 MAX, 1.8 TYP	+22 MIN	+32 dBm	2.0:1
CA02-3112	0.5-2.0	36	4.5 MAX, 2.5 TYP	+30 MIN	+40 dBm	2.0:1
CA26-3110	2.0-6.0	26	2.0 MAX, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA26-4114	2.0-6.0	22	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA618-4112	6.0-18.0	25	5.0 MAX, 3.5 TYP	+23 MIN	+33 dBm	2.0:1
CA618-6114	6.0-18.0	35	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA218-4116	2.0-18.0	30	3.5 MAX, 2.8 TYP	+10 MIN	+20 dBm	2.0:1
CA218-4110	2.0-18.0	30	5.0 MAX, 3.5 TYP	+20 MIN	+30 dBm	2.0:1
CA218-4112	2.0-18.0	29	5.0 MAX, 3.5 TYP	+24 MIN	+34 dBm	2.0:1

LIMITING AMPLIFIERS

Model No.	Freq (GHz)	Input Dynamic Range	Output Power Range Psat	Power Flatness dB	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dBm	+7 to +11 dBm	+/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dBm	+14 to +18 dBm	+/- 1.5 MAX	2.0:1
CLA712-5001	7.0 - 12.4	-21 to +10 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1
CLA618-1201	6.0 - 18.0	-50 to +20 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	Gain Attenuation Range	VSWR
CA001-2511A	0.025-0.150	21	5.0 MAX, 3.5 TYP	+12 MIN	30 dB MIN	2.0:1
CA05-3110A	0.5-5.5	23	2.5 MAX, 1.5 TYP	+18 MIN	20 dB MIN	2.0:1
CA56-3110A	5.85-6.425	28	2.5 MAX, 1.5 TYP	+16 MIN	22 dB MIN	1.8:1
CA612-4110A	6.0-12.0	24	2.5 MAX, 1.5 TYP	+12 MIN	15 dB MIN	1.9:1
CA1315-4110A	13.75-15.4	25	2.2 MAX, 1.6 TYP	+16 MIN	20 dB MIN	1.8:1
CA1518-4110A	15.0-18.0	30	3.0 MAX, 2.0 TYP	+18 MIN	20 dB MIN	1.85:1

LOW FREQUENCY AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure dB	Power-out @ P1-dB	3rd Order ICP	VSWR
CA001-2110	0.01-0.10	18	4.0 MAX, 2.2 TYP	+10 MIN	+20 dBm	2.0:1
CA001-2211	0.04-0.15	24	3.5 MAX, 2.2 TYP	+13 MIN	+23 dBm	2.0:1
CA001-2215	0.04-0.15	23	4.0 MAX, 2.2 TYP	+23 MIN	+33 dBm	2.0:1
CA001-3113	0.01-1.0	28	4.0 MAX, 2.8 TYP	+17 MIN	+27 dBm	2.0:1
CA002-3114	0.01-2.0	27	4.0 MAX, 2.8 TYP	+20 MIN	+30 dBm	2.0:1
CA003-3116	0.01-3.0	18	4.0 MAX, 2.8 TYP	+25 MIN	+35 dBm	2.0:1
CA004-3112	0.01-4.0	32	4.0 MAX, 2.8 TYP	+15 MIN	+25 dBm	2.0:1

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Layered Protection Survivability Conce More Sophisticated

By Andrew White

On 24 February, the Russian Federation invaded Ukraine for the second time in eight years with columns of armored and non-armored platforms entering the country from the North, East and South. More than a month later, Russian and Ukrainian forces remain locked in fierce fighting across the eastern half of the country – a campaign which has highlighted the complexities associated with the mass deployment of armored platforms into non-permissive environments.

The vulnerabilities of Russian main battle tanks (MBTs), infantry fighting vehicles (IFVs) and armored personnel carriers (APCs) have subsequently come under stringent focus, particularly following the donation of specialist anti-armor weapon systems to Ukraine from NATO members. Official and unofficial social media channels on Facebook, Twitter and Instagram have highlighted what appears to be large numbers of destroyed Russian armor, as well as a smaller number of Ukrainian platforms, perhaps indicative of western nations' support for Ukraine's Armed Forces in the conflict.

Commenting on the situation, one defense source in the UK described how Explosive Reactive Armor (ERA) remained the most preferred survivability solution for Russian armored platforms in the conflict, in addition to bar armor and metal frames installed above turrets to disrupt "top attack" anti-tank guided munitions (ATGMs) and loitering munitions (LMs) in particular. However, some experts have told *JED* that Russian T-80 and T-90 MBTs might also be equipped with the "Shtora-1" electro-optic countermeasures system, which is designed to disrupt the laser guidance systems of wire-guided SACLOS and laser-guided ATGMs. It also remains unclear if Ukrainian armored platforms have deployed the domestically manufactured "Zaslon" radar-cued APS.

The war in Ukraine has illustrated the grim reality that anti-armor weapons are more than a match for armor-only survivability concepts. Above, Ukrainian forces apparently used an ATGM to destroy a Russian T-72, fitted with a makeshift cage on the turret to protect against KE anti-tank weapons. UKRAINIAN DEFENCE FORCES

BEYOND ARMOR

Extremely wary of the emerging threat of great power conflict in the information age, Europe's defense industrial base continues to push forward with the development of next-generation APS, which are expected to protect armored platforms from ATGMs, LMs ballistically guided ATMs, and other threats.

Sam Cranny-Evans, Research Analyst in C4ISR at the Royal United Services Institute (RUSI), explained how, generally speaking, the survivability of armored platforms has "always lagged behind lethality" in terms of vehicle protection. "It is possible to protect against some of the threats some of the time, but not all of them all of the time," he warned. "The big topic at the moment is weapons using High Explosive Anti-Tank (HEAT) shaped charges to achieve target defeat

– Armored Vehicle pts Getting

– this seems to be an overriding concern for many [armed forces] based on the protection systems being procured and developed. "I suspect that, in part, this trend is informed by wars in Ukraine (2014), Syria and Libya. The proliferation of ATGMs in those conflicts means that even in a sub-peer deployment, armored forces are likely to face advanced ATGMs with tandem HEAT warheads," he continued.

However, Cranny-Evans is not yet sure the ongoing conflict in Ukraine has affected the strategic thinking of armed forces in terms of the design, development and selection of APS. "I would hope that any shifts in thinking would be at the CONEMP level as opposed to technological demands. An NLAW or RPG-29 fired at the side of most MBTs – assuming they are not fitted with an APS – will always be a real problem for passive and even reactive armor. Even with an APS fitted, the engagement ranges that seem to be employed with shoulder-fired weapons in Ukraine would create considerable challenges for some systems. I think Ukraine shows, more than anything, the need for integration at the CONEMP level, and firepower at the technical level to respond to a large dispersed threat moving over multiple axes with a smaller and 'boutique' force."

He further explained, "First-hand accounts indicate that vehicles like the BTR-82A armed with the 30-mm 2A42 automatic cannon are absolutely devastating to infantry formations, even those armed with shoulder fired weapons. It stands to reason that armored infantry vehicles should probably look to carry a turret with a medium-caliber weapon of some sort. Packing firepower is sometimes a good form of defense," he added.

Considering the APS market in general, Cranny-Evans added: "I think that the market as a whole is relatively healthy, with innovations coming from the UK, Israel and Europe in both conceptual and technological solutions to the problems of modern combat. There appears to be an understanding that the weight-mobility spiral is approaching its limits, which is shifting a focus on to lighter protective solutions."

