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Advancing Electromagnetic Warfare TOGETHER
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JED

Journal of Electromagnetic Dominance

Camouflage, Concealment and Deception in the EMS

- Artificial Intelligence in EW and SIGINT
- News: AFRL Plans Mjolnir HPM Weapon Prototype
- EW 101: More About ISR Applications of 5G


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Journal of Electromagnetic Dominance

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Potential adversaries can utilize a wide range of EO/IR, radar and ESM sensors to detect, locate and identify targets across the electromagnetic spectrum. This is driving ground forces to focus harder on concealing their EMS signatures, whether it is multispectral camouflage (above) or radars and radios that employ low-probability-of-detection (LPD) waveforms. TDU SAVUNMA SISTEMLER

COVER PHOTO COURTESY OF SAAB

Cryptologic Technician (Collection) 2nd Class Jeremy McLoud prepares to load a chaff canister into an Mk36 launcher onboard the USS John S. McCain (DDG 56) as it operates in the waters near Japan. McCain is assigned to Task Force 71/Destroyer Squadron (DESRON) 15, the Navy's largest DESRON and the US 7th Fleet's principal surface force.

US NAVY PHOTO BY MASS COMMUNICATION SPECIALIST 3RD CLASS ARTHUR ROSENN

CAMOUFLAGE, CONCEALMENT AND DECEPTION

Our cover story this month, written by Andrew White, takes a look at camouflage, concealment and deception (CCD) in the EMS – something *JED* has not written about for many years. Why haven't we covered this for so long? The answer is that for the past 30 or so years, CCD hasn't been at the forefront of military planning. Just as western air forces have trained two generations of pilots that have mostly operated in permissive, low-threat air environments, so too have ground forces planned, organized and trained two generations of soldiers with who have little experience with enemy aircraft, air-to-ground munitions or heavy artillery. This western attitude is changing, however, as Russia, China, Iran and other potential adversaries reshape their forces to leverage commercial advances in autonomous vehicles, ubiquitous battle networks, advanced sensors and long-range precision weapons. Russian forces have used the conflicts in eastern Ukraine and in Syria to demonstrate how tactical UAVs equipped with multispectral sensors and datalinks can find ground targets 10, 30, or even 50 km behind the front line and immediately relay the information to artillery units that can attack entire formations with fairly precise long-range fires.

In the face of these developments, western military planners are beginning to realize the importance of CCD in the EMS. This is going to be a long haul, however. CCD is a part of EMS maneuver that doesn't normally receive a lot of attention – even within the EMS Operations (EMSO) community. We have traditionally focused more on EMS maneuver in the context of offensive RF electromagnetic attack (EA) and electromagnetic support (ES) activities and less on Electromagnetic Protection (EP) measures. In most western armies, the EP community is hard to find because it is so small and balkanized, and perhaps because it is so poorly defined and understood by military leaders. In fact, can we even say there is an EP or CCD community in any western army? Russia, on the other hand, has a dedicated unit: the 45th Separate Engineer-Camouflage Regiment. Some may chuckle at their inflatable tanks, but the larger point is that Russia is thinking in CCD terms while western armies are still discovering the challenges they are facing on a modern connected battlefield with lots of adversary EMS sensors and weapons.

This is not to point a finger at anyone. As I mentioned, *JED* is only waking up to these problems after many years of neglect. The bigger challenge is to recognize that our ground forces can't simply buy a new set of multispectral camouflage or low-probability-of-detection radios and check "CCD" off the to-do list. Like anything in EMSO, it requires an EMS-centric shift in our thinking. In addition to equipping for CCD, we need to develop more people with CCD skills, burn EP it into our EMS maneuver planning and train with it in our force level exercises. 21st century CCD is a core element of EMSO, and we need to treat it that way. *– J. Knowles*

JED
Journal of Electromagnetic Dominance

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Calendar *Conferences & Trade Shows*

SEPTEMBER

MSPO 2019
September 7-10
Kielce, Poland
www.targikielce.pl

Satellite 2021
September 7-10
Washington, DC
www.satshow.com

AAAA Aircraft Survivability Equipment Symposium
September 13-14
Kissimmee, FL
www.quad-a.org

