ASSOCIATION OF OLD CROWS
Advancing Electromagnetic Warfare TOGETHER
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JED

Journal of Electromagnetic Dominance

A New Generation of EW Decoys

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JED
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Naval decoys are getting a performance boost from autonomous platforms that enable solutions with more size, weight, power and longer endurance. THALES

Cpl Sydney Hassler, an electronic warfare operator with Marine Air Ground Task Force Support Company, 2nd Radio Battalion, II Marine Expeditionary Force Information Group, operates the Communication Emitter Sensing and Attack System (CESAS) II Manpack during an exercise in November at Marine Corps Auxiliary Landing Field 3 Bogue, NC. U.S. MARINE CORPS PHOTO BY CPL. ALEXANDER RANSOM

COVER PHOTO COURTESY OF US NAVY

ENDURANCE

This month's cover story, written by Richard Scott, covers the latest developments in endurance naval electromagnetic warfare (EW) decoys. Most active naval EW decoys have only been able to offer relatively short windows of performance. In spite of the operational advantages that endurance decoys can provide, such as disrupting an adversary's sensors at earlier points in the kill chain, expanding a decoy's performance timeframe has been a difficult goal to achieve – until recently.

One area where active decoys have been able to perform for longer periods is airborne towed decoys. This is because the decoy is tethered to the host platform, where power and jamming techniques can be sent down the towline to the transmitter. This configuration is not so easy to achieve with a naval decoy, which must maneuver separately from the host ship (provide autonomy), present a large RCS (generate lots of power) and respond to agile RF threats (employ reactive jamming techniques) throughout the kill chain sequence. And they must be compact or easily stowed, because available deck space – even on a large surface combatant – is precious. Until recently, these characteristics have been achievable in short-endurance active decoys that were developed for endgame countermeasures applications.

This does not mean "endurance" has not been a long-held goal of EW decoy developers. What has changed in the past decade is the maturing of some key enabling technologies. Today, autonomous air vehicles and unmanned surface vehicles can operate for minutes and hours at the same speeds as surface ships, EW payloads can rely on vehicle power or advanced battery power to generate the required ERP, and the EW technology itself is more compact and less expensive while still being sophisticated enough to operate alone or coordinate with other EW systems to disrupt an adversary's anti-ship missile kill chain. These developments are enabling active decoys to transition from reactively deployed endgame countermeasures to pre-emptively deployed decoys and jammers that can fulfill an escort role. In the future, a ship may be escorted by a formation of two or three of these autonomous decoys to cover multiple threat vectors, such as from a saturation attack. For navies, which have focused more and more of their fire-power on ship self-defense over the past few decades, these decoys will certainly help restore more balance between offensive and defensive missiles.

It's also important to understand that this endurance active decoy technology is not exclusive to any single country or alliance. Earlier this year, four researchers from China's College of Weapon Engineering, Naval University of Engineering, in Wuhan, published a paper, "Study on the Jamming-Position Maneuver Algorithm of Off-Board Active Electronic Countermeasure Unmanned Surface Vehicles," which described a prototype endurance decoy configured on a USV. The decoy was evaluated in simulation. More significantly, however, the paper described how the "active ECM USV" also participated in live-fire tests in which it successfully protected a surface ship from two anti-ship missiles. Endurance active decoys have arrived, and in more places than usual. – *J. Knowles*

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ASSOCIATION of OLD CROWS

AOC Europe

Montpellier, France

10-12 May 2022

INTEGRATING ELECTROMAGNETIC EFFECTS ACROSS ALL DOMAINS

We are pleased to announce the flagship international event of the Association of Old Crows (AOC) will take place in France for the first time next year. Join the EW community in Montpellier on 10-12 May 2022.

Interested in exhibiting?

If you would like to become a sponsor or exhibitor for AOC Europe 2022, please contact Max Webster.

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Calendar *Courses & Seminars*

JANUARY

AOC Virtual Series Webinar: Microwave GPS Spoofing – History and Prevention
Jan. 13
2-3 p.m. EST
www.crows.org

AOC Virtual Series Webinar: Microwave Photonics Improving DRFM Capabilities Against a New Generation of Radars
Jan. 27
2-3 p.m. EST
www.crows.org

Radar EW
Jan. 31 - Feb.4
Shrivenham, Swindon, UK
www.cranfield.ac.uk

FEBRUARY

Communications EW
Feb. 14-18
Shrivenham, Swindon, UK
www.cranfield.ac.uk

AOC Virtual Series Webinar: Tactical ESM
Feb. 24
2-3 p.m. EST
www.crows.org

Advanced RF Electronic Warfare Principles
Feb. 28 - March 4
Atlanta, GA
www.pe.gatech.edu

MARCH

AOC Live Virtual Professional Development Course: Microwave Photonics
March 7-28
10 Sessions, 3hrs. each
www.crows.org

Principles of Millimeter Wave Radar EW
March 9-10
Atlanta, GA
www.pe.gatech.edu

AOC Virtual Series Webinar: How to Use Simulation to Align Your Work Team
March 10
2-3 p.m. EST
www.crows.org

Aircraft Survivability
March 14-18
Shrivenham, Swindon, UK
www.cranfield.ac.uk

SIGINT Fundamentals
March 15-16
Denver, CO
www.pe.gatech.edu

Counter IED Capability
March 21-25
Shrivenham, Swindon, UK
www.cranfield.ac.uk

Infrared/Visible Signature Suppression
March 22-25
Atlanta, GA
www.pe.gatech.edu

APRIL

AOC Live Virtual Professional Development Course: Tactical ISR Principles, Systems, and Techniques
Apr. 4-27
8 Sessions, 3hrs. each
www.crows.org

AOC Virtual Series Webinar: EW and the Moscow Criteria
Apr. 7
2-3 p.m. EST
www.crows.org

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

Calendar *Conferences & Trade Shows*

JANUARY

Surface Navy Association 34th Annual National Symposium
Jan. 11-13
Arlington, VA
www.navysna.org

DSEI Japan
Jan. 26-28
Makuhari Messe, Japan
www.dsei-japan.com

FEBRUARY

Modern Threats: Surface-to-Air Missile Systems Conference
Feb. 1-2
Secret/US Only
Redstone Arsenal, AL
www.crows.org

DEPS Joint Conference on T&E Support to Prototyping and Experimentation
Feb. 1-3
Albuquerque, NM
www.deps.org

Singapore Airshow
Feb. 15-20
Singapore
www.singaporeairshow.com

WEST 2022
Feb. 16-18
San Diego, CA
www.westconference.org

MARCH

AFA Aerospace Warfare Symposium
March 2-4
Orlando, FL
www.afa.org

Dixie Crow Symposium 46
March 20-23
Warner Robins, GA
www.dixiecrowsympsoium.com

IEEE Radar Conference
March 21-25
New York, NY
www.radarconf2022.org

Defence Services Asia
March 28-31
Kuala Lumpur, Malaysia
www.dsaexhibition.com

APRIL

AAAA Mission Solutions Summit
April 3-5
Nashville, TN
www.quad-a.org

Navy League Sea-Air-Space
April 4-6
National Harbor, MD
www.seaairspace.org

Fiesta Crow 2022
April 19-21
San Antonio, TX
www.crows.org

MAY

Cyber Electrometric Activities (CEMA) 2022
May 3-5
Secret/US Only, TS/SCI
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

JUNE

Cyber/Electronic Warfare Convergence
June 7-9
Charleston, SC
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.*

President’s Message

FORWARD TO 2022

Happy New Year Crows! The 58th Annual International Symposium and Convention in Washington DC was a resounding success with more than 2,000 people registered and over 1,750 attending, and the energy that you brought and that I and others experienced was electric and exhilarating. The AOC Staff, Convention Committee, volunteers and Board members did an awesome job making this a wonderful event and “reunion” after two years of being apart, and 2022 will be even better.

As I discussed at the Assembly of Delegates at the 58th Annual International Symposium and Convention – I need you, my fellow Crows, to engage as a team (academia, industry, government and military) to help us execute our new five-year strategy to enable AOC to be successful, grow and thrive in the future. We need you to engage with your Chapters and AOC Headquarters, to help us achieve the AOC 2022-26 strategic goals described below.

1. Grow our global membership commensurate with our market to reach at least 20,000 individual members and 350 industry members by 2026.
2. Build an advocacy and communications enterprise to deliver timely and professional resources and support to stakeholders.
3. Diversify streams of revenue to strengthen our ability to adapt to a changing business environment.
4. Strengthen international programs to reflect our global presence by increasing international membership, enhancing membership experience, and developing a plan to improve member engagement.
5. Grow professional development certification and STEM programs in accordance with recently established roadmaps.

One of my other emphasis areas is investing and growing AOC’s Education Foundation. Educating and informing the Electromagnetic Warfare Community is at the heart of AOC’s mission. Your Professional Development Training hours, EW school curriculum and operational and/or technical experiences can now be applied towards a **Certified Specialist in Electromagnetic Warfare (CSEW) Certification Program, with** three certification levels.

Level 1 is for knowledgeable individuals with 0-5 years of EW/EMSO experience.