LAYERED DEFENSE

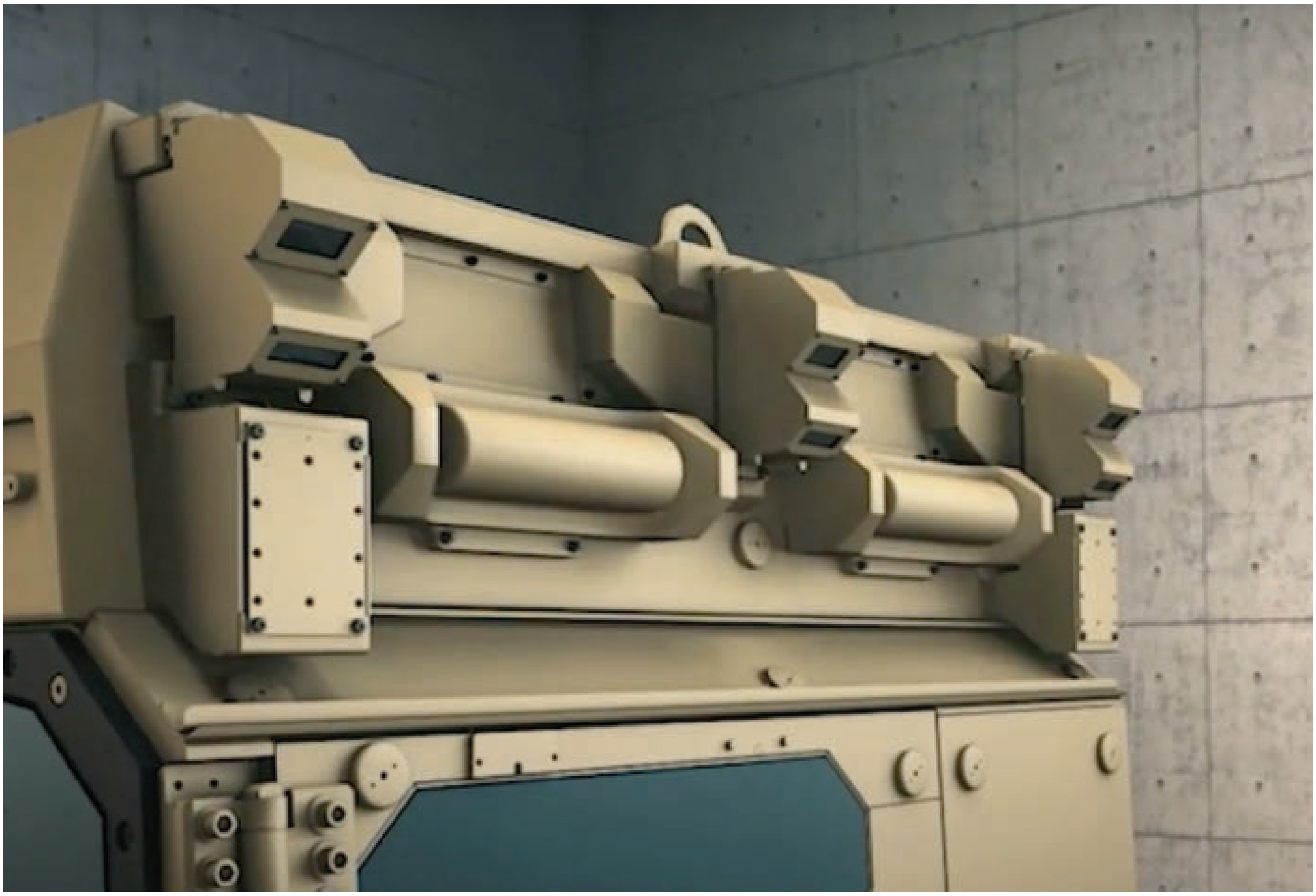
However, Cranny-Evans also warned of a lack of competition in the area of APS, suggesting how Rafael's Trophy appears to be a "fairly dominant" solution in the global market. "I suspect that this might partly be a result of its operational experience," he observed, "which likely means it has been refined and programmed to better-classify threats and respond to them. This is pretty important to an APS, as those [APS systems] without combat exposure will be lacking that data input and so may struggle in competitions. So, whilst other systems like Rheinmetall's StrikeShield and Elbit's Iron Fist exist and have won some tenders, there is a lack of operational experience for those systems, which means we do not yet understand which system is best for which situation, and so on."

Moving forward, Cranny-Evans suggested a layered defense for armored vehicles, featuring a mix of active and passive protection solutions, in addition to both soft- and hard-kill countermeasures. "There are many threats and fewer [countermeasures] systems, so increasing survivability right now is important if it can be done without reducing mobility. One school of thought, which I find very interesting, is that passive armor should be tailored specifically to kinetic energy (KE) threats, leaving HEAT-type projectiles to the APS. This could enable the passive armor to be designed specifically for KE, enabling it to be more effective in that role."

GETTING SERIOUS

Some of the most innovative developments in European APS are being pursued by the UK Ministry of Defence's (MOD's) Defence Science and Technology Laboratory (Dstl). Tom Newbery, Land Survivability Scientist at Dstl, described how he was watching events in Ukraine unfold with interest. "Clearly we're curious to see what is being employed," he said, "both from a technological and a tactical point of view, as well as strategic point of view. But I'm not sure there's really much more I can say on that."

Newbery provided insight into the analysis of integrated survivability technologies for mounted platforms and mission survivability across contemporary and future operating environments. As the MOD's technical authority for land armor solutions, Dstl is investigating a variety of protection technologies and test methods in support of the British Army and the Defence Equipment and Supply (DE&S) procurement agency. Ar-



Germany's Rheinmetall has designed the StrikeShield APS which will be integrated on board Lynx infantry fighting vehicles in the Hungarian Armed Forces. RHEINMETALL IMAGE

eas of interest include the de-risking and through-life capability development of APS, in addition to the development of future threat intervention solutions.

According to Newbery, APS can be categorized into several areas, including "current-generation APS; next-generation, layered APS; and finally, aligned and complementary APS". Current solutions, which include Rafael's Trophy and Elbit's Iron Fist, feature radar and electro-optical payloads to detect and track threats integrated with hard-kill countermeasures to counter RPGs and ATGMs, in addition to laser warning systems for situation awareness; and manual or semi-automated obscurants.

Next-generation systems, Newbery suggested, would feature multi-sensor fusion to generate a common threat picture, as well as common controllers that facilitate the coordinated countermeasures responses. These systems will also use open architectures to more efficiently implement new technologies and subsystems into the APS suite.

Finally, aligned and complementary sensor and countermeasures capabilities could see mission systems providing not only situational awareness and APS but also perform additional responsibilities, such as counter-uncrewed air systems (C-UAS), which would enable platforms and crew to "detect, understand and react in an optimal manner."

The demand signal for APS is growing stronger, too. "We've seen the kind of explosion of interest [in APS] apart from anything else but we're not seeing a greater range of capabilities come from industry at the moment," Newbery suggested. "There aren't new systems appearing as such, but there does seem to be quite a push on maturity. And in recognition of the increasing acceptance and recognition from different nations that actually APS is now required, it's no longer really an optional technology. People are getting serious about it now."

According to Newbery, APS remains an "embryonic technology," which continues to progress its way through a long gestation period and into service with some of the most modern armed forces around the World. "What we see at the moment – and I don't want to name any particular systems – is all the APS that are out there at the moment have had a long history of developing maturation of understanding how the threat-engagement cycle works," he explained. "But actually, how do you employ that? How do you apply that to their particular choice of mode of action? Within the APS space, this is difficult because the truth is, it's really difficult to shoot down an RPG and ATGM in the kind of timelines and the kind of spaces we're talking about, with sufficient robustness to make it worthwhile. We talk about taking off armor or swapping out armor, or trading out other survivability aspects, adding mass to a platform, so there's more of a cost that comes with it. Therefore, I think the burden is higher to complete various systems verification – essentially the evidence behind the capabilities – to show that it's actually functioning and going to give you what you want."

CAPABILITY GAPS

As a result, Dstl is focused on the modularization of APS and the ability to switch and change subsystems to tailor capabilities and to include novel capabilities or novel subsystems as they develop. Newbery used EO sensors as an example: "So this is an example of something that you may not necessarily want to add to every implementation, but it may bring benefit to have on platform. For example, EO sensing that can support your APS function – and you could consider that part of your APS. Or you could consider it part of your platform situation awareness that can be applied to all major APS. And that's where this boundary is between people who tend to think about APS as a protection system and an alternative to armor. Instead, we're increasingly thinking of APS as a mission system and as a situation awareness solution that happens to give you a threat feed functionality, as well, so that they're understanding an environment with sensors integrated with your communications and your situation awareness. And yes, in many cases, they will then choose or they will then act to defeat a threat. This is kind of a different way of thinking about it ,and it brings about different priorities in how you then look towards your integration and your procurement activities," he added.