AFCEA 2021 Intelligence and National Security Summit
September 13-14
National Harbor, MD
www.afcea.org

SPIE Security + Defense 2021
September 13-16
Madrid, Spain
https://spie.org/conferences-and-exhibitions/security-and-defence

DSEI
September 14-17
London, UK
www.dsei.co.uk

AFA 2021 Air, Space and Cyberspace Conference
September 20-22
National Harbor, MD
www.afa.org

Modern Day Marine
September 21-23
Quantico, VA
www.marinemilitaryexpos.com

AOC Asia Virtual Summit
September 28
www.crows.org

2021 EW Live
September 28-30
Tartu, Estonia
www.electronic-warfare-live.com

OCTOBER

AOC Europe
October 11-13
Liverpool, UK
www.aoceurope.org

AUSA 2021
October 11-13
Washington, DC
www.ausa.org

10th Annual AOC Pacific Conference
October 18-22
Honolulu, HI
www.fbcinc.com/e/aocpacific

AUVSI Unmanned Systems Defense Phase III – Virtual
October 19-21
www.auvsi.org

Precision Strike Technology Symposium (PSTS-21)
October 19-21
Laurel, MD
www.ndia.org

Seoul ADEX 2021
October 19-24
Seoul, ROK
www.seouladex.com

Directed Energy Systems Symposium
October 25-29
Washington, DC
www.deps.org

NOVEMBER

Defense & Security 2021
November 1-4
Bangkok, Thailand
www.asiandefense.com

2021 Aircraft Survivability Symposium
November 2-4
Monterey, CA
www.ndia.org

Dubai Airshow 2021
November 14-18
Dubai, UAE
www.dubaiairshow.aero

MILCOM 2021
November 29 – December 2
San Diego, CA
www.milcom.org

I/ITSEC
November 29 – December 3
Orlando, FL
www.iitsec.org

58th Annual AOC International Symposium & Convention
November 30 – December 2
Washington, DC
www.crows.org

Avalon 2021
November 30 – December 5
Geelong, Victoria, Australia
www.airshow.com.au

JANUARY 2022

Surface Navy Association 34th National Symposium
January 10-14
Arlington, VA
www.navysna.org

FEBRUARY 2022

Modern Threats: Surface-to-Air Missile Systems Conference
February 1-2
Redstone Arsenal, AL
www.crows.org

European Microwave Week 2022
February 13-18
London, UK
www.eumwa.org

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

AFCEA West 2022
February 16-18
San Diego, CA
www.afcea.org

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


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Calendar *Courses & Seminars*

SEPTEMBER

AOC Virtual Series Webinar: Radar Ambiguities
September 9
1400-1500 EST
www.crows.org

AOC Professional Development Live Web Course: Aircraft RCS Engineering
September 13-29
www.crows.org

Test and Evaluation of RF Systems – Online
September 14-16
www.pe.gatech.edu

AOC Virtual Series Webinar: US Loses First Global Space War to Russians
September 16
1400-1500 EST
www.crows.org

Infrared Technology and Applications – Open Access
September 21-24
Atlanta, GA
www.pe.gatech.edu

AOC Virtual Series Webinar: Bandits at Three O'Clock! The RAF's Chain Home Radar and British Strategic Success
September 23
1400-1500 EST
www.crows.org

OCTOBER

AOC Virtual Series Webinar: 5G for Critical Communications
October 7
1400-1500 EST
www.crows.org

Airborne EW System Integration
October 19-21
Atlanta, GA
www.pe.gatech.edu

Electromagnetic Materials and Measurements: RAM, Radome and RAS
October 19-21
Atlanta, GA
www.pe.gatech.edu

AOC Virtual Series Webinar: Eliminating the Pain of Transitioning EW Systems from Lab Tests to Field Tests
October 21
1400-1500 EST
www.crows.org

Principles of Modern Radar
October 25-29
Atlanta, GA
www.pe.gatech.edu

Signals Intelligence (SIGINT) Fundamentals
October 26-27
Lake Buena Vista, FL
www.pe.gatech.edu