Level 2 is for EW Practitioners with demonstrated expertise and 5+ years of experience.

Level 3 is for senior-level EW professionals with demonstrated technical expertise (verified by oral review) and leadership with 20+ years of experience.

The AOC Board of Directors and Governors approved the 2022 budget, which provides significant investment to achieve our strategic goals and execute the operating plan. This will be a journey, not a sprint, and some pieces will take time; Again this is a five-year strategy and plan.

I am truly excited about what 2022 will bring, and I am looking forward to growing our CSEW program and seeing people certified in EW. I and the rest of the AOC Board will be out and about to visit chapters and attend conferences in person and grow our network around the globe. We will continue to reach out to you, and I hope you will reach out to us with opportunities to mentor, support STEM and grow the next generation of Crows. – *Glenn “Powder” Carlson*

ASSOCIATION of OLD CROWS
Cyber Electromagnetic Activity (CEMA) 2022
MAY 3-5
Belcamp, MD
SAVE THE DATE
REGISTRATION OPENS IN FEBRUARY!
The Invisible Battlefield: Deterrence During Competition, Dominance Throughout Conflict
VISIT CROWS.ORG/CEMA2022 FOR MORE INFORMATION

ASSOCIATION of OLD CROWS
EW Capability Gaps & Enabling Tech 2022
MAY 10-12
Crane, Indiana
CALL FOR PAPERS
Technical papers will be sought from United States Government, academia, industry, operational units, and subject matter experts on concepts, technologies and capabilities that will enable Force Level Electromagnetic Warfare.
There will be three sessions focused on Joint Long Range Fires, Joint All-Domain Command and Control, and Information Advantage.
SAVE THE DATE
REGISTRATION OPENS IN FEBRUARY!
VISIT CROWS.ORG/Crane2022 FOR MORE INFORMATION

BABCOCK/ELBIT/QINETIQ TEAM SECURES UK MEWSIC CONTRACT

A team of Babcock, Elbit Systems UK and QinetiQ – dubbed the BEQ collaboration – has captured a £100 million (US$134 million) contract to deliver the UK Royal Navy's next-generation surface ship EW system.

The Ministry of Defence (MoD) announced the long-awaited Maritime Electronic Warfare System Integrated Capability (MEWSIC) Increment 1 contract on November 9. The Babcock-led team was selected ahead of a rival bid led by Thales UK.

MEWSIC Increment 1 – which combines a wideband digital radar electronic support measures (RESM) sensor and an EW command and control (EWC2) subsystem – is the first phase of a £500 million (US$670 million) Maritime Electronic Warfare Programme (MEWP) intended to recapitalize the RN's shipborne EW capabilities. According to the MoD, the new EW suite will allow more simultaneous detection and identification of emitters over a greater frequency range than current capabilities, accelerating decision-making, enhanced situational awareness and improved anti-ship missile defense (ASMD) response.

Under the BEQ collaboration, Elbit Systems UK will provide both the RESM sensor and EWC2 subsystem. Both are part of Elbit Systems UK's proprietary eM-e EW suite, which is itself built on the pedigree of EW systems previously delivered by its Israeli parent to the Israeli Navy, the Royal Canadian Navy and the Royal New Zealand Navy.

The MEWSIC Increment 1 contract will be delivered over a 13-year period, with the new EW equipment suite to be fitted to RN Type 26 and Type 31 frigates from build, and retrofitted to Type 45 destroyers and Queen Elizabeth-class aircraft carriers. The scope of contract also includes in-service support, the provision of training solutions, technical test and integration and technical authority services.

Babcock said that operational sovereignty and freedom of action would be assured by its industry team through "ongoing significant investment in technology and infrastructure in the UK, and throughout the life of the contract, creating new skilled jobs in manufacturing and software development." It added that all ship fits would be undertaken in the UK, together with all new development activity.

The MEWP is intended to deliver an improved maritime EW capability enabled by openness, with the potential to keep pace with developments in anti-ship missile technology, contribute to the development of shared situational awareness, and provide force protection through the automated coordination of ASMD. A follow-on Electronic Warfare Counter Measures (EWCM) effort is also planned as part of the MEWP; it is intended to introduce a new trainable decoy launcher plus a suite of soft-kill countermeasures/offboard EW payloads. – *R. Scott*

AFRL TO DEVELOP NEXT-GENERATION EO/IR SENSORS FOR EW

The Air Force Research Lab Sensors Directorate (Wright-Patterson AFB, OH) is seeking proposals for a new program to develop prototype integrated threat warning systems and advance multispectral test and developmental risk reduction methodologies. The program, Electro-Optic Sensing Defensive Electronic Warfare (EOS-DEW), is part of a larger effort named Multi-Spectrum Defensive Electronic Warfare (MSDEW).

The EOS-DEW program is managed by the Sensors Directorate's Spectrum Warfare Division, Electro-Optic Countermeasures Branch (AFRL/RYWW). The aim of this effort is to develop new sensor technologies that will advance missile approach warning, laser sensing and hostile-fire indication (HFI). This effort will focus on providing sensors that offer better performance than current EO-IR threat warning sensors because the scope of the threat is growing. According to the program's Statement of Objectives (SOO), "...effective missile countermeasure techniques rely on early launch detection and launch envelope timelines, dictating continual improvements in missile warning sensor architectures exploiting different portions of the electromagnetic spectrum. Directed energy threat detection, on the other hand, requires laser detection schemes containing multiple discriminants. The relative fidelity of coherence, wavelength, direction-of-arrival, geolocation, fluence and pulse processing discriminants is dictated by the threat spaces of interest and drives the complexity of warning sensor architectures to satisfy hand-off requirements for protection countermeasures." To address these challenges, one of the program's focus areas calls for development of component hardware and algorithms for advanced EO-IR threat warning systems.

These advances in EO-IR threat warning sensor hardware and software in turn are driving a need for more advanced testing. The SOO states, "Validating the fidelity of sensor architectures requires specialized and customized testing methodologies involving high fidelity threat simulation, radiometry, platform motion simulation, tracker characterizations and data analysis techniques." In response to this need, the EOS-DEW program will address multi-spectral threat simulation, including missile, laser and HFI threat signatures, kinematic motion, atmospheric turbulence and scene clutter. Modeling and simulation tasks will focus on aircraft and missile trajectory generation, missile plume signature generation and laser propagation modeling.

EOS-DEW program funding is estimated at $44.4 million over 4 years. Program officials expect to award one contract for the entire scope of the effort. The program points of contact are Donna Hawes, Program Manager, AFRL/RYWW, (937) 713-8159, e-mail

FRANCE LAUNCHES SIGINT SATELLITE CONSTELLATION

Airbus Defense and Space and Thales Defense Missions Systems have successfully launched three new signals intelligence (SIGINT) satellites into Low Earth Orbit (LEO). The satellites, which provide electronic intelligence (ELINT) and communications intelligence (COMINT) functions, will operate together and collect signals for the Armée de l'Air et de l'Espace (French Air and Space Force). While several European countries operate SIGINT satellites for national intelligence agencies, the CERES satellites are thought to represent the first military SIGINT satellites launched by European nation.

The three CERES satellites, weighing 446 kg (983 lb) each, were lifted into orbit on a Vega rocket from the European spaceport in Kouru, French Guyana, on November 16. They were deployed in a 670-km semi-synchronous orbit with a 75-degree inclination. Each satellite will complete an orbit every 90 minutes. They will be used to detect, identify and locate radar and telecommunications emitters.

The CERES development contract was awarded to Airbus and Thales in 2015 by the French Armament General Directorate (DGA). Airbus is responsible for the overall space segment, including satellite integration. Thales developed the sensor payload, which is about the size of a shoe box according to the company, as well as the ground segment. It is also responsible for the full mission chain from sensor to ground segment. Airbus subcontracted the satellite bus portion to Thales Alenia Space. France's Centre national d'études spatiales (CNES) assisted DGA by procuring the launch services and the ground segment.

DGA started the CERES program following the successful demonstration of a COMINT satellite cluster, launched in 2004 under the Essaim (swarm) program and an ELINT cluster launched in 2011 under the ELISA program. Thales provided the sensor payloads to both programs.

The French Air and Space Force plans for the CERES constellation to achieve operational status in 2022. – *J. Knowles*

donna.hawes@us.af.mil and Daniel Whitman, Technical Lead, AFRL/RYWW, (937) 713-8815 or daniel.whitman.2@us.af.mil. The solicitation number is FA8650-20-S-1119. Proposals are due by January 4, and program officials anticipate a contract award by March. – *J. Knowles*

AIRBUS SIGNS CONTRACT WITH BEL FOR C295 PROGRAM

Bharat Electronics Limited (BEL) (Bengaluru, India) has signed a contract with Airbus Defence and Space to supply both electro-optical and radar warning systems for C295 tactical transport aircraft on order for the Indian Air Force.

Valued at US$93.2 million, the contract covers the supply of radar warning receiver (RWR) and UV missile approach warning systems (UVMAWS) for the C295 program. India ordered 56 C295 aircraft from Airbus in September 2021. Under the contractual agreement, Airbus will deliver the first 16 aircraft in "fly-away" condition from its final assembly line in Seville, Spain. The subsequent 40 aircraft will be manufactured and assembled by the Tata Advanced Systems in India as part of an industrial partnership between the two companies.