Newbery also considered the ways in which APS sensors and effectors must be deconflicted with other EW assets on the battlefield. "I think there's a much looser understanding of how the sensor technologies related to APS actually work, and how they interrelate with other platform systems on the battlefield. So what are the complications around your electronic countermeasures and your electronic warfare and your communications technologies, and how does that mission system interface work?" he asked. This issue of EM compatibility, while not new to EW planners, is an area that could slow the adoption of APS technology if not adequately understood and addressed at the operational level.

MODULARIZATION

According to Newbery, one of the most prevalent capability gaps facing APS at present is the desire to modularize holistic solutions and increase capability across additional mission sets, including C-UAS and situational awareness. Efforts include Dstl's Icarus program, which comprised a two-year effort to create a Modular Integrated Protection System (MIPS) industry standard. "Last summer," Newbery explained, "we had our end-to-end verification trials, where we were able to fire threats at a MIPS-enabled system and we derived the subsystems from the existing COTS marketplace. We were able to show the capability of the architecture to support end-to-end threat defeat and support modularity of the APS. So we were very pleased that it came on the back of simulated activity, followed by hardware in-the-loop activity and then finally, end-to-end live fire trials as a progressive and staged verification process. That has led to us publishing the first version of the MIPS standard, and there are some ongoing development activities with MIPS, in particular, expanding our use cases," he continued, before confirming C-UAS was one of the activities currently underway. "We're not building a C-UAS system, but expanding the scope of the architecture definition to support the ability for [an APS] to be employed in a C-UAS role. And that's just underway at the moment with delivery in the next few weeks – so that's been very good."

Dstl also sees a place for both active and passive protection systems to co-exist on board the same vehicle, albeit performing very different roles and capabilities. "What I'm trying to get across to the community is they're both required in the long-term," Newbery explained. "But they're doing different roles that they will fulfill, and we need to understand and to develop an understanding of how that is going to function and how those technologies are going to be managed appropriately," he added before describing obvious concerns regarding weight burdens on tactical ground vehicles.

"From an integrated scalability perspective, we should be looking at allocation of threat and defeat requirements to different systems, and thereby freeing up the alternatives," he said. "So, for example, passive protective solutions could focus on threats unable to be identified by an APS."

"We must also try to avoid saying, 'APS defeats threats.' Instead, it converts an incoming threat from a highly lethal form to, hopefully, a significantly less lethal form. But we still need our passive protection to deal with those much reduced residuals. And therefore we need the design of those systems of our APS, of passive protective systems or maybe reactive solutions to be done in harmony and to be considered holistically back to that highest level for the for the overall vehicle. This is why APS is such a growth sector."

Conceding there is currently much greater focus on the procurement of hard-kill effects for APS, Newbery also described how soft-kill countermeasures were "equally as valuable and very frequently complementary" to hard kill solutions. Particular considerations include the ability of soft-kill solutions to deal with shorter range threats that might not be dealt with by slew-to-cue hard kill effects. "As with hard kill, we're looking at things like greater threat independence and the shorter timelines associated with our engagement cycle, and therefore the shorter range of threats that can be dealt with. So they do really work complementary to each other."

Newbery went on to ask, "But how do we get them working cohesively together in a complementary manner, like having joined-up, tuned-up modularized systems. That was one of the reasons behind the MIPS development to enable hard and soft to be used effectively together. So when we have different sensor types, we are building a single threat picture that we're then in a position for a system to – in an automated manner – determine how can I best approach that threat?"

"Every system has advantages and disadvantages," he said. "There's no magic bullet in APS, and we need to get across to the user what the limits of capability are and ensure that user is appropriately informed as to what the limits of capability are, so that they can ensure when they're operating that system they don't stray across that boundary without realizing it. That is one of our key focuses. It is one element of the overall survivability suite of a platform."

Looking to the future, Newbery described how a more layered APS approach could enter service in the late 2020s through the introduction of a common controller, which he suggests is not a great challenge. One example is the MIPS Maturation phase, which is scheduled to last two years and aims to deliver a MIPS control function existing within a verified end-to-end APS, allowing for the operation of a layered APS, including hard and soft kill functionality.

Beyond the introduction of a layered APS approach, Newbery suggested aligned and complementary APS will enter service with the British Army in the "late 2020s/early 2030s". "This is when we can be exploiting true commonality of processing, and commonality of subsystems to provide an enhanced overall system," he said.

One specific growth area being pursued by Dstl is next-generation electro-optics, which Newbery described as providing more robust threat detection capabilities. "I think this is very important," he said. "And I think it's reflected back into the kind of understanding within the defense community of APS, as something that people generally very well understand the engagement mechanism. For example, how you actually defeat the threat, and what they expect to come out of the back of that. So I think that is where as a community, we need to improve the understanding and potentially improve the capabilities of what we're seeing in the marketplace. So the ability to detect missile launch and missile flight, and do that in a hopefully covert manner."

As Newbery stated, better EO sensing is likely to reduce the APS's reliance upon active sensors, such as radar, which can be detected and recognized by adversaries. "Active emissions from radars are something that we are aware of," he said. "And we are aware that others are aware of it. And this is one of the factors behind topics like the next-gen EO. If we have robust EO sensing, then that potentially allows us to mitigate some of our active signatures. It also has to be considered within the context of what signatures exist for a given platform or given group of platforms? And what are the detection capabilities thereof? And that all goes into that global consideration."

INDUSTRY OFFERINGS

European industry continues to offer up a variety of active and passive protection solutions for armored platforms.

Options include Elbit's Iron Fist; Rafael's Trophy APS, which is integrated on board M1A2 SEP V.2 Abrams and Leopard 2A7V MBTs; and Rheinmetall's StrikeShield, which is set to be integrated on board Hungary's Lynx infantry fighting vehicle (IFV).

Referring to Rheinmetall's StrikeShield solution, RUSI's Cranny-Evans added, "As a distributed system, it provides protection for lighter vehicles at a reduced weight penalty and a few other advantages, such as engaging threats at reduced ranges and also providing passive protection as part of the solution."

The latest APS emerging from the Russian Federation includes the Arena-M solution, although defense sources suggested it has yet to be witnessed in Ukraine and may not yet be in operational service with the armed forces. In 2017, Russian news agency TASS announced

Rafael's Trophy APS installed on a German Leopard 2 tank. Trophy is available in HV and MV configurations, the latter of which provides significant size and weight savings while retaining the same capability, according to company officials. KRAUSS-MAFFEI WEGMANN

Arena-M as a "new APS for T-72 and T-90 tanks capable of protecting armored vehicles from US Tube-launched Optically-tracked Wire-guided (TOW) missiles." At the time, Arena-M was claimed to be undertaking trials in Russia with the Machine-Building Design Bureau.

The TASS article also quoted an unnamed chief designer of the Machine-Building Design Bureau who described how conflicts in the Middle East had shown that it is "impossible to do without tanks and, secondly, they can no longer be protected by traditional means, including reactive armor." Consequently, Arena-M was designed to protect armored platforms from anti-tank grenades and ATGMs. It features a multifunctional radar to detect and track targets and "instant-effect ammunition used for the aimed destruction of incoming targets", the article added.