Basic EO-IR Concepts
October 26-28
Lake Buena Vista, FL
www.pe.gatech.edu

Basic RF Electronic Warfare Concepts
October 26-28
Atlanta, GA
www.pe.gatech.edu

Phased Array Radar Systems
October 26-28
Atlanta, GA
www.pe.gatech.edu

NOVEMBER

AOC Virtual Series Webinar: The Spectrum of AI Applications
November 4
1400-1500 EST
www.crows.org

Radar Principles
November 15-19
Shrivenham, Swindon, UK
www.cranfield.ac.uk

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

ENGAGEMENT AND SPREADING THE MESSAGE

There were two recent events that I encountered that I believe link to our mission. First, our local chapter (Granite State Chapter) hosted a social event (attended a minor league baseball game), and one of our young Crows informed us that he was leaving his current defense industry job and was going to a commercial company. He was curious whether he should remain a Crow or not. Myself, our regional director (who had come from out of state to attend the event), our chapter president and others said of course you can remain a Crow. We explained that we are more than EW and that the Spectrum is integral to almost everything we do in today's world.

Second, I was boating in New Hampshire, heading back to my marina; there were thunderstorms on the north side of the lake. The weather forecast and radar predicted that the storms would remain to the north, but my gut told me to head back. I was returning along the south side of the lake and came upon a classic mahogany boat that was not moving, and its engine covers were up. I slowed down and maneuvered to see if the other boater needed assistance, and they did. Their engine was pumping water into the bilge when running. They did not have the correct tools and were in trouble. The storms were moving south, the wind was increasing, and the lake was getting rough. I had the tools they needed, and in our brief conversation I discovered that their dock was very close to mine. They were drifting close to other boats and ultimately the shore. We rigged a towline, and I began the tow back as they continued to work on the engine and bail water. During the tow, they were able make a temporary fix to run the engine safely and run under their own power. I disconnected the towline and followed them in case the temporary fix failed. We safely reached the docks just prior to the storm arriving.

"So," you may ask, "Powder, what's the point?" We never know what circumstances will put us in a position to engage with others, provide assistance, answer questions, gain new friends, retain members and have a positive impact on others. I could have bypassed the boat in distress, and they might have fixed it without me. Someone else could have assisted them, or they could have foundered and possibly sank. Our young Crow could have left our event wondering if membership was only applicable to some and if the AOC cares about its members. I hope when presented with situations to assist, talk and answer questions that we engage and spread the word; the world is a better place when we interact and help each other.

Elections are coming. This is your opportunity to elect future leaders of AOC, so spread the word, engage and vote. Later this month, we are hosting a new virtual event, AOC Asia, which I think you will enjoy. We are also holding more in-person events: AOC Europe, AOC Pacific Conference, and of course our 58th International Symposium and Convention. Hopefully, I will see some of you at these events. – *Glenn "Powder" Carlson*

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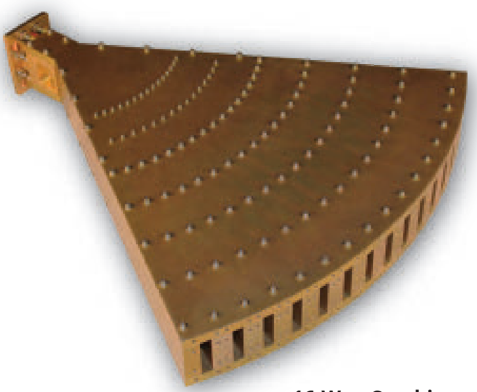