The RWR and UVMAWS systems to be supplied by BEL are both based on technology originally developed by India's Defence Electronics Research Laboratory (DLRL) in Hyderabad. The DRDL – India's center of excellence in EW technology – is part of the Defence Research and Development Organisation. – *R. Scott*

IN BRIEF

Kleos Space S.A. (Kockelscheuerm, Luxembourg) is scheduled to launch four new ESM satellites into space from Cape Canaveral on January 10 as part of the SpaceX Transporter 3 mission (Falcon 9 rocket). The new cluster, known as Patrol Mission (KSF 2), will be the company's third ESM satellite group, joining four Patrol Mission satellites and four Vigilance satellites. The new satellites will be launched into a 500-600km Sun Synchronous Orbit. Collectively, the 12 satellites will enable ESM coverage of a 15-degree latitude area on the earth's surface with a revisit rate of approximately five times per day. The company also signed contracts to launch its fourth cluster, Observer Mission (KSF 3), in mid-2022.

The **NATO Communications and Information (NCI) Agency** organized a large counter-drone exercise November 2-12 at the Lieutenant General Best Barracks in Vredepeel, the Netherlands. The event, Counter Unmanned Aircraft Systems (C-UAS) Technical Interoperability Exercise 2021 (TIE21) demonstrated how commercial systems from different NATO Nations could be employed together to defeat commercial drones. According to NATO, more than 20 industry participants deployed around 70 systems during the exercise, including sensors, effectors, command and control systems and threat drones. Among the systems participating in the demonstration was NCI's ARTEMIS prototype, which uses machine learning algorithms to detect and classify drones, and the ARDRONIS drone detection solution from Rohde & Schwarz with the recently released SkyAI Autonomous Optical technology from OpenWorks. The exercise was hosted by the NCI Agency with the support from NATO HQ's Defence Against Terrorism Programme of Work and the C-UAS Joint Nucleus within the Netherlands Ministry of Defence.

Lockheed Martin has exercised a $493 million contract option with **BAE Systems** (Nashua, NH) to upgrade and modernize the ASQ-239 EW system on the F-35 Lightning II. The improved system will provide new sensors and signal processing for enhanced situational awareness and electromagnetic attack. The company will also provide engineering support services and test infrastructure, including the Non-Intrusive Electronic Warfare Test Solution (NIEWTS) fault isolation and diagnostics capability.

Northrop Grumman has received a $153 million contract for continued production of the Advanced Anti-Radiation Guided Missile (AARGM). The contract, awarded by Naval Air Systems Command, covers full-rate production for Lots 10 and 11 of the AGM-88E2 for the US Navy and German Air Force. The contract includes the conversion of AGM-88B High Speed Anti-Radiation Missiles (HARMs) into AGM-88E AARGMs.

Marine Corps Systems Command, Portfolio Manager Command Element Systems (PfM CES), issued an RFI on November 10 seeking industry input for transitioning Programs of Record (PoR) from stove-piped solutions to multi-function Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance / Electronic Warfare (C4ISR/EW) Modular Open Suite of Standards/Sensor Open Systems Architecture (CMOSS/SOSA) systems. The multi-function CMOSS/SOSA systems will perform electromagnetic support (ES), electromagnetic attack (EA) and communications functions in team portable, dismounted and mounted configurations. Communications will feature LPD, LPI, Low Probability of Geolocation (LPG), and Low Probability of Exploitation (LPE) performance. Responses to the RFI were due on December 21. The RFI is significant in that it outlines a future vision for Marine Corps EMS Operations capability, with networked EW and communications distributed across the force. The contracting point of contact is Brittney Moore, e-mail Brittney.moore@usmc.mil.

The **Air Force Program Executive Office for Weapons (AFPEO/WP**), Aerial Targets Program Office (AFLCMC/EBAY) (Eglin AFB, FL) has issued an RFI for "Next Generation Aerial Target Electronic Attack/Electronic Warfare (EA/EW) payload solutions" that can enable aerial targets to replicate the RF signatures and EW capabilities of advanced adversary fighter aircraft. According to the RFI, this would include RF emitters, Electronic Attack (EA) capabilities and expendables, such as chaff and flares, capable of providing adequate fidelity representations of advanced adversary aircraft (Su-57, J-20 and FC- 31) for specific test scenarios. The RFI calls for internally configured EW suites that are low cost (they will be used on attritable targets) and which enable government users to easily reprogram them. Solutions should be at a minimum of Technology Readiness Level 3. The Notice ID is FA867822R0200, and responses to the RFI are due by February 28. The point of contact is Capt Anthony Urbik, 850-883-1330, e-mail anthony.urbik.1@us.af.mil.

The **Defense Advanced Research Projects Agency (DARPA),** Microsystems Technology Office (MTO) issued an RFI on November 16 to identify new approaches and technologies for compact, high energy density electromagnetic pulse (EMP) generation. The RFI, "Generation of Moderate-band Electromagnetic Pulses from Compact Sources" (RFI DARPA-SN-22-08), seeks solutions that overcome the SWAP limitations of electrically sourced High Power Electromagnetic (HPEM) systems and the handling, transportation and deployment constraints of chemically sourced HPEM systems. Based on responses to the RFI, MTO hopes to develop a better understanding of the current state-of-the-art in compact sources capable of generating moderate-band (20 MHz – 5 GHz) EMP and new concepts for compact, portable devices. Portability (deployment by a single individual and/or on volume- and weight-constrained platforms) is a key metric, and both single-pulse and repetitively-pulsed electromagnetic outputs are of interest.

The **US Army** issued an Army Applied Small Business Innovative Research Opportunity (ASO) Announcement on November 16 to solicit proposals for its "Artificial Intelligence/Machine Learning (AI/ML) for Radio Frequency (RF) Modulation Recognition" effort. Under this project, the Army wants to "... demonstrate the ability to interface to a modern Software Defined Radio (SDR) and its Photon digital signal processing framework in order to characterize large swaths of the RF spectrum in near-real-time (NRT) using AI/ML techniques for signal modulation recognition and sorting (Blue Force emitters; Red Force emitters; Civilian emitters); Demonstrate the ability to 'learn' new or unique threat signals of interest so they can be rapidly identified when they transmit." The solicitation further states, "Phase I consists of completing Requirements

Definition, developing digital Interfaces to SDR and Photon, and demonstrating initial modulation recognition AI/ML capabilities for selected signals." Phase II consists of demonstrating advanced modulation recognition capabilities for multiple signal and demonstrating its ability to "learn" unique signals. The Solicitation Number is W50RAJ-20-S-0001_SBIR_BAA_A214-049. Proposals are due January 4.

Lockheed Martin Missiles and Fire Control (Orlando, FL) received a $124.9 million contract option from the Air Force Life Cycle Management Center (Eglin AFB, FL) to produce additional Long-Range Anti-Ship Missiles (LRASMs). The contract covers production of 42 Long Range Anti-Ship Missiles and 24 Weapons Data Links under Lot 6. Deliveries are scheduled to be completed by September 2025.

BAE Systems (Merrimack, NH) has won a $17.5 million contract from DARPA under the Generating RF with Photonic Oscillators for Low Noise (GRYPHON) Program. The company will develop compact, low-noise microwave frequency synthesizers to enable advanced sensing and communication applications. According to a DARPA program description, GRYPHON's aim is to leverage the advantages of photonic microwave generation to develop integrated sources with phase noise performance that meets or exceeds that of the best discrete oscillator modules. The company will perform advanced prototype development, as well as research studies into novel microwave generation techniques and components. In addition to the primary focus on performance and integration, later program phases will harden GRYPHON prototypes to basic environmental stresses sufficient to validate the technology for application-specific maturation after the conclusion of the program. DARPA awarded a separate GRYPHON contract ($4.9 million) to **HQPhotonics Inc.** (Pasadena, CA).

Naval Information Warfare Systems Command (NAVWAR) (Charleston, SC) issued a Request for Information (RFI) on November 9 seeking industry responses about adversary EW and cyber threat simulation. NAVWAR's Communications Technology and Waveform Working Group (CTWWG) Resiliency Sub-Working Group (RSWG), led by the Joint Tactical Networking Center (JTNC) Innovation Branch lab, intends to conduct standardized lab resiliency testing of similar tactical radio-waveform systems in encounters with adversary electronic warfare (EW) and cyber threats to identify candidates for acquisition by the DOD. The JTNC is seeking software and hardware "to represent adversary EW and cyber threats identified by the US intelligence community (IC) as the most likely encountered and most stressful threats to categories of radio-waveform systems under test (SUT)." Initial responses to the RFI were due on December 9. The technical point of contact is William J. Brickner, JTNC Directorate Lead, DoD Communications Standards and Technical Analysis (CS&TA), 619-316-8865, e-mail william.j.brickner1@navy.smil.mil.