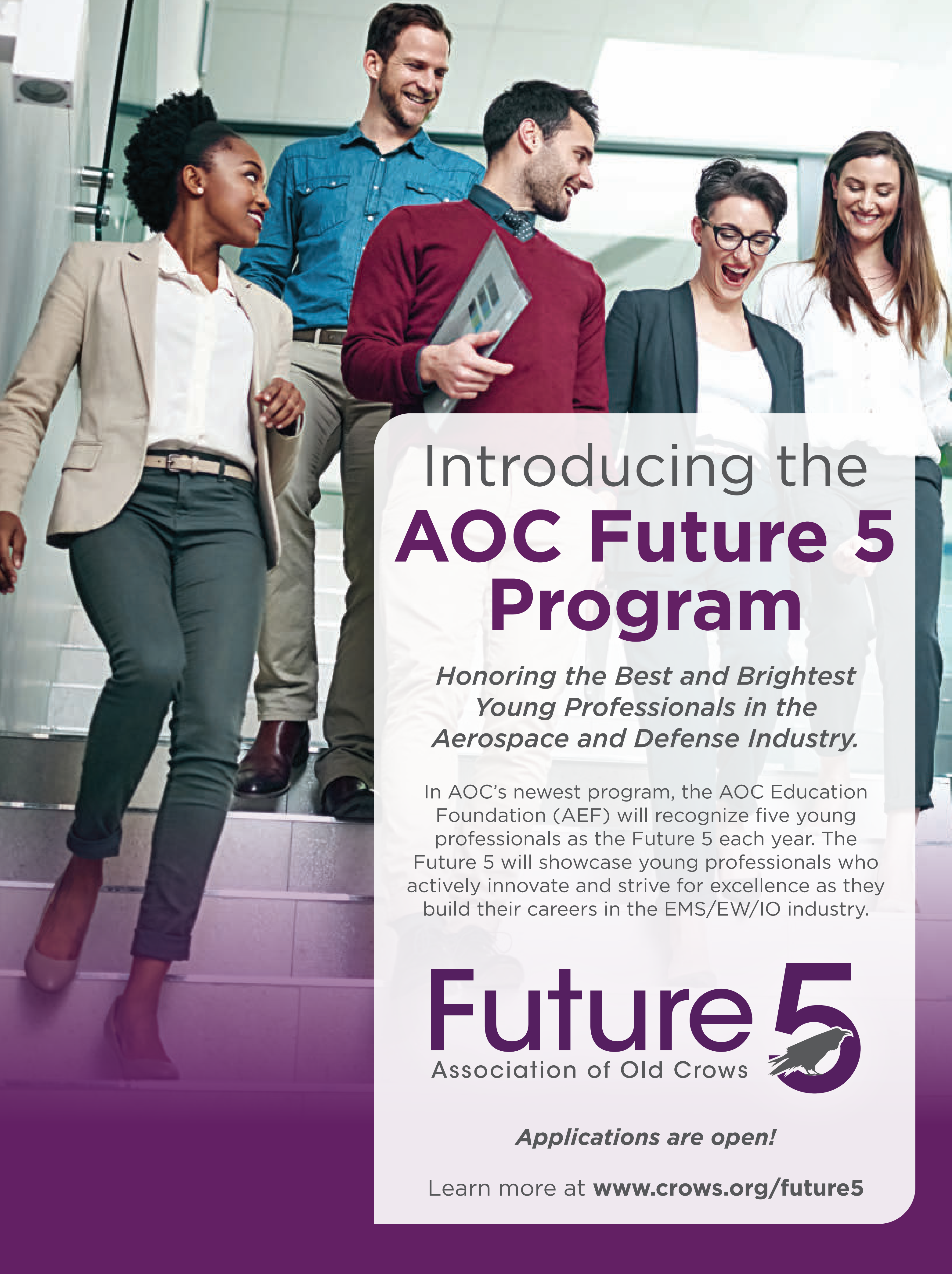
According to a company spokesperson at Rafael, the international market for protection systems is growing in line with the global armored platform sector. The spokesperson explained: "It looks like the asymmetric warfare that peaked in the 80s and 90s is now just a part of a greater, more complicated type of warfare known as 'multi-dimensional warfare.' Not only is this new multi-dimensional warfare taking its own shape, it has already proven effective in conflicts like the Nagorno-Karabakh conflict and the current conflict in Ukraine. Thus, the most prevalent capability gaps are only now being shaped as a reaction to the new type of conflicts and warfare."

Referring to the ongoing conflict in Ukraine, Rafael's spokesperson explained: "It seems like existing plans and programs to procure [APS] will only be expedited and that the time-to-market that is needed is even shorter than before. It also seems that nations that have been reluctant to procure such systems in the past, mainly complex systems like APS, are now strongly considering introducing such systems into their armored fleets. (This is mainly due to the fact that many are seeing first-hand what modern day anti-tank ambushes look like, and how useless a modern MBT or IFV is without such systems.)"

Rafael offers Trophy HV and MV configurations – the latter boasting 40% size and weight savings despite maintaining identical performance and capabilities, the spokesperson said. "In addition to that, Rafael has landed several contracts with key nations for the procurement of Trophy MV including the British Army's Challenger 3 program. In collaboration with the current users of the Trophy HV, Rafael plans to modernize the existing systems that are already in service to the Trophy MV variant, also depending whether the trends and budgets will now go to modernization of already existing systems or to the procurement of new ones."

Trophy MV has also been selected for South Korea's K2 and Germany's Leopard 2 MBTs as part of the tender for a next-generation MBT in Norway. "Besides that, we are of course working on integrations to new platforms including

The British Army's Challenger 3 MBT (pictured above) will be upgraded with Trophy APS as a COTS solution and will receive more layered protective systems in the future. RHEINMETALL BAE SYSTEMS LAND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MBTs, APCs, IFVs and even 30-mm turret vendors asking for Trophy to be integrated as part of their proposed replies to RFQs," the spokesperson continued.

Describing Rafael's approach to APS, the spokesperson described how passive solutions, reactive armor and APS remain complementary to one another. "Optimal protection and survivability capabilities are achieved through the right balance of protection technologies," the spokesperson said. "Therefore they should be used in combination. One example is the armor-piercing fin-stabilized discarding sabot (APFSDS) KE threat – we believe currently the best way to handle those is through the integration of reactive armor. Integrating reactive armor to the platform to defeat KE threats and using an APS on the same platforms to focus on shaped charges, such as RPGs and advanced ATGMs, is our approach. With regards to soft-kill vs hard-kill, fielding of Trophy with different user nations has shown that not only do they need a hard-kill APS, but they need a "Hit-to-Kill" APS. A soft-kill system can be added to the platform as another layer of protection, but that only goes together with a hard-kill system."

MOVING FORWARD

According to Rafael's spokesperson, the APS market will continue to benefit from the introduction of new capabilities over the next 5 to 10 years.

RUSI's Cranny-Evans said, "APS will gain traction, and I suspect additional ERA types will become more prevalent. Overall, lighter solutions that fit within the current constraints of strategic mobility will be preferred."

Finally, Dstl's Newbery suggested APS will have plenty more to offer in protecting armored platforms of the future. "To continue that transformational role in the risk-balance case of platforms operating on land, what threats do they have to be working around and how can they respond to those?" he asked. "These thoughts are absolutely critical for growth, but I think divergence as well – so we can't necessarily afford and we don't have the appetite necessarily for what we see at the moment as 'big ticket,' blackbox, end-to-end capabilities."

According to Newbery, the UK MoD does not have the appetite to drop large COTS solutions across the entire fleet of land platforms. Instead, he suggested, the MoD must consider how to scale capabilities to a given situation: "What is an appropriate fit for a light platform? How can we enable that, versus scaling that all the way up to platforms that don't have either the cost budget or the mass budget or the power budget to bear fully layered capabilities. So we need to understand how to develop this understanding of how to scale APS implementations according to need?"

"How does it scale according to theater of deployment and scenario that it might be used in?" he asked. "And how does that then relate to what you actually fit on board a vehicle using a MIPS controller as part of your GVA [Generic Vehicle Architecture] screen, which allows you to add or remove components as and when required." That is a question many European armies are aiming to answer by the end of the decade.

Long-Range Strike Role of the Bombe

By John Knowles

Last month, the US Air Force recognized the 80th Anniversary of the Doolittle Raid against Japan in 1942. For that Joint US Army and US Navy mission, the US Army Air Force outfitted 16 B-25B Mitchell bombers with additional fuel capacity and launched them from the deck of the USS *Hornet* 650 miles off the coast of Japan. Their mission was to attack 10 targets in six Japanese cities before continuing on to eastern China. (One crew flew north and landed in the Soviet Union, but the rest flew to China.) The tactical value of the Doolittle Raid was fairly small – in order to add fuel capacity, each aircraft carried just four 500-lb bombs – but it's strategic affect was significant. The Doolittle Raiders caught Japanese forces by surprise, and the country's military leadership was deeply embarrassed by the attack. It ultimately influenced the Japanese Command's decision to attack Midway Island some six months later, which was a costly defeat for the Imperial Japanese Navy – four aircraft carriers and one cruiser sunk – that also began to shift the strategic advantage to the Allies in the Pacific for the remainder of the war.