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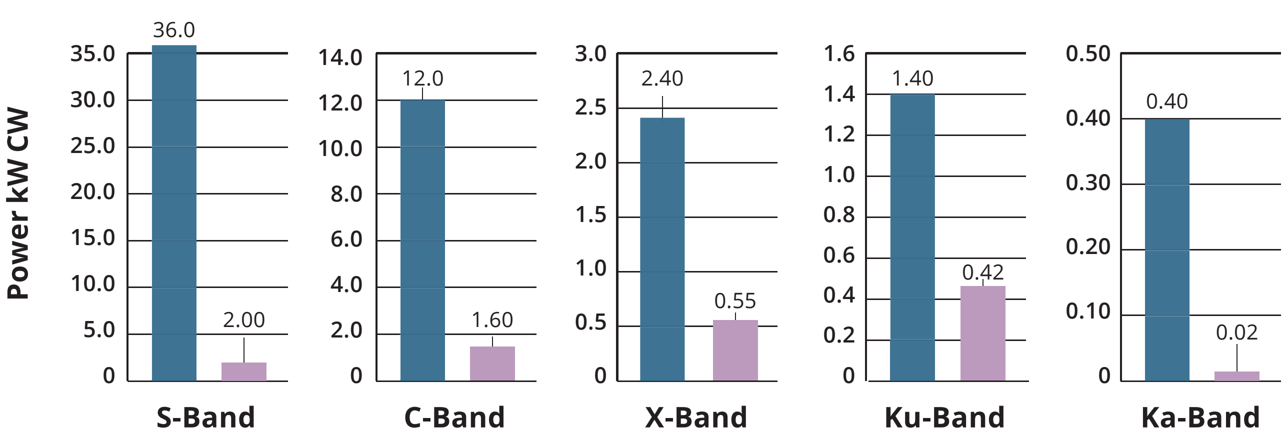

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AFRL PLANS MJOLNIR HPM WEAPON PROTOTYPE

The Air Force Research Laboratory's (AFRL's) Directed Energy Directorate (Kirtland AFB, NM) has disclosed plans to develop a new high-power microwave (HPM) weapon system prototype intended to leverage from AFRL's existing Tactical High-Power Operational Responder (THOR) technology demonstrator. Given the name Mjolnir – recounting mythical Norse god Thor's hammer – the new system is intended to demonstrate advances in HPM technology for the counter unmanned aerial systems (UAS) mission.

AFRL's goal with Mjolnir to develop a "blueprint" for industry partners in order to grow the embryonic industry, and to ensure that a future HPM weapon can be economically produced in volume. The current THOR system has been under test since 2019, including a 2020 field demonstration in Africa. Designed to be able to disable the electronics in multiple UASs, so providing a capability against swarm attacks, the system is housed in two standard 20-ft containers that can be deployed by air and assembled by a crew of just two.

On July 28, the Directed Energy Directorate's High-Power Electromagnetics Division (AFRL RDH) issued a call (FA9451-21-S-0001 Call 0006) for the follow-on Mjolnir effort under its Directed Energy Technology Experimentation Research (DETER) program. The Mjolnir project aims to "procure a single, near-production representative, cost- effective counter-unmanned aerial system (cUAS) that is suited to operational environments and performs at levels equal to or greater than AFRL's existing Tactical High-Power Microwave Operational Responder (THOR) cUAS prototype. This prototype development intends to capitalize on earlier high-power microwave (HPM) systems and enable future transition to a program of record," according to the program description. Program officials anticipate awarding a single contract, valued at approximately $20 million, for the 36-month Mjolnir effort.

AFRL is working closely with cross-service partners in the Joint Counter Joint Counter-Small Unmanned Aircraft Systems Office and the Army's Rapid Capability and Critical Technologies Office. The Mjolnir HPM program is planned to start later in 2021, with the delivery of the prototype weapon scheduled for 2023. Proposals are due by September 13. The contracting point of contact is Ms. Deborah Moyer, +1 (505) 853-6494, e-mail deborah.moyer@us.af.mil. – *R. Scott* and *J. Knowles*

CROWN SETS OUT TO MATURE EUROPEAN MULTIFUNCTION RF SYSTEM

The European Commission has awarded a €10 million grant to a seven-nation consortium led by Indra for the design and development of an airborne multifunction radio frequency (RF) system based on active electronically scanned array (AESA) technology.