Dr. Jerry Wohletz, Vice President/ General Manager of Electronic Combat Solutions at BAE Systems

Dr. Jerry Wohletz

Dr. Jerry Wohletz grew up in Kansas wanting to be an astronaut. He attended the University of Kansas, where he received a Bachelor's degree in Aerospace Engineering before going on to MIT to earn a Master's degree in Aeronautics and Astronautics and then a Ph.D. in Estimation and Control. By the time he finished his Ph.D., he was 29 years old – too old for flight school – and began a different career. Early on, he worked in aircraft design at McDonnell Douglas. He has also held positions at the Air Force Research Lab and NASA's Dryden Flight Research Center. Eventually, Jerry took a position with ALPHATECH, where he pioneered mission control system for autonomous airborne systems. He joined BAE Systems when ALPHATECH was acquired by the company in 2004. After several years at BAE Systems, he became the VP/GM of the company's FAST Labs business, which focuses on developing next-generation technologies in areas as diverse as advanced electronics, autonomy, cyber, EW, sensors and processing. In January 2020, he was named to his current position as VP/GM of Electronic Combat Solutions, which develops EW systems and technologies for a range of programs, including F-15, F-22, F-35, classified programs and LRASM.

JED

What are some of the key things you have learned during your career?

JW

When I first realized I wanted to be an astronaut, I knew that meant I needed to be a fighter pilot first, which meant I needed good grades. So, I started taking steps toward that goal every day. I wasn't starting from a strong position. Fortunately for me, however, Kansas public universities had open admissions for state residents at that time, so I got my one shot – my one opportunity to go to college and pursue my dream. The effort I put into going down that path brought me to where I am today. That road was not always smooth. There were a lot of failures along the way – I never was a fighter pilot, and I'm not sitting here today as an astronaut. But I learned something from every failure; I kept pushing myself to do my best, and I re-evaluated my priority at every transition.

One of the most difficult transitions for me was moving from an engineering role to a manager role. All of a sudden, instead of doing the hands-on work myself, I had to instead redistribute that energy into developing people and leading them to find their own ways of achieving the product, program and the company's objectives. I learned a lot about motivation, and I learned that leadership is the ability to develop a vision and inspire others to achieve great results.

JED

How do you think about EW today?

JW

Full-spectrum, cross-domain EW from the sea to the stars. We understand the threat landscape, and we're focusing on the next challenges facing our warfighters, and systems that outpace the threat. Product velocity, upgradeability and sustainability are priorities, as is maintaining our strong relationships with our customers and partners.

JED

What does EW look like in 2025 and beyond?

JW

2025 is already here. We're focusing on 2040, and we're prioritizing agile engineering, advanced manufacturing and innovative sustainment. We're aiming to create the fastest pathway from the lab to the field as part of our Extreme EW 2.0 (EWX) dual-transformation strategy. The environment is becoming more complex, congested and contested, and threats are evolving. Full-spectrum, multifunction, multi-domain EW with adaptive capabilities is the future.

JED

As EW evolves into electromagnetic spectrum operations (EMSO), how are you thinking beyond EW?

JW

We see the future evolving into a full-spectrum environment to handle the advanced threats. It's important to point out that current and future products need to be designed for Open Missions Systems and continue to take advantage of digital engineering.

JED

Because you have a large Air Force footprint among EW suppliers, how does this affect the company?

JW

We are proud of our Air Force footprint, and equally proud of our Navy footprint that is less well understood but significant, including the F-35C, F/A-18, and LRASM. We have made thousands of EW systems for a variety of different platforms, from large systems to small-form-factor solutions for bombers, fighters, missiles and classified platforms – and with that experience, we are able to constantly look for opportunities to make our processes more efficient, and our systems more exquisitely capable. Core to our EWX strategy is to leverage the current installed footprint to additional platforms across all services, including the Army, as we have recently flight tested our most advanced small form factor payload in an Army exercise.

JED

Beyond profit and loss, what are some of the other areas where you focus your efforts in the ECS business area?

JW

Time-to-market and culture. Product velocity is just as important as performance, cost and schedule, and this is essential for our EWX strategy. Clearly, the bedrock to any strategy is the culture of your team; at BAE Systems, we have a team and culture that is focused on our missions including "We Protect Those Who Protect Us."

JED

What do you need to think about today, that you didn't need to think about 5-10 years ago?

2025 is already here. We're focusing on 2040, and we're prioritizing agile engineering, advanced manufacturing and innovative sustainment.

JW

Today, scientific advances must co-evolve with manufacturing advances. With continuing miniaturization, we have parts that are not even visible by the human eye. We're also thinking about commercial versus custom military electronics to ensure our allied air forces have overmatch against our adversaries, and finding the right manufacturing mix and volume.

JED

How have rapid acquisition initiatives affected the industry?

JW

As I wrap up my third decade supporting this industry, acquisition reform has been a persistent topic, but I am not sure that our industry is any faster or efficient today. Either way, we are moving out to reduce our time to market.

JED

How are you accelerating time-to-market?

JW

Core to our EWX strategy, we are targeting short timelines from contract award to fielding. That means, beyond development reviews and testing, and getting to mission-ready equipment installed on aircraft. We are re-evaluating every aspect of our business model, including converting to a hybrid defense-commercial model. To accomplish this, we are forecasting requirements out 20 years, looking at robust designs, the uncertainty we'll face over that time period, and the critical components we'll need to procure and build – all ahead of the acquisition process.

JED

How do you learn what EW operators want, especially when most of your contact is with the acquisition community and with DOD leadership?

JW

There are really two answers here. First, we take a lot of pride in hiring veterans, many who have firsthand experience with EW and our products. We combine their knowledge with frequent interactions with our broad customer community to help guide our strategies and investments for the future. So, in essence, the first answer is simple, you just talk to them and then do the right thing by addressing their "pain points."

The second answer is that we're constantly examining innovative ways to improve our products that spans future threats to sustainment. We like to create solutions for our customers before they come to us asking for them. For example, our Sustainment team created an EW test tool that can be used in the field to pinpoint sources of problems that help the customer avoid taking the platform apart in some cases, and avoid returning working systems. It has helped them significantly cut maintenance costs and helped our team streamline maintenance support. That's not something our customer came to us and asked for. That was a tool that we saw would make everyone's lives easier and save everyone time and money – so we made it. We do the same with EW operators. We know that our warfighters – bottom line – want to get home to their families. So, we are constantly evaluating our products and finding innovative solutions that will make our data more precise, make the user experience as intuitive as possible, and keep the end user as safe as possible.

Persistent Effect: Decoys for Ship S

By Richard Scott

Ship-launched countermeasures – radio frequency (RF) chaff, infrared (IR) cartridges, RF corner reflectors and active offboard decoys – are long-established as part of the anti-ship missile defense (ASMD) toolbox. Fired from the defended ship to an appropriate range and bearing, these expendable soft-kill devices are designed to break an adversary's "kill chain" by either confusing the targeting solution, distracting the onboard seeker of the inbound anti-ship missile in its search phase, or seducing the missile during its terminal phase to break lock.

However, these soft-kill systems all suffer from three major limitations. First, they are reactive in operation, which means that there is an inevitable delay between receipt of warning, system programming/initialization, launch activation and flyout, and payload deployment/effect. Second, there are the complexities associated with delivering the decoy payload to the right point in time and space so as to ensure that it presents a credible response within the seeker field of view. And third, the decoys themselves have a relatively short duration of effect – anything from just tens of seconds to a few minutes.

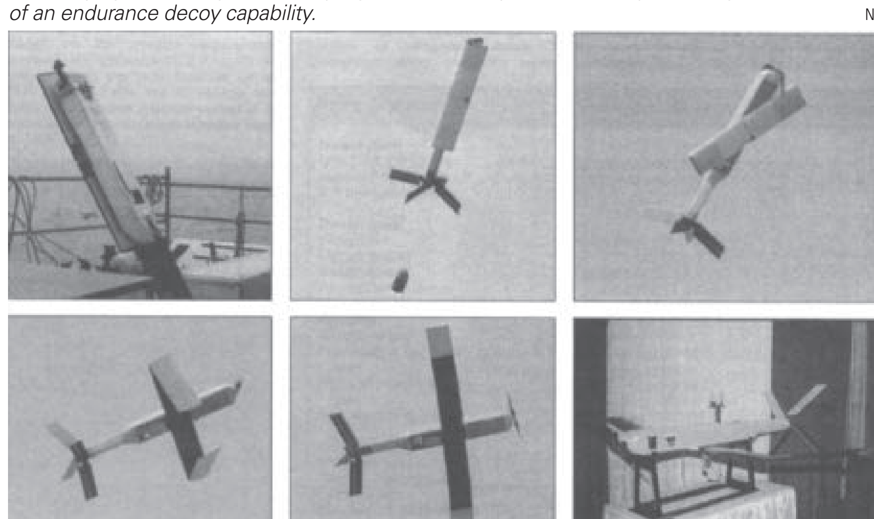
As ASMD warning times are further reduced – whether by means of speed, stealth, or scenario complexity – and the potential increases for sustained salvo attacks, there is recognition of the need to explore alternative had-kill and soft-kill strategies as part of a layered defense approach. One key part of this is the development of electronic decoy payloads that deliver a more persistent effect by means of deployment on a long-endurance carrier vehicle.