The Doolittle Raid is recognized as an early example of a long-range strike (LRS) mission that generated strategic effects. In honor of this achievement, the US Air Force's newest bomber is named the B-21 Raider and it is expected to support the Air Force's LRS mission for the next few decades. In this article, we'll look at a specific aspect of LRS, namely the bomber programs under Air Force Global Strike Command (AFGSC).

THE MISSION REMAINS THE SAME – THE TECHNOLOGY DOES NOT

AFGSC stood up in 2009 with headquarters at Barksdale AFB, LA. Along with Air Force Reserve Command, it is responsible for all of the Air Force's long-range bombers, comprising the B-52, B-1B, B-2 and future B-21 units. AFGSC traces its heritage back to Strategic Air Command (SAC), which had responsibility for long-range bombers and land-based ICBMs, in addition to reconnaissance aircraft and aerial refueling aircraft.

With the end of the Cold War, the Air Force re-organized in part to reflect a smaller force structure and also to support a new US national security posture. In 1992, SAC's bomber fleet was moved under the newly established Air Combat Command (ACC). Over the following 15 years, the B-1B and B-52 were used extensively in Operation Desert Fox (1998) and Operation Allied Force (1999), and during the opening phases of Operation Enduring Freedom (2001) and Operation Enduring Freedom (2003).

In the late 2000s, Air Force leaders established AFGSC in an effort to consolidate all Air Force nuclear capabilities (bombers and ICBMs) under a single command, and today it is the only Air Force component command that reports to US Strategic Command. Initially, AFGSC took responsibility for the B-52 and B-2 as the Air Force's only nuclear-capable bombers. (Shortly after the Cold War ended, the B-1B had been converted to a purely conventional role and, as such, remained under ACC until 2015, when the Lancer fleet was transferred to AFGSC.)

Throughout these organizational changes, the role of Air Force's bomber fleet has remained constant: to conduct global conventional strike and nuclear strike operations. That said, in almost every other aspect a lot *has* changed: the threat environment; the force mix; the sensors, communications networks and weapons technology; and the training.

THE THREAT ENVIRONMENT

One of the most interesting aspects of the Air Force's current bomber fleet is its long lifespan. The average age of its current bomber fleet – comprised of B-52Hs (introduced in 1961), B-1Bs (IOC in 1986) and B-2s (first delivered in 1993) – is 43 years, making it one of the oldest fleets in the Air Force. One characteristic that has kept these aircraft operationally relevant is their adaptability. Their communications suites have been constantly replaced to help them receive targeting information in real-time and to support mission routing and re-targeting on the fly. They also have been continuously modified to carry just about every kind of air-launched weapon, from cruise missiles to precision stand-off weapons, such as JDAM-enabled bombs and the AGM-154 JSOW and AGM-158 JASSM families.

As these bombers were fielded and modified, air defense technology was also evolving. The B-52, for example, initially relied on high-altitude flight in order to penetrate Soviet air defenses in the 1950s. By the late 1950s and early 1960s, Soviet forces began fielding the SA-2, which was armed with missiles could reach the high-flying bombers. As the shift occurred, EW became much more important to the B-52's survivability. As Soviet air defense capabilities continued to evolve in the 1960s and 1970s, the Air Force determined that low-altitude flight could provide some degree of sanctuary, and it developed the B-1B to fit this mission profile to hide from radars in the ground clutter. As Soviet radar technology began to solve the ground

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clutter problem, the Air Force introduced the B-2, which featured innovative stealth technology and the APR-50 ESM system to help it perform deep strike missions.

In the 30 years since the B-2 was first introduced, air defense technology has continued to evolve, most recently with low-band passive radars, frequency- and waveform-agile radars, and long-range surface-to-air missiles. Past concepts, such as evading radars and flying above or around threat bubbles are no longer viable. All-aspect stealth is an essential characteristic for a penetrating aircraft, as are AI/ML enabled EW systems. While these bomber traits are important, it is the survivability contributions that come from offboard capabilities, such as air-launched RF decoys and jammers (i.e., MALD) and escort jammers, that are critical for bombers to conduct deep strike missions.

LEGACY FLEET: B-52

Today, the Air Force operates three bomber types, each developed for performing conventional and nuclear long-range strike missions, but also featuring different designs and capabilities.

The Air Force's B-52H fleet stands at 76 aircraft. This includes 54 aircraft in the active force that are assigned to the 5th Bomb Wing at Minot AFB, ND, and the 2nd Bomb Wing at Barksdale AFB, LA. The Air Force Reserve Command's 307th Bomb Wing, also at Barksdale AFB, operates 18 aircraft. The remaining four aircraft are held by the 419th Test squadron at Edwards AFB, CA to perform flight testing.

The B-52H 's EW suite has been remarkably consistent for much of its operational life. The ALR-20 panoramic receiver was introduced in the early 1960s and many B-52 EWOs consider it to still be one of the most effective ESM systems in the hands of an experienced operator. In 1999 the Air Force, acting through B-52 prime contractor Boeing, considered selecting a new off-the-shelf ESM system under an effort known as the Situational Awareness Defensive Improvement (SADI) program, on the B-52. Due to the projected costs, however, the program was eventually abandoned.

On the countermeasures side, the Air Force has mainly focused on sustaining the B-52's ALQ-155 low- and mid-band jamming system and its ALQ-172 high-band jammer with multiple spares and engineering support contracts to Northrop Grumman and BAE Systems (for the ALQ-155) and L-3Harris Technologies (for the ALQ-172).

Aside from its defensive suite, the B-52H also has a role in supporting Airborne Electronic Attack (AEA) missions via its ability to carry and launch the ADM-160 Miniature Air Launched Decoy (MALD) and the jamming variant, MALD-J.

B-1B

Last year, the Air Force retired 17 B-1Bs, reducing its fleet to 45 aircraft operated by the 7th Bomb Wing at Dyess AFB, TX, and the 28th Bomb Wing at Ellsworth AFB, SD. As mentioned earlier, the B-1B was designed to perform long-range strike missions at extremely low altitude. It relied on a combination of reduced radar cross section (not "true" stealth, however) and a capable EW suite comprising the ALQ-161 RF countermeasures system, the ALQ-153 pulse-Doppler missile warning system and the ALE-45 dispenser, which ejected flares upward to meet the aircraft's low-altitude mission profile. The ALQ-161 was designed to detect and geolocate radar emissions while flying nap of the earth in order to enable the B-1B aircrews to penetrate deep into enemy airspace.

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After the Cold War ended, however, the Air Force began a long process of converting the B-1B fleet to perform conventional strike missions under the Conventional Mission Upgrade Program (CMUP). As the B-1B's s mission profile changed from low altitude to higher altitudes, it pursued a new set of EW capabilities for the aircraft. This included the addition of the ALE-50 towed RF decoy as an interim solution, which proved very effective against Serbia's single-digit SAMs during Operation Allied Force in 1999. The long-term EW plan was to conduct the Defensive Systems Upgrade Program (DSUP), which would focus on updating the bomber's ALQ-161 RF countermeasures system, including a new techniques generator and the addition of a fiber-optic towed decoy capability, as well as replacing certain ALQ-161 subsystems, such as the threat warning system. The DSUP ran into delays, particularly with the integration of the fiber-optic towed decoy, and the program was cancelled in 2002 in favor of a more modest (and more affordable) set of ALQ-161 improvements. The B-1B has also retained the ALE-50 capability.

B-2

Even as the last B-1Bs were coming off the production line in 1988, some Air Force analyses were suggesting that the aircraft would experience reduced survivability against new Soviet air defense capabilities that were designed to detect and attack low-altitude targets. In anticipation of this, the Air Force had started early development of a new stealth bomber under the Advanced Technology Bomber (ATB) program, which was to become the B-2 Spirit. The B-2 featured advanced stealth and an EW suite that included the APR-50 ESM system, which enabled it to avoid threats entirely or plan routes that minimized its RCS profile. The end of the Cold War (and the associated drawdown), however, led the Air Force to reduce its planned B-2 buy from 132 aircraft to just 21.