Known as CROWN (Combined Radar, cOmmunications, and electronic Warfare fuNctions for military applications), the program is intended as the first step towards an EU program for an AESA-based multifunction RF system embodying functionality for radar, electronic warfare and communications. The project, which has been co-financed by the European Defence Agency within the Preparatory Action in Defense Research (PADR) initiative, aims to ultimately mature multifunction AESA technologies to Technology Readiness Level 4. The long-term goal, is to continue developing these technologies in a subsequent development phase and mature them to TRL 7, when they will be demonstrated in an aerial platform by 2027.

According to a notification issued by the EU, the CROWN study program, will last for 30 months from July 2021. As well as developing critical components and system technologies, CROWN is also intended to establish roadmaps and priorities avoid dependencies on non-EU supply chains.

Spain's EW systems house, Indra, will coordinate management of the CROWN project. It will additionally lead the technical activities on Work Package 6 (wideband Digital Beam Forming [DBF]) and Work Package 9 (laboratory demonstration) alongside participation in the remaining work packages. These include tasks such as requirements and architecture definition, plus other technical activities related to the AESA antenna, resource manager, and compact transmit/receive module (TRM) definition and implementation.

Other industry participants in the CROWN project comprise Thales DMS (France), Office National d'Etudes et de Recherches Aerospatiales (ONERA – France), Hensoldt Sensors (Germany), Saab (Sweden), Leonardo (Italy), and Elettronica (Italy). Fraunhofer Research (Germany), the Swedish Defence Research Agency, TNO (Netherlands) and the Baltic Institute of Advanced Technology (Lithuania) are also participating.

CROWN is intended to exploit a number of advanced technologies, including new broadband digital AESA architectures for multifunction operation; antenna technologies supporting multifunction shared apertures; algorithms and processing for digital beamforming; artificial Intelligence for smart resource management; and monolithic microwave integrated circuit integrated circuit design using different semi-conductor technologies – such as Gallium Nitride and Silicon germanium – for compact, high power, wide bandwidth and tunable TRMs.

A small-scale prototype (TRL 4) will be designed, manufactured and tested in a laboratory environment. System modelling will integrate models from the main building blocks (antenna, TRMs, DBF and the software-based resource manager) to assess the performance of the defined system in different scenarios. – *R. Scott*

EUROPEAN COMMISSION ANNOUNCES EW-RELATED CAPABILITY PROJECTS

The European Commission (EC) has awarded contracts for several electronic warfare (EW)-related development projects under its European Defense and Industrial Development Programme (EDIDP).

Within the scope of the EC's defense technology strategy, studies and research are conducted under the Preparatory Action on Defence Research (PADR) program. This work is continued into the "capabilities" phase under the EDIDP. In late June, the EC awarded €158.3 million for 26 EDIDP projects that were identified in response to research calls issued in 2020. Several of these will be conducted under the Permanent Structured Cooperation (PESCO) framework, which enables EU member states to plan, develop and invest in shared capability projects.

Among the recently announced EDIDP projects are:

CARMENTA: The €8.1 million, 30-month CARMENTA project aims to design a future airborne self-protection system capable of countering a wide range of current and evolving threats. "It will use artificial intelligence and cognitive behavior to support the operation of the system in a complex environment [and] will be based on open architecture and international standards to allow easy integration into existing and future platforms and for the implementation of new technologies," said the EC. Italy's Elettronica is coordinating an eight-nation consortium comprised of Leonardo (Italy); Thales DMS, MBDA and Safran Electronics and Defense (France); Indra and Airbus Helicopters Espana (Spain); Airbus Defence and Space, Airbus DE, Hensoldt Sensors and Saab DE (Germany), Terma (Denmark), DA Group (Finland), and BPTI (Lithuania)

JEY-CUAS: The Joint European sYstem for Countering Unmanned Aerial Systems (JEY-CUAS) is among the largest of the 2020 PADR projects with the EU contributing €13.5 million of the €15 million program cost. JEY-CUAS seeks to "advance technologies at system and subsystem level to develop a new generation C-UAS system based on a modular and flexible plug'n'play architecture to address the emerging challenge of micro and mini drones increasingly used for defence purposes." This effort draws on expertise from 38 organizations working across radar, EO/IR sensors and EW. Leonardo (Italy) is serving as coordinator. EW companies, such as CERBAIR (France), Elettronica (Italy), Hensoldt, (Germany), Indra (Spain), Rheinmetall Electronics (Germany) and Saab (Sweden), are supporting the JEY-CUAS project.