Developments in both unmanned surface platforms and air vehicles, coupled with appropriate EW command and control, now offer the prospect of making such strategies viable. The challenge now is to maturing both vehicle and payload technologies, and also the development of robust command and control, and associated tactics/doctrine.

It should be recognized that efforts to design, develop and prototype long-endurance EW payload carriers have in fact been underway for many years. For example, the Naval Research Laboratory's (NRL's) Tactical Electronic Warfare Division, under the sponsorship of the Office of Naval Research (ONR), began research and development in the early 1990s to de-risk and demonstrate potential technology solutions. The first of these Advanced Technology Demonstration (ATD) projects was FLYRT (FLYing Radar Target), a fold-out unmanned air vehicle (UAV) designed to be fired out from a standard Mk 36 launcher using a small rocket booster, then deploy fold-out flight surfaces to transition to powered flight at ship-like speeds.

Claimed to be the first ship-launched EW expendable air vehicle of its kind, FLYRT was tested between 1991 and 1993. Using electric propulsion and containing an NRL-developed fiber-optic gyroscope (providing highly accurate angle rate data), the FLYRT decoy was first modelled in a full-engagement decoy simulator, which provided a detailed model of specific missiles, allowing for close examination of specific soft-kill ploys. In

NRL's Flying Radar Target (FLYRT) program in the early 1990s was a pioneering demonstration of an endurance decoy capability. NRL



Long-Endurance elf-Defense

September 1993, the decoy's performance was fully demonstrated during testing at NRL's Chesapeake Bay Detachment.

FLYRT was followed by Eager, a recoverable, electrically-powered maneuverable tethered rotary-wing vehicle with an RF repeater payload developed by NRL in an ATD running from 1994 to 1996. The concept of operations envisaged Eager being deployed prior to entering a potential engagement area, enabling it to detect the first radar pulse emitted by approaching missiles (in contrast to reactive soft-kill decoys which are not deployed until after a threat is detected). The Eager vehicle demonstrated six hours continuous, autonomous flight in mid-1997 for the ATD program. Payload effectiveness measurements were conducted in the latter part of 1997.

A later NRL effort, again under the sponsorship of the ONR, developed and demonstrated a DFRM-based electronic attack (EA) payload suitable for installation on board an unmanned surface vehicle (USV). To demonstrate utility for ship self-protection, NRL teamed up with the Naval Sea Systems Command's Carderock Division to integrate the payload onboard the High Speed Unmanned Sea Surface Vehicle (HS-USSV), a remote-controlled 11-m hydrofoil USV.

An initial EA experiment with the HS-USSV was conducted in August 2006 focusing on ASMD. Using a shore-based anti-ship missile simulator to track the ship target, the experiment examined the set of effective station positions that would prevent the threat radar seeker from tracking the target vessel. According to NRL, the experiment revealed that an unmanned surface platform performing EA could deny radar tracking of the target vessel using generic jamming waveforms. Subsequent testing examined performance in the counter-surveillance role.

BEYOND AOEW

The Advanced Offboard Electronic Warfare (AOEW) program was established by the US Navy back in 2012 to deliver a new long-endurance offboard countermeasures capability for use in

The AOEW program is developing the AN/ALQ-248 Active Mission Payload to integrate with the MH-60R and MH-60S helicopters. LOCKHEED MARTIN coordinated EW missions against current and future anti-ship missile threats. While the use of an unmanned payload carrier was seriously considered, the US Navy in 2014 announced that it would fulfil the AOEW requirement by mounting a self-contained EW pod – hosting both high sensitivity receiver and EA subsystems – on MH-60R and MH-60S helicopters to provide battle groups with enhanced electronic surveillance and ASMD countermeasure capabilities. Lockheed Martin Rotary and Mission Systems (Sytacuse, NY) is developing the pod – designated AN/ALQ-248 – under contract to the Naval Sea Systems Command (NAVSEA). A number of engineering development models (EDMs) are now supporting AN/ALQ-248 test and certification activities. NAVSEA awarded a first low-rate initial production contract to Lockheed Martin in September 2021.

Notwithstanding the choice of a manned payload carrier for AOEW, it has remained in the Navy's mind to seek an unmanned and autonomous long-endurance EW decoy flight vehicle for ASMD. Going back to 2015, the NRL disclosed Future Naval Capability (FNC) S&T effort intended to mature a rapid reaction Ship-launched EW Extended Endurance Decoy (SEWEED). The proposed concept envisaged a rocket-launched expendable vehicle that would transition to rotor-borne flight for rapid deployment and orientation.

Key technologies to be addressed under the SEWEED FNC included surface treatments and airframe materials/geometry for EW-compatible antenna isolation, payload thermal management and advanced control algorithms. The project also investigated power and propulsion aspects, such as a swashplate-less rotor and rotary-wing rapid deployment.

However, the SEWEED effort did not progress beyond completion of the preliminary design. Based on evolving mission and payload technology, NRL concluded that "payload SWAP [size, weight and power] and overall SEWEED vehicle size [could] be greatly reduced".

Instead, NRL's Vehicle Research Center went on to develop and test the Netted Offboard Miniature Active Decoy (NOMAD) low-cost rotary-wing mini-UAV as a part of ONR's NEMESIS (Netted Emulation of Multi-Element Signatures Against Integrated Sensors) Innovative Naval Prototype (INP) program. The NEMESIS INP set out to develop a system of systems providing the ability to synchronize EW effects across a variety of distributed platforms so as to create a coherent and consistent EW response that confuses adversary surveillance and targeting systems. As well as the development of modular and reconfigurable EW payloads, the program also encompassed decoy and unmanned air and surface platforms and the implementation of EW functionality and decoys with autonomy, networking and countermeasures coordination techniques.

The NOMAD vehicle developed by NRL features flip-out counter-rotating coaxial rotors located at either end of a longitudinally-extending body. The system, developed as part of ONR's Netted Emulation of Multi-Element Signatures Against Integrated Sensors INP, is shown here during testing from USS Coronado *in August 2017.* US NAVY

TO LEAP TO LEEP

Capable of deployment as either as a single unit, or in a coordinated "nest" of multiple decoys, the tube-launched NOMAD vehicle developed by NRL features flip-out counter-rotating coaxial rotors located at either end of a longitudinally-extending body. A soft-launch CO_2 ejection system is used to eject the round.

First at-sea launches of NOMAD were performed from the guided-missile destroyer USS *Pinckney* during mid-2016 as part of the RIMPAC 2016 exercise. During testing, the air vehicle achieved 30 minutes flight time – twice the expected endurance – so allowing NOMAD to keep up with the ship for more than 8 nmi, including transit at 20 kt.

Further testing of NOMAD was performed from the Littoral Combat Ship USS *Coronado* in August 2017. In this series, multiple NOMAD vehicles were launched in quick succession, conducted formation flying operations, and were then recovered sequentially on board. This marked the first time that the NOMAD multi-launch/recovery technology had been trialed on a US ship.

Subsequent to these demonstrations, ONR in 2019 released a special program announcement for a Long Endurance Advanced Off-board Electronic Warfare Platform (LEAP) as the basis for a follow-on capability to complement the AN/ALQ-248 pod. Key target requirements included: a launcher assembly that fits within the deck space allocated for EW topside equipment aboard the DDG-51 Arleigh Burke class destroyer design and maximizes number of decoys available for use; the ability to deploy and transition to stable controlled flight while providing safe and stable separation from the ship; autonomous flight control capability, to include collision avoidance, with an ability to accept mission tasking at launch with waypoint updates from a shipboard control station and the ability to reposition and realign to maintain focus on the threat; ship-relative navigation with air and sea platform awareness with the ability to operate in a GPS-denied environment; a minimum flight endurance of one hour on station; the capability to employ modular EW payloads in both the primary RF and EO/IR domains; operation in conditions up to Sea State 5 (>20 kt steady winds); and secure bi-directional communication between the decoy and the control station.

A number of small scale study contracts were subsequently let to industry for the concept development of candidate LEAP payloads (in both RF and EO/IR bands). BAE Systems, Raytheon and Lockheed Martin all received contract awards.

The LEAP effort subsequently went quiet, but in October 2020 the Navy disclosed plans to move forward with a Long-Endurance Electronic Decoy (LEED) program. According to the Navy's Fiscal Year 2022 budget request, LEED will deliver an expendable long-endurance autonomous off-board decoy countermeasure system, comprised of a flight vehicle and a modular RF payload, for ASMD. Budget documents further stated that LEED will integrate with the AN/SLQ-32 shipboard EW system, and "provide the fleet with enhanced EW coordination and capability, including the ability to stretch engagement timelines and counter heterogeneous missile attacks".

The intention is that LEED countermeasure development Phase 1 will be initiated in FY2022. This will include competitive development of operational-level countermeasure prototypes that demonstrate and validate critical capabilities, including flight performance and RF functionality.

Phase 2 will build on the critical technologies from Phase 1 to develop production-representative Engineering Development Models. LEED will be developed alongside the ONR's LEAP effort – now retitled as the Long Endurance Airborne Platform – and will leverage technologies developed and matured under this same effort.