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As the APR-50 grew older and threat radar technology evolved, incorporating waveform agility and other performance enhancements, the Air Force by the late 2000s had begun planning for a new EW system that would enable the B-2 to continue performing deep strike missions against a modern IADS. In 2010, it launched the B-2 Defensive Management System-Modernization (DMS-M) program and B-2 prime contractor Northrop Grumman awarded a technology maturation contract to BAE Systems (Nashua, NH). For some aspects of the DMS-M program, BAE Systems would leverage advanced EW technologies developed for other aircraft programs, such as the F-35. EMD work began in 2016, but the DMS-M program eventually began to see schedule delays that pushed its Milestone C production date from December 2019 to September 2021 and slipped IOT&E start from June 2020 to February 2022, according to a 2019 Selective Acquisition Report. Around the same time, the Air Force was deliberating the future composition of its bomber fleet. By March of 2020, when it released its FY2021 budget proposal, the Air Force had de-scoped the B-2 DMS-M program considerably, opting only to modernize the B-2's threat warning cockpit displays and display processors and addressing specific parts obsolescence issues.

B-21

One of the reasons the Air Force decided it could afford the risk of descoping the B-2 DMS-M program was the excellent progress it was making on the B-21 Raider program. In 2015, the Air Force selected Northrop Grumman as the B-21 prime contractor, and the company tapped BAE Systems to provide the Raider's EW suite the following year. Few details of the B-21 or its EW suite have been released. The Raider is expected to make its first flight later this year, and the first few aircraft could be fielded in the 2025-2026 timeframe.

NORTHROP GRUMMAN

Currently, six B-21s are in production, and the Air Force has said it wants to buy up to 100 aircraft. This would enable the Air Force to begin retiring the remainder of its B-1Bs and all of its B-2s – perhaps within a decade – thus freeing up some of the funds it will need to pay for B-21 production.

For its long-term force mix, the Air Force plans to retain its B-52 bomber fleet, possibly through 2040. This would see the Air Force rely on its newest and oldest bombers – using the B-21 to penetrate advanced IADS and reserving the less survivable B-52 mainly for conventional strike missions in more permissive threat environments.

FLEXIBILITY MEANS VERSATILITY

When the Air Force was debating whether to pursue what would eventually become the B-21 Raider, some military analysts argued that bombers are the weakest part of the nuclear

triad, compared with land-based ICBMs and submarine launched ballistic missiles. But the Air Force opted for the B-21 because the Raider, like its predecessors, can carry a number of munition types and it can support a variety of other missions from conventional strikes to overflights near potential adversaries, such as North Korea and Iran.

The question for the future may not be which weapons the bombers can carry, but rather, how can they integrate with other aircraft to support a mission, whether it is to help attack air defense nodes in a high-threat environment or perform deep strike missions against other critical targets in the opening phase of a conflict. Unlike most tactical aircraft, bombers have the available space to carry many types of payloads and their larger engines can provided lots of power for them. Like the Doolittle Raid 80 years ago, if a crazy idea can be imagined, a versatile aircraft like a bomber can probably provide part of the solution.

FRAMING THE BOMBER CHALLENGE

In his 2015 testimony to the House Armed Services Committee's Subcommittee on Seapower and Projection Forces, Mark Gunzinger (currently Director Future Aerospace Concepts and Capabilities Assessments at The Mitchell Institute for Aerospace Studies) delivered an opening statement that succinctly describes the two main challenges in the LRS mission. This portion of his testimony is excerpted here:

"I would like to suggest a framework that might help you think about the LRS-B [Long-Range Strike Bomber] and other capabilities in the long-range strike family of systems. Now what I postulate is two competitions. One we call the hiders-finders competition; the other is a salvo competition.

"Now the hiders-finders competition, what that is about is developing the capabilities to penetrate contested airspace, contested areas, and an enemy, a thinking enemy who develops countermeasures. It is a cycle. As we develop advantages, they develop countermeasures. Keeping advantage in that cycle in this competition is critically important. In the 1950s, for example – the B-52 was designed about then; 1952 I think was the first flight – the most significant threat to our bombers was aircraft, interceptors, and surface-to-air fires – artillery. So the B-52 was designed to fly at high altitudes, and they gave it a gun in the tail to defend against fighters until SAMs, surface-to-air missiles, came on the scene in the latter half of that decade in the early 1960s. So the Air Force adapted and started flying B-52s at low altitude so it could terrain mask and hide in ground clutter, and fighters couldn't find them effectively, and it designed the B-1 to be a low-altitude, high-speed sprinter to penetrate contested airspace.

"Until, about 1979, DOD announced that, well, Russia, or the Soviet Union has developed "look-down/shoot-down" radars for its fighters, capable of fighting our bombers at low altitude. So they started a program called the Advanced Technology Bomber Program, which led to the B-2 program to buy 132 B-2s to replace the B-52, and that would be a high-altitude stealthy penetrator.

"1990, end of the Soviet Union, we essentially disengaged from this competition. DOD shifted its attention from preparing to fight two regional conflicts against North Korea, Iran, Iraq. They didn't have advanced air defenses, so while it continued to invest in stealth technologies for future platforms, it stopped the B-2 buy at 21 aircraft. And it also shifted the weight of its effort in terms of strike campaigns toward its fighter forces under the assumption that, well, we will be able to deploy our fighter forces very quickly into a theater of conflict, stage them at bases on the borders of our enemies; to bring the high-volume fires. We just didn't need the bombers to do that after the opening stages of a conflict.

"The problem is our competitors didn't stop. China, Russia, Iran, and others have developed advanced air defenses – developed them or bought them – that are a real challenge to our current force. So while we modified our current bomber force to stay current and give it new radars and so on over the intervening years, we didn't invest in a new bomber.

"Now the second competition is what we call the salvo competition, and that occurs between two adversaries who both have PGMs [precision guided munitions], not just the ability to attack with precision but also defend against the PGMs of an enemy. That is the situation we have today, certainly with Russia, China, North Korea, and Iran. They have capabilities to attack our bases in the western Pacific and the Middle East, all of them. So the assumption DOD made in the 1990s, it said: Well, we will rely mostly for strike on our fighters, and we will stage them really close to bases. Those bases are now at risk. That is an increasingly risky proposition. But we can compensate for that by beginning to use bases that are further away from our adversaries that, frankly, are out of the most immediate threat, out of range of those short-range cruise missiles and ballistic missiles. And we can also disperse our fighter forces at those close-in bases to expeditionary airfields, civil airfields suitable for military use, as well as military airfields, to complicate the targeting problem of our enemies who have their own PGMs.

"So what this suggests, both the hider-finder competition and the salvo competition, is we might start thinking about reversing priorities that we established for bombers and fighters back in the 1990s.

"Perhaps future air campaigns, the weight of the strike should be provided by long-range strike capabilities. They are stealthy and have large payloads staged at more distant bases. Whereas our fighters at the close-in dispersed posture provide counter-air, help kick down the door, provide close-air support, and other missions rather than relying on those fighters, which have about one-tenth the payload of a bomber and one-fifth the range of a bomber primarily for strike.

"The Air Force has made a great start – and DOD has as well – at reengaging in both these competitions with the LRS-B, but it is just a start, and it is only one element of a long-range strike family of systems..."

ADVERTORIAL

Artificial Intelligence for Radio Signals Exploitation

image©PROCITEC GmbH

By Hanno Böttcher

Team Leader Signals Classification,
R&D Department PROCITEC GmbH

Artificial intelligence (AI) has long been on the rise in a variety of fields. In automatic image and speech recognition, for example, AI has been performing very well for years and has made modern, more sophisticated applications in the field possible. For this reason, we at **PROCITEC GmbH** began some time ago to investigate and successfully apply AI techniques as part of the further development of our Communications Intelligence (COMINT) and Radio Reconnaissance solutions to suit our customers' Capability Development (CAPDEV) needs.

AI is very often based on the machine learning (ML) approach. Here, an algorithm learns independently to perform a task when the task's solution path is not predetermined; the algorithm finds the solution itself through a special learning phase.

ML achieved a major breakthrough with the application of Deep Neural Networks (DNN). These can now solve increasingly complex tasks through so-called Deep Learning (DL). These DNNs deliver very good results, particularly in the areas of signal-classification and pattern recognition.