SIGNAL: The Photonics-bAsed SIGINT payloaD fOr Class II RPAS (SIGNAL) project will develop a photonics-based ESM and ELINT system for Class II unmanned aerial systems.

According to the project description, "A major advantage of the solutions is that it can be installed on small flexible platforms that can be updated and deployed according to the threats and battlefield scenario evolution in order to ensure Information Superiority in complex and/or saturated electromagnetic environments." The EU is providing €2.5 million toward this €3.1 million program. DAS Photonics (Spain) is the project coordinator, with support from DA Group (Finland) and Tekever UAS (Portugal).

PADIC: The Passive Acquisition by Digital Convergence (PADIC) effort is focused on developing a network of passive radars for coastal and harbor defense applications. According to the program description, "The project will make use of low-cost and commercially available passive radars across Europe that are spectrally non-congesting during peacetime, while sustainable and immune against stealth attempts during conflicts. It will also maximise the performance through digitalization towards function-transparent, software-defined sensor hardware platforms." Saab (Sweden) is leading a group that includes Finland's Patria and Estonian firms Rantelon and CAFA Tech in this €5.9 million (€4.8 million EU contribution) effort.

Most of the EDIDP projects will run for 2-3 years and will culminate with technology demonstrations. – *R. Scott* and *J. Knowles*

US ARMY FOCUSING ON AIR-LAUNCHED EXPENDABLES VEHICLE DESIGNS

The US Army's Combat Capabilities Development Command (CCDC) is seeking proposals from companies to conduct configurations, trades and analyses (CTA) for its nascent Air-Launched Effect (ALE) Science and Technology (S&T) program. Under the ALE concept, the Army wants to develop a family of small, attritable unmanned air systems that can be deployed by manned helicopter, such as the Future Airborne Reconnaissance Aircraft (FARA). The ALE platforms will fly out ahead of the manned aircraft, provide ISR information to the FARA via datalinks and engage targets with kinetic and non-kinetic weapons. The FARA and ALE will work together in a manned-unmanned teaming paradigm.

As described in the solicitation, "The synergistic effect of the ecosystem enables the penetration and dis-integration of an adversary's Anti-Access Area Denial (A2AD) environment, which is comprised of an Integrated Air Defense System (IADS), Integrated Fires Complex (IFC), and electronic warfare (EW) systems. ALE must be able to detect, identify, locate, report (DILR), and deliver lethal and non-lethal effects against threats across multiple scenarios and domains in a constantly changing Operational Environment (OE). ALE will provide RSTA and organic extension/standoff to the FARA ecosystem, using supporting Long Range Precision Fires (LRPF) to deliver effects against peer threat IADS, IFC, and electronic warfare (EW) systems."

The CCDC's Aviation and Missile Center (AvMC), Technology Development Directorate - Aviation (TDD-A) is soliciting the proposals for the ALE CTA effort. According to the solicitation, the focus of the CTA work is to identify key ALE aircraft design trades, including dash airspeed, stowed volume, and propulsion type. A separate series of trade analyses is looking at ALE payload types.

The solicitation number is W911W6-21-R-0014, and proposals are due by September 13. This is a small-business set aside effort. The contracting point of contact is Brian Cosgriff, +1 (757) 878-2306, e-mail brian.m.cosgriff.civ@mail.mil. – *J. Knowles*

UNICORN BLUE TO EXPLORE NOVEL SIGINT, OFFENSIVE CYBER SOLUTIONS

Geon Technologies LLC (Columbia, MD) and North Point Defense (Rome, NY) have each been awarded $49.9 million contracts to investigate advanced techniques and technologies for signals intelligence (SIGINT) and cyber exploitation under the Air Force Research Laboratory's (AFRL's) Unicorn Blue program.