ANOTHER NOMAD

As one of a number of initiatives intended to recapitalize the Royal Canadian Navy's EA capability, the Naval Electronic Attack Recapitalization – Unmanned (NEAR-U) project aims to implement and test a potential solution to improve naval platform survivability by incorporating an EW payload into an existing USV platform. This system – also adopting the acronym NOMAD, in this case short for Naval Off-Board anti-Missile Active Decoy – is being tested and evaluated as an offboard active decoy or jammer for ship and task group ASMD, as well as serving as an EW test set for radar testing and training.

In May 2019, Rheinmetall Canada was awarded a C$4.5 million contract to lead the NOMAD effort. Under the award, the company is delivering two NOMAD systems that integrate an EW payload into QinetiQ Target Systems' Humpback USV (a variant of QinetiQ's existing Hammerhead unmanned surface target vehicle modified for specific payload applications).

It was announced in October 2019 that Israel's Elbit Systems had been selected by Rheinmetall Canada to supply the DRFM-based EW payload for the program. This system is able to generate a range of EA techniques (including coherent and non-coherent jamming, wideband noise, noise cover pulse, range gate stealing, and multiple false target generation).

The USV and the NOMAD system are designed for launch, recovery and remote control from a larger surface combatant, such as a frigate, with line-of-sight control to be maintained from the controlling platform at ranges of not less than 2,000 m. Prior to launch, the mast and the mast-mounted components of the NOMAD system will be installed on the USV. For recovery, the USV with the NOMAD system will be recovered from the sea and, once on board the host ship, the mast and mast-mounted components of the NOMAD system will be removed from the USV and prepared for storage.

Israel's Rafael Advanced Defense Systems has exploited technology from its C-Pearl-DV digital ESM and Digital Shark EA systems to develop a lightweight, compact EW module suitable for unmanned vehicles. Drawing on this technology solution, the company has pursued the development of a dedicated EW variant of its Protector USV system able to contribute to both ASMD and area defense. According to the company, the modular EW payload includes a wideband digital receiver subsystem, an advanced multi-channel DRFM-based techniques generator, and directional solid-state multibeam array transmitters offering high ERP. The EA subsystem, based on a GaN AESA technology, transmits both coherent and non-coherent responses, and is able to support both distraction and seduction modes of operation. Rafael claims a multi-threat capability, and has engineered payload solutions offering either 180 deg or 360 deg spatial coverage. The company adds that it offers flexible installation to support topmast or integrated mast designs. Control of Protector EW is exercised remotely via a datalink. This also allows for the uplink of mission taskings and threat library updates, and downlink of situational awareness and jamming scenario status.

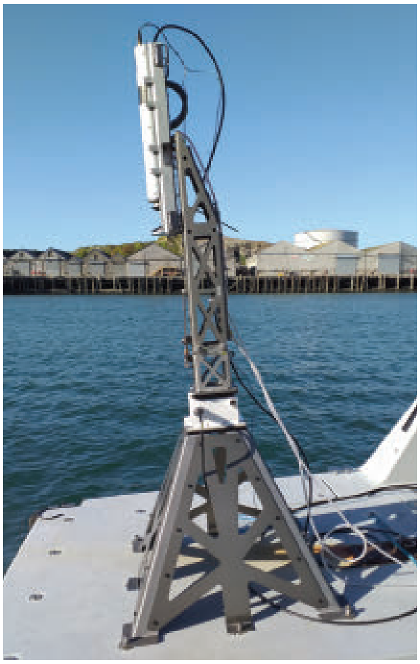
Rafael has developed a dedicated EW variant of its Protector USV system designed to contribute to both ASMD and area defense. RAFAEL

PLANS EWCM

The UK Ministry of Defence (MoD) and the Royal Navy (RN) are currently proceeding with a major recapitalization of the RN's surface ship EW capability under the umbrella of the Maritime Electronic Warfare Programme (MEWP). The first phase of this effort, known as the Maritime Electronic Warfare System Integrated Capability (MEWSIC) Increment 1, covers the delivery into service of a new wideband digital electronic support measures (ESM) system and an EW command and control (EWC2) subsystem for EW planning and realtime coordination.

The second phase of MEWP, known as Electronic Warfare Countermeasures

Thales UK used its Halcyon USV demonstrator to demonstrate an offboard EW payload as part of the NATO NEMO trial in late 2019. The EW payload was originally developed by Thales for the joint French/UK ACCOLADE Technology Demonstrator Programme. THALES



(EWCM), is planned to introduce a trainable decoy launcher system and a new suite of offboard countermeasures. Consideration is being given to a number of potential maritime offboard active decoy technologies, including expendable delivery vehicles, unmanned air systems and electronic payloads.

The MoD's Defence Science and Technology Laboratory (Dstl) has undertaken extensive operational analysis in support of EWCD and has also undertaken research activities to explore a future recoverable offboard decoy system. One concept that has been explored is a quick-reaction multi-rotor rotary-wing UAS carrier vehicle that could take a compact EW payload aloft for 20-30 minutes. An alternative concept studied by Dstl would use a fully autonomous USV – possibly an adaptation of a standard Pacific 24 seaboat – configured with an EW payload.

Dstl's understanding has also been informed by work completed by Thales UK to demonstrate an offboard EW payload fitted to a USV. This self-funded activity was showcased in late 2019 as part of the NATO Naval Electro Magnetic Operations (NEMO) trial undertaken off the south coast of England.

As part of the NEMO 19 event, Thales demonstrated the use of an offboard active RF payload mounted on board the company-owned USV testbed *Halcyon*. The active RF payload was originally developed by Thales for the joint French/UK ACCOLADE Technology Demonstrator Programme (TDP), which completed in February 2016. Although the original ACCOLADE concept of a maneuvering expendable airborne carrier vehicle was not fully matured, the TDP de-risked a number of enabling technologies for future ASMD countermeasures, including a miniaturized RF payload featuring an advanced techniques generator derived from Thales's own Scorpion shipborne jammer.

According to Thales, the NEMO 19 trial allowed investigation of stabilization performance and propagation effects close to the sea surface and also demonstrated the feasibility for autonomous control of an off-board EA asset. While the ACCOLADE payload encapsulation already had its own stabilization, Thales additionally built an azimuth positioner/stabilization mount for installation on *Halcyon's* aft deck. That was in turn integrated with *Halcyon's* own stabilization system.

Across the Channel, French countermeasures and pyrotechnics group Lacroix in 2020 revealed a package of studies and associated risk reduction work aimed at demonstrating the feasibility of an active offboard decoy deployed using a UAV. Known as VESTA (Véhicule Ejecté Support Tactique d'Autoprotection), the concept development effort has been funded under a call released by France's Agence Innovation Défense. The accelerator project, being undertaken in partnership with specialist UAV house Aviation Design, is intended to establish the feasibility of reactive soft-kill anti-ship missile defense decoy that employs a maneuvering multi-rotor UAV to deploy a jammer payload.

According to Lacroix, the VESTA decoy is intended to provide an additional and complementary layer of ship self-protection, operating inside the envelope of hard-kill anti-air guided missiles but further offboard than typical soft-kill seduction decoys. The current program is focused on the launch system and the performance of the multi-rotor carrier vehicle: the EW payload itself is outside the scope of the project.

In Lacroix's concept, a rocket boost motor is used to power the VESTA round offboard. Once deployed to range, the air vehicle deploys six rotor arms and transitions to controlled flight. The EW payload, housed in the forward section of the flight vehicle body, then begins to transmit a suitable jamming modulation.

TIMING

As anti-ship missile technologies mature and threat tactics continue to evolve, the need for endurance naval EW decoys is becoming more apparent for ship defense. After decades of concept demonstrations and assessments, the time for procuring a new generation of decoys has arrived.

5G Communications – Part 10

Communications Jamming of 5G Signals

By Dave Adamy

After a brief sidebar about propagation formulas over the past couple of columns, we are returning back to our main discussion of 5G communications.

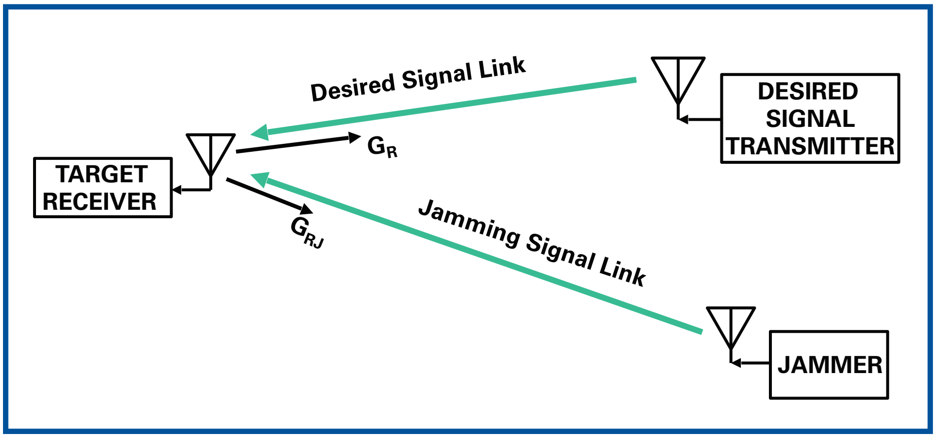


Fig. 1: Both the desired signal and the jamming signal are received by the target receiver. The J/S is the ratio between these two signals as input to the target receiver.