Primary steps during the automatic prosecution of a Signal Of Interest (SOI) are detection and classification of the SOI's signaling characteristics. Therefore, it is advantageous to apply neural networks also for these types of auto-tasking. Numerous proposals to achieve this can be found in academic publications. Very often these classification approaches are proposed for use in the field of Cognitive Radio Systems, where, primarily, tasks such as Spectrum Interference Monitoring and Dynamic Spectrum Access are to be solved.

The core techniques and procedures for radio signals exploitation do not only include the detection and classification of signals. Detection and classification are the initial steps on the way to extracting signal content and therefore should not be considered in isolation. The full signals exploitation process can be roughly divided into the following steps:

- Detection of SOIs
- Classification of SOIs
  - Determination of the modulation type
  - Determination of the transmission protocol
- Demodulation and decoding (extraction of the signal content)

Upon detection of individual SOIs, classification is then performed. The modulation type and transmission protocol of the signal are determined. If these are known, the signal can be demodulated and decoded.

Classification can be based on ML approaches or, classically, by defining and directly measuring characteristic parameters of the individual modulation types or transmission methods. The latter approach is often termed 'Expert System'.

At **PROCITEC**, we have been applying the processes described here in our software products to enable the prosecution of radio signals for many years. So far, we have successfully relied on the Expert System approach for the classification of SOIs. In the course of further development and continuous improvement of our products, we have now started to integrate DNN-based approaches into the signals exploitation processes.

As a first step, for modulation types not yet supported in our software, we examined whether DNN-based classification leads to good results and how it can be integrated into the existing process in parallel with our expert system. The basis for this was formed by approaches referenced from previously mentioned documentation.

A crucial challenge in using a DNN is to provide statistically meaningful signal examples in sufficient numbers for its learning phase ('training'). Since in a DNN the decision for a classification, in contrast to the expert system, is not transparently traceable, great care must be taken to determine which characteristic properties the training data set contains and whether these data reflect reality.

In addition, when generating the data set, it is important to selectively vary certain signal parameters (e.g., noise, frequency offset, etc.) so that the DNN can later respond robustly to such variations in the signals in real-world applications. It has been shown that a sufficient data set can only be generated with reasonable effort using artificial signals.

Based on training data generated in this way, we succeeded in training a DNN and evaluating it for SOI-classification using real radio signals. The work was carried out in close cooperation with a local university.

Subsequently, the new DNN was integrated into our existing software. Great attention was paid to the interaction with the existing software components during the integration process. After successful quality tests, **PROCITEC's go2signals** products now feature our first AI-based signal classifiers.

The experience from the development described here has shown that the use of DNNs for the classification of radio signals has very large potential. Therefore, we will continue to push this capability-development initiative at **PROCITEC** and consider that a balanced combination of the proven classical 'Expert System' approach and these newer AI-based technologies will deliver even more effective classification results for our customer and end-user communities.

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Electromagnetic Protection

By Dave Adamy

This month, we begin an EW 101 series on Electromagnetic Protection (EP). In Joint US doctrine, Electromagnetic Protection was known as "Electronic Protection" from 1993 until 2020. Before 1993, it was known as Electronic Counter-Countermeasures (ECCM). While the DOD has evolved Electromagnetic Warfare terminology over time, the Joint definitions of those terms has remained fairly constant. The current definition of EP, as stated in Joint Publication 3-85, is the "Division of electromagnetic warfare involving actions taken to protect personnel, facilities, and equipment from any effects of friendly or enemy use of the electromagnetic spectrum that degrade, neutralize, or destroy friendly combat capability." In the context of our EW 101 EP discussion, we can summarize this further to state that EP involves actions and technologies that help friendly spectrum-dependent systems to maintain their access to the EMS and operate as intended. In a radar, radio or satellite navigation receiver, for example, this can include filters and algorithms that help to mitigate enemy jamming and allow the system to function as normally as possible in a contested or congested EM environment. In our first article of this series, we'll go over some of the basics. (Please note that we are using the DOD's latest Joint EW terminology from JP 3-85, in which most of the terms replace the word "electronic" with "electromagnetic.") – *Editor*

ELECTROMAGNETIC PROTECTION

Electromagnetic Protection (EP) is one of the primary elements of Electromagnetic Warfare, as shown in **Figure 1.** Note that this figure also shows earlier names (ESM, ECM and ECCM) for the currently used EW functions, and it shows the changes in the scope of Electromagnetic Attack (EA) by the addition of anti-radiation missiles (ARMs) and directed energy weapons (DEWs). (Originally, ARMs and DEWs were not considered part of EW because they were weapons.) This has also changed the scope of EP to include protection of their associated sensors against EA.

EP is different from Electromagnetic Support (ES) and EA in the sense that these other two elements usually involve special hardware (sensors, receivers and transmitters). EP comprises features and capabilities designed into spectrum-dependent systems and subsystems to protect them against adversary EA, as well as unintentional interference, and to minimize their detection by adversary ES systems.

Also note that in the context of DOD doctrine it is important to recognize that EP does not involve jamming and does protect platforms against guided weapons. Again, EP protects spectrum-dependent systems, such as radars, communication systems and GPS receivers, by reducing the effectiveness of enemy jamming (ideally, making the jammers completely ineffective), and, as shown in **Figure 2,** EP can be implemented as antenna measures, as receiver functions, or as processor functions:

- **Antenna Techniques**
  - Directional antennas that feed a receiver have narrow beams and provide high gain toward desired signals and significantly lower gain in all other directions, including the direction to a jammer.
  - There are also techniques which generate a null in the antenna pattern in the direction of a hostile emission (such as a jammer). Phased array antennas can be designed with multiple nulls to protect against multiple jammers.
  - Antenna EP techniques prevent jamming signals from entering the receiver.

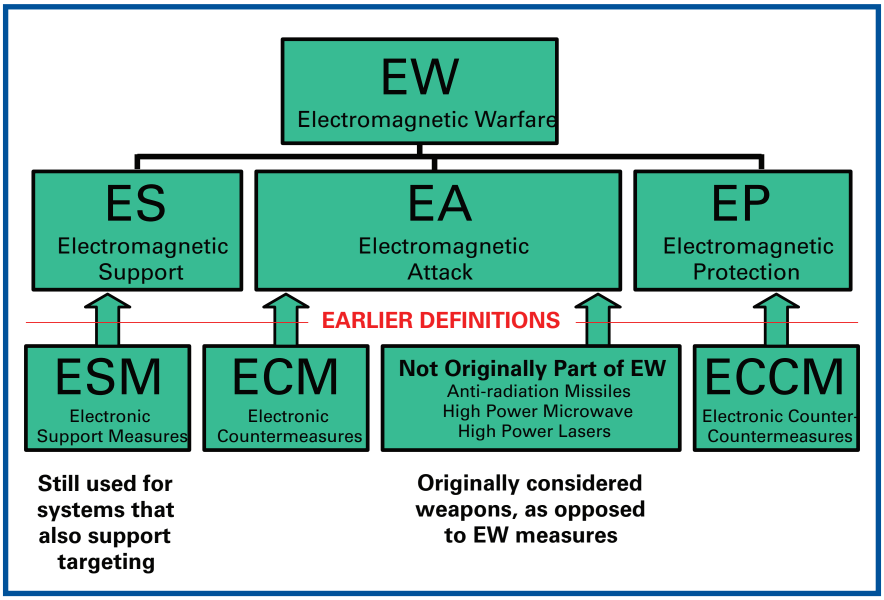

Fig. 1: Electromagnetic Protection is one of three branches of Electronic Warfare. It does not protect platforms against enemy weapons, but rather protects friendly sensors against enemy Electromagnetic Attack and Electromagnetic Support capabilities.