According to the AFRL, the Unicorn Blue program is intended to enhance and upgrade capabilities for intelligence, surveillance and reconnaissance (ISR) missions and Offensive Cyber Operations (OCO). The 60-month contracts, placed by the AFRL's Information Directorate (Rome, NY) in July, will see Geon Technologies and North Point Defense work to develop and mature digital signal processing capabilities able to scan through the RF spectrum to detect high priority emissions. The companies will also perform research, development and integration of technologies that will provide collection, detection, exploitation and geo-location capabilities of emerging signals of interest for various collection platforms.

Unicorn Blue has been established in response to the emergence of adversary/threat systems embodying techniques and technologies simultaneously using multiple portions of the electromagnetic spectrum and cyberspace. "As such, novel processing techniques are required to provide decision-makers with relevant information in near real-time," according to the Statement of Work. "New technologies will enable edge processing against emerging communications targets. Software Defined Radio development will be heavily leveraged to promote modularity in distribution of the newly developed capabilities. New algorithms will be developed for implementing machine learning (ML) and artificial intelligence (AI) methodology to add greater autonomy to unmanned sensors."

In its original Unicorn Blue solicitation, the AFRL noted the increased challenge posed for SIGINT operations against uncooperative, denied targets in environments characterized by noise, channel conditions and obfuscation efforts. It further identified the need to alleviate the high workload of mission analysts through increased automation, aided by AI/ML, to perform modulation identification, internal data structures and overall signal classification.

Against this backdrop, Unicorn Blue is intended to focus on providing real-time processing solutions - while expanding the unique knowledge and experience base -- to automatically extract the contents of transmissions and provide time-critical alerts and information on the signals collected. Additionally, this effort will develop prototype systems that can be rapidly fielded, upgraded and transitioned to the frontline community to meet current and emerging requirements.

The Unicorn Blue program is focused on two general lines of effort: ISR capabilities for tactical and strategic forces, and capabilities for cyberspace operations. "Work undertaken will intrinsically develop, improve, and/or advance capabilities for both ISR and OCO," said the Statement of Work. "Unique signal processing methods will be explored to expand multi-access techniques OCO opportunities. Innovative Cyberspace applications will create capabilities for network awareness and effects while exposing new ISR opportunities."

SIGINT research and development for ISR will be grouped into three broad technology areas: Information Extraction, Signal Processing, and Automation Enhancements. Information Extraction mines information from broadband signals to identify and catalog Signals of Interest. Signal Processing distinguishes the signal communication layers for the information extraction capabilities. This area represents research and reverse engineering of complex RF waveforms to recover channel or multiple channels data. Automation Enhancements uses AI/ML to automate the manual signal processing techniques currently in practice which are insufficient against the emerging electromagnetic spectrum. – *R. Scott*

HENSOLDT FLIGHT TESTS ADVANCED SIGINT CAPABILITIES

Hensoldt has concluded a flight test campaign intended to demonstrate new airborne signals intelligence (SIGINT) techniques and technologies.

Undertaken from Hohn Air Base in Schleswig-Holstein using a GFD GmbH Learjet 35A aircraft, the six test flights were designed to provide German customer representatives with an insight into the company's current system portfolio and its future technology roadmap. Hensoldt self-funded the demonstration – which used a payload in an underwing pod – with the intention that it will inform plans for future airborne SIGINT capability.

Outputs are also feeding into the further development of the company's own KALÆTRON Integral product. KALÆTRON Integral has been conceived as a modular SIGINT payload that can be scaled for installation on various airborne platforms, including unmanned aerial systems.

The so-called "expansion stage 1" demonstrated the localization, direction finding, tracking and recording of communications band signals in the communications band in a range of tactical signal reconnaissance scenarios. For this demonstration, the system concept developed by the company was specifically designed for high-bearing accuracy and fast detection.