COMMS JAMMING

5G signals are communications signals, so the formulas for communications jamming apply. Every communications link includes a transmitter, a transmitting antenna, a receiving antenna and a receiver. It is important to remember that all communications jamming requires that the jamming signal be directed to the receiver in the jammed link. We will call the receiver being jammed the target receiver. The jamming-to-signal ratio compares the jamming signal strength in the target receiver to the desired signal (from the link transmitter) in the target receiver. **Figure 1** shows the 5G link that is being jammed and the jamming link.

The effective radiated power (ERP) of the desired signal is the product of the transmitter output power and the gain of the transmitting antenna in the direction of the target receiver. Likewise, the ERP of the jammer is the output of the jammer's transmitter and the gain of the jamming antenna in the direction of the target receiver.

The general formula for the jamming-to-signal ratio is given by the formula:

J/S = ERPJ – ERPS – LJ + LS + GRJ - GR

Where: *J/S* is the jamming-to-signal ratio in dB,
ERPJ is the effective radiated power of the jammer in dBm,
ERPS is the effective radiated power of the desired signal transmitter in dBm,
LJ is the propagation loss between the jamming antenna and the target receiver antenna in dB,
LS is the propagation loss between the desired signal transmitter antenna and the target receiver antenna in dB,
GRJ is the gain of the target receiving antenna in the direction of the jammer in dB, and
GR is the boresight gain of the target receiving antenna in dB

Note that it is normal practice in jamming problems to assume that hostile antennas are oriented in the optimum direc-

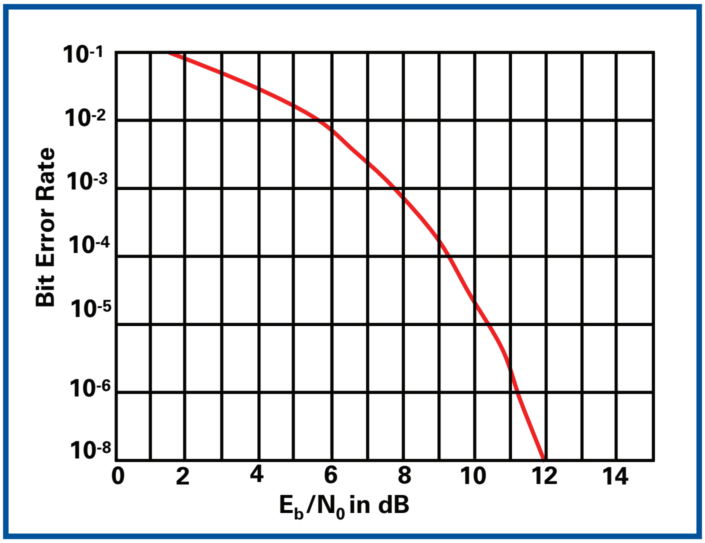


Fig. 2: For digital quadrature phase shift keying (QPSK) signals, the bit error rate is a function of the E_b/N_0 as shown on this graph.

tion. In this case, the target receiver's antenna would be aimed at the desired signal transmitter.

There is a very important case in which the target receiving antenna has 360 degrees azimuthal coverage. This is provided by a whip or dipole antenna. These are sometimes called "omni-directional" antennas, but this is not true because whip antenna has a null in the direction of the whip and a dipole antenna has a null in the directions of each of its elements. For this special case the jamming to signal ratio formula is simplified because the two antenna gain values cancel each other in the equation:

J/S = ERPJ – ERPS – LJ + LS

Note that the low- and mid-band 5G links will normally use 360 degree antennas, while the high-band (mmW) links will normally us directional phased array antennas.

EFFECTIVE JAMMING

5G links pass their information in digital formats. There are two ways in which jamming can prevent a digital link from passing its information. Since a transmitted signal must pass data in serial format (i.e., one bit at a time) there must be a way that the receiver is synchronized to the transmitter to reconstruct the transmitted signal. If the synchronization approach is simple, it would be very efficient to prevent the receiver from synchronizing properly. However, the synchronization approaches can be very robust, so it is normally best to jam the receiver by creating large numbers of bit errors. A bit error is a transmitted "one" that is received as a "zero" or vice versa.

As shown in **Figure 2,** the bit error rate (BER) is a function of E_b/N_o (the ratio of energy per bit (Eb) to the spectral noise density (No)). The BER is the total number of incorrect bits divided by total number of transmitted bits. E_b/N_o is the pre-detection signal-to-noise ratio in the target receiver adjusted for the bit rate to bandwidth ratio of the link. If this ratio is unity, E_b/N_o is the pre-detection signal to noise ratio abbreviated CNR (carrier noise ratio) or RFSNR (radio frequency signal-to-noise ratio).

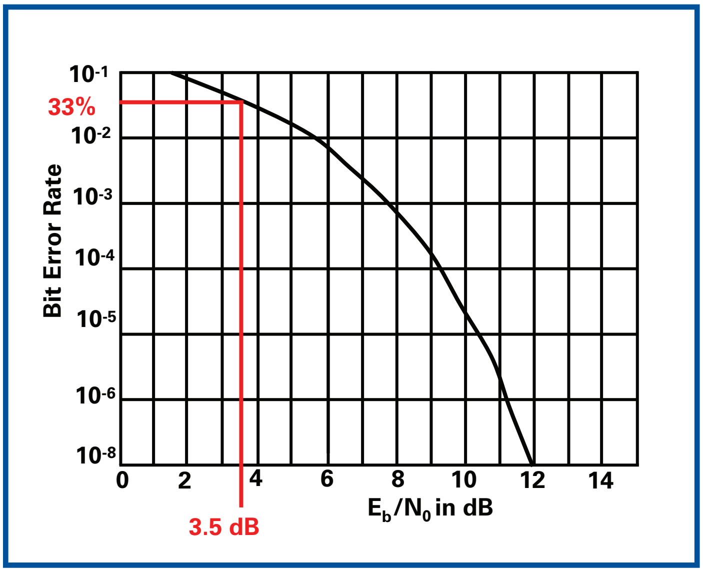


Fig. 3: A 33% bit error is caused by a 3.5 dB E_b/N_0.

The required bit error rate to support effective jamming is typically taken as 33%. However, if some types of information are transmitted, a lower bit error rate may be adequate. An example is steering commands transmitted to an unmanned platform. From **Figure 3,** you can see that 33% BER would require an E_b/N_o of about 3.5 dB. For quadrature phase shift keying (QPSK) modulation, the 3-dB bandwidth is 0.88 times the clock rate. This is the typical bandwidth for digital transmission. Setting the clock rate at 500Mbps (i.e., the middle of the mid frequency 5G range), the transmission bandwidth would be 440MHz. The ratio of the bit rate to the bandwidth is thus 0.88. This is approximately minus 0.5 dB, which makes the required jamming-to-signal ratio 3.5 dB - 0.5 dB = 3 dB.

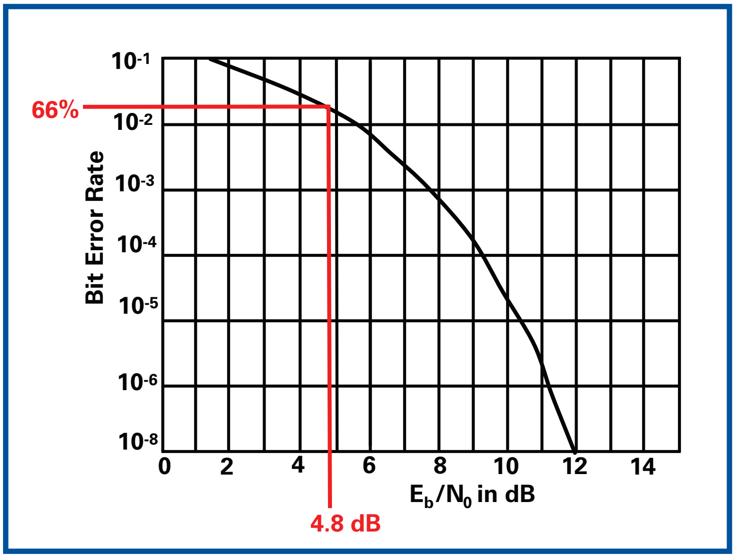


Fig. 4: A 66% bit error is caused by a 4.8 dB E_b/N_0 . This leaves a 33% bit error rate after half of the errors have been corrected.

ERROR CORRECTION CODES

In military applications, it makes good sense to protect the links with error correcting codes. If a Reed Solomon block code is applied, the number of incorrect words in a code block can be corrected up to a limit. A word is a group of bits, and a block is a group of words. That limit is half of the difference between the total number of words in a block and the number of data words. In many of the examples in literature, the added word-to-data-word ratio is 1 to 1. This means that half of the errors caused by jamming (or anything else) would be corrected, which reduces the bit error rate by half. This means that effective jamming of a link with error correction requires 66% bit error rate. From **Figure 4,** this can be seen to require 4.8 dB (less 0.5 dB) equals 4.3 dB jamming-to-signal ratio.