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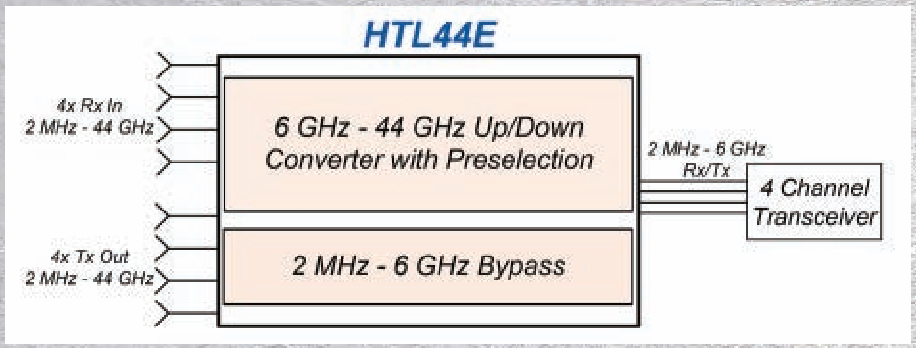

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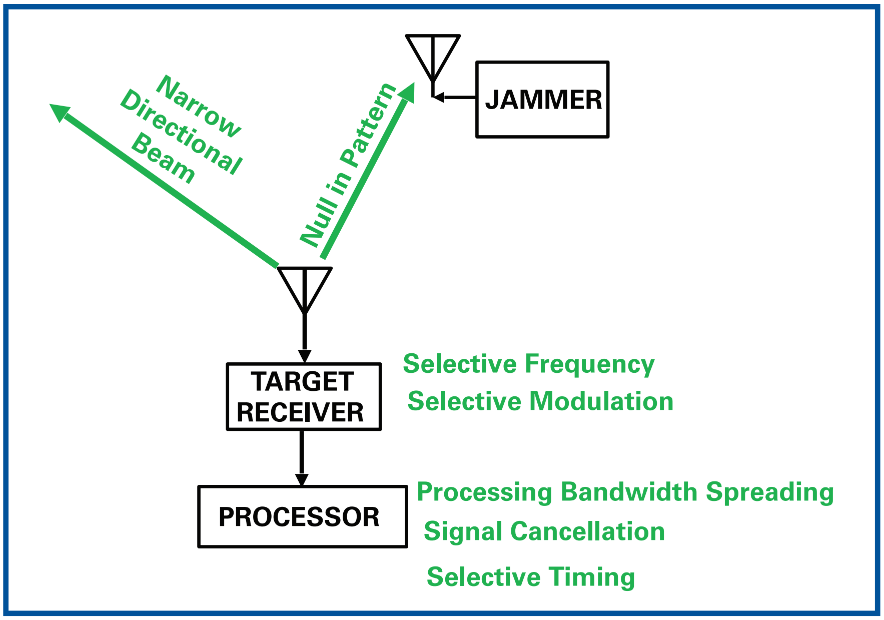

Fig. 2: *EP can be implemented in the receiving antenna, the receiver or the processor of a protected sensor.*

- **Receiver Techniques**
  - Narrow-band receivers will discriminate against signals at frequencies other than that used by the desired signal to be received. As mentioned above, the narrow-beam antenna will also provide gain in the desired direction to allow the desired signal to be received at greater range.
  - If a desired signal changes frequency by sweeping or hopping over a frequency range, a jammer will not normally be able to keep the jamming signal within the bandwidth of the protected receiver. The sweeping pattern will be randomly timed or the hopping frequencies will be randomly selected to prevent an EA system from anticipating the moment-to-moment frequency of the signal.
  - If the desired signal has an unusual or varying modulation, the receiver will discriminate against any signal (including a jamming signal) that does not have that modulation.
  - Receiver EP techniques prevent jamming signals from being output by a receiver.
- **Processor Techniques**
  - If a desired signal has a transmission bandwidth much wider than the bandwidth of the information carried by that signal, the received signal-to-noise ratio will be too low to allow an enemy to recover the information carried by that signal or to detect or locate the emitter. An example is use of a data rate that is increased manyfold by remodulating a digital signal at a much higher bit rate. Note that this causes the transmitted signal to spread over a bandwidth that is significantly higher than the information rate. This is called a direct sequence spread spectrum signal.
  - If a 180-degree delayed signal is added to a hostile received signal, the received signal is cancelled.
  - Information packets of signals can be randomly delayed to prevent coherent hostile reception.
  - Processor EP techniques prevent signal information from being output from the receiving system.

Figure 3 deals with the impact of EA and EP on a weapon-associated radar or hostile communication link. EA makes the threat system less capable, by diminishing the radar's performance and/or preventing the communication system from passing the information necessary for operational success. EP involves modifying the radar or communication transmitter to allow it to receive, process and pass the required information in the presence of hostile EA.

The specific types of EP provided can include:

- Protection against transmitter detection
- Prevention of accurate emitter location
- Reduction of the jamming-to-signal ratio (J/S) achieved by a jammer
- Prevention of side-lobe jamming
- Increased burn-through range

In this new series, we will be discussing the specific features of radars and communication systems which provide EP against specific types of jamming.

What's Next

Next month, we will continue our discussion by the consideration of radar EP techniques. Dave Adamy can be reached at dave@lynxpub.

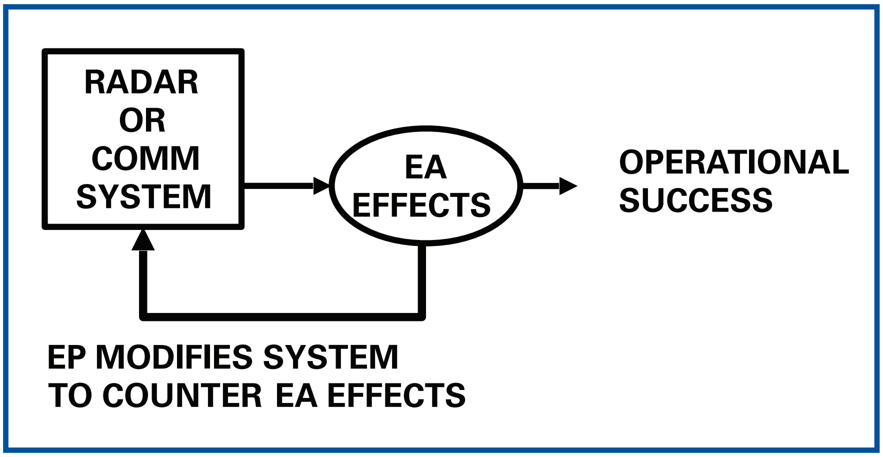

Fig. 3: *Friendly EA is intended to reduce the effectiveness of enemy radars and communication. Enemy EP restores the effectiveness of the hostile sensor in the presence of friendly EA.*

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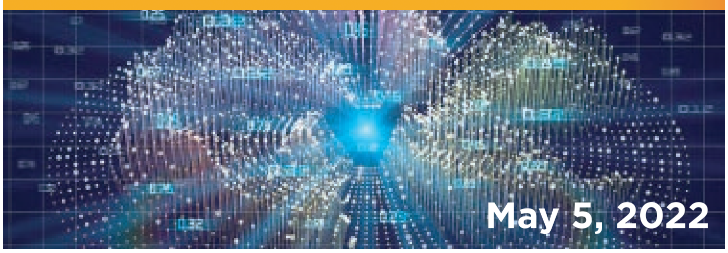

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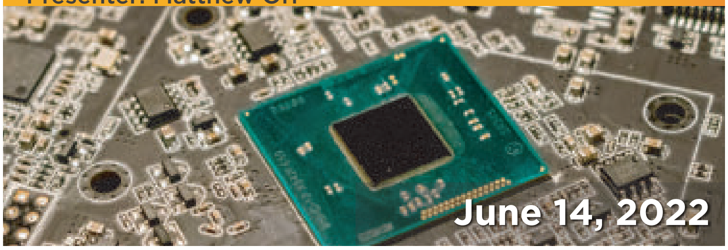

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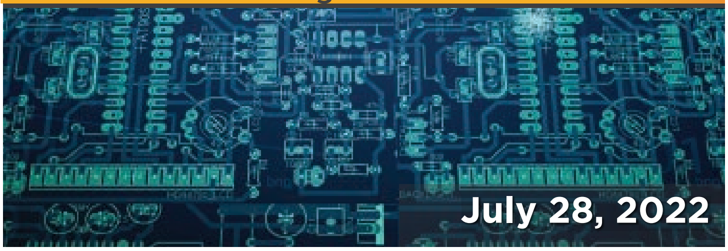

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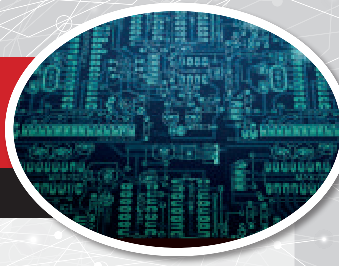

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