WHAT'S NEXT

Next month, we will continue our discussion of 5G signal jamming by running some link calculations for various engagement scenarios. For your comments and suggestions, Dave Adamy can be reached at dave@lynxpub.com.

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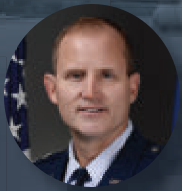

BANQUET SPEAKER
Maj Gen Cameron Holt
SAF/AQC

KEYNOTE SPEAKER
Brig Gen Tad Clark
HAF A2/6L

GUEST SPEAKER
Col William Young
350th SWW/CC

SCHEDULE OF EVENTS

SUNDAY, MARCH 20

Registration	Best Western Plus Executive Residency, Warner Robins, Georgia	5:00 PM-8:00 PM
Welcome Reception	Best Western Plus Executive Residency, Warner Robins, Georgia	5:00 PM-8:00 PM

MONDAY, MARCH 21

Registration/Lunch	Southern Landings Golf Course, Warner Robins, Georgia	11:30 AM-12:55 PM
Spring Golf Tourney	Southern Landings Golf Course, Warner Robins, Georgia	12:00 PM Tee Time

TUESDAY, MARCH 22

Registration	Century of Flight Hangar, Museum of Aviation	7:00 AM-6:00 PM
Exhibits Open	Century of Flight Hangar, Museum of Aviation	7:00 AM-7:00 PM
Exhibitor Reception	Century of Flight Hangar, Museum of Aviation	5:00 PM-7:00 PM

WEDNESDAY, MARCH 23

Registration	Century of Flight Hangar, Museum of Aviation	7:00 AM-2:00 PM
Exhibits Open	Century of Flight Hangar, Museum of Aviation	7:00 AM-3:00 PM
Crows N.E.S.T.	INDIVIDUAL SCHOOL EVENT	
Banquet	Nugteren Exhibit Hangar, Museum of Aviation	Cocktails – 5:30 PM-6:30 PM Dinner – 6:30 PM-8:30 PM

WELCOME TO DIXIE CROW SYMPOSIUM 46!

Our Symposium Committee, Dixie Crow Chapter President, Adam Delestowicz, and the Chapter Directors cordially invite you to join us for all the exciting events described here. Thank you in advance for your support of this important electromagnetic spectrum.

Sincerely, Lisa Frugè-Cirilli, *Chair* | lisa.fruge@baesystems.com
Tristan Caruso, *Co Chair* | Tcaruso33@gmail.com

VIRTUAL EVENT

8TH ANNUAL THE CROW'S

N.E.S.T.

(Novel Experiments with Science & Technology)

Already in progress: The Dixie Crow Chapter's approach to our 8th Annual Crows N.E.S.T. will be focused on providing monetary donations to surrounding schools to supplement the teacher's STEM classroom planning. (Unfortunately, there will be NO student STEM event during our Symposium as in years past.) However, we will still provide all participating schools' students with t-shirts displaying Industry logos and names of our Dixie Crow Chapter Education Foundation Donors! We greatly appreciate your support educating our "Leaders of Tomorrow!"

REGISTER NOW! WWW.DIXIECROWSYMPOSIUM.COM

PLEASE CONSIDER DONATING TO AEF!

Start the new year off right, and consider making a contribution to the AOC's Educational Foundation (AEF) and help our mission to assist future crows in their career goals.

Through the AEF, AOC distributes over $250,000 annually for scholarships and grants to assist military enlisted personnel and U.S. undergraduate students in electrical engineering, physics, mathematics, and related disciplines.

The foundation also supports STEM education relating to the electromagnetic spectrum to middle and high school students worldwide.

To donate: Text DONATE2AEF to (202) 858-1233, scan the code to the right or if you are on-site at AOC 2021, you can visit the Membership Desk in the Crows' Nest.

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JED QuickLook

US Space Force Lt Gen Stephen Whiting, Space Operations Command commander, and US Space Force Chief Master Sgt John Bentivegna, SPOC senior enlisted leader, watch a presentation on the experimental Multiband Assessment of the Communications Environment (MACE) system at Peterson Space Force Base, CO. During his visit, General Whiting presented USSF Space Delta 3 - Space Electromagnetic Warfare with an award recognizing it as "Best Missions Delta." Some of DEL 3's accomplishments include creating the first ever exchange officer position for the Royal Air Force, embedding the first remotely piloted aircraft pilot in the DEL 3, and deploying members with the US Marine Corps' 31st Marine Expeditionary Unit to support USMC operations. The award was accepted by DEL 3 commander Col Christopher Fernengel. Former DEL 3 commander, Col John Thein, was also invited to the award ceremony to acknowledge his contributions before leaving DEL 3.

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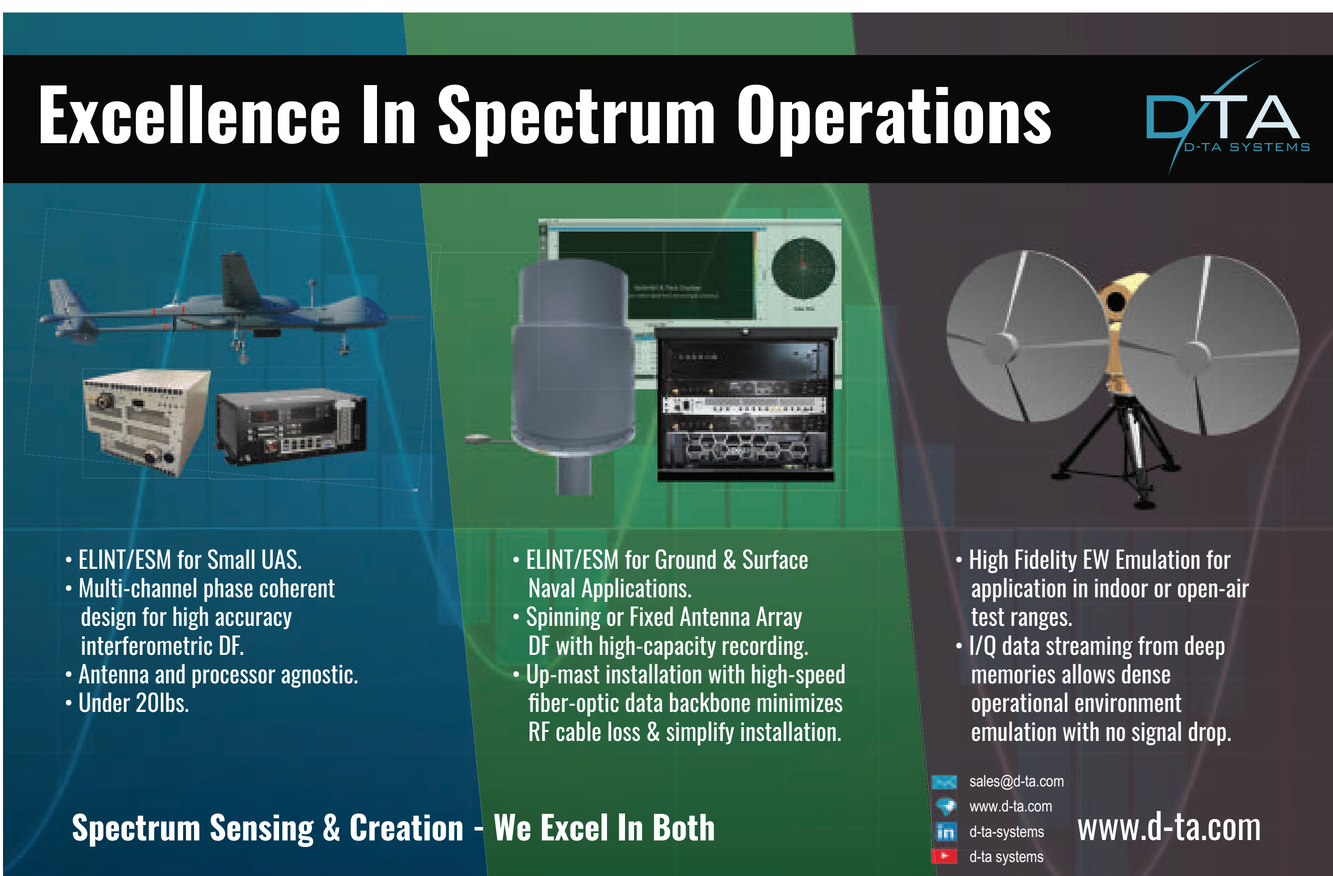
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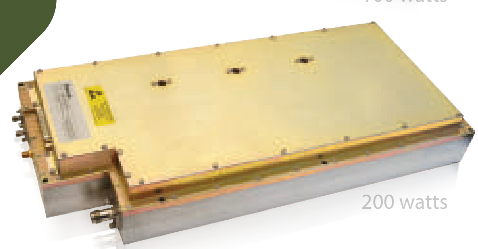

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