A follow-on "expansion stage 2" is planned. According to Hensoldt, this will be designed to highlight monitoring and pattern recognition techniques, potentially including artificial intelligence algorithms. – *R. Scott*

IN BRIEF

The DOD announced that Secretary of Defense Lloyd Austin signed the Implementation Plan for the **Electromagnetic Superiority Strategy (EMSSS)** on July 16. One of the larger goals of the EMSSS is to eliminate the organizational and process silos that have characterized the DOD's EMS Enterprise. According to DOD officials who spoke to the press last month, the Implementation Plan will help to achieve this integration. While most of the details in the Plan are classified and will not be released, some of the highlights were discussed. The EMSSS oversight responsibilities will transfer from the DOD's EW Senior Designated Official, Vice Chairman of the Joint Chiefs of Staff Gen John Hyten, to the DOD's Chief Information Officer (CIO) in the fall. The CIO, which has a Spectrum Policy and Program Directorate, will have responsibility for long-term implementation of the EMSSS. In addition, US Strategic Command, will reform its Joint EMS Operations (JEMSO) organization into a Joint EMSO Center (JEC) led by a two-star directly reporting to the USSTRATCOM commander. The JEC will be providing operational risk assessments identifying requirements and gaps to the DOD CIO as the EMS Enterprise operational lead.

Howard Ellowitz, who was the first publisher and editor of *JED,* passed away on May 23. Ellowitz was also the publisher and editor of *Microwave Journal* and was for many years the manager for IEEE-MTS tradeshow aligned with the International Microwave Symposium.

The US Space Force's main electronic warfare unit has a new commander. During a ceremony at Peterson AFB, CO, in late July, Col Christopher Fernengel formally accepted command of **Space Delta 3** from Col John Thien, who had led the unit since Space Command was stood up in 2019. Space Delta 3 includes 300 personnel and comprises the 4th Space Control Squadron (SPCS), 5th SPCS, 16th SPCS and 721st Operations Support Squadron. Prior to assuming command of Space Delta 3, Colonel Fernengel was the division chief for operational capability requirements for the US Space Force Chief of Strategy and Requirements Office at the Pentagon.

The Naval Surface Warfare Center, Port Hueneme Div., has selected **VTG** (Chantilly, VA) to install AN/SEQ-4 Optical Dazzler Interdictor, Navy (ODIN) systems onto five Arleigh Burke-class destroyers. Last year, the company integrated an ODIN system onto the USS Stockdale and the USS Spruance.

The Naval Air Warfare Weapons Div. (Point Mugu, CA) announced plans to award a sole-source $9.9 million contract to **Toyon Research Corp.** (Goleta, CA) for hardware and engineering services in support of US Marine Corps ALQ-231 (V) Intrepid Tiger II electronic attack pods. Work will primarily be performed at the company's facilities.

BAE Systems announced that it has received a $62 million production contract from the US Army for the 2-Color Advanced Warning System (2CAWS). The contract marks the third (of four) production lots under the Limited Interim Missile Warning System (LIMWS) for US Army helicopters. According to the company, the 2CAWS uses machine learn-

ing algorithms "specifically designed for complex, high-clutter environments and rapid threat updates."

Raytheon Missiles & Defense (Tucson, AZ) said that its Coyote Block 3 air vehicle, which is fitted with a non-kinetic effector, successfully defeated a swarm of drones during a demonstration at the Army's Yuma Proving Ground in Arizona. The jet-powered Block 3 system engaged and defeated 10 drones that differed in size, complexity, maneuverability and range. Throughout the demonstrations, the Block 3 systems were recovered, refurbished and re-used for subsequent flights.

The **US Air Force** last month demonstrated the ability to deliver a mission data file (MDF) update to an EW system while the host aircraft was in flight. Executed as part of a demonstration of the Advanced Battle Management System (ABMS), an F-16 Block 50C "was able to receive an MDF update from the Hill Software Integration Lab, process it using custom developed Center Display Unit software, and load the new data into the ALQ-213 Countermeasures Signal Processor," according to an Air Force press release. "We believe this is the first time a fighter aircraft has received a software update and gained new capability all while in flight," said Lt Col Zachary Probst, a flight test pilot and commander of the 84th Test and Evaluation Squadron. The next step, according to the Air Force, is to integrate high-speed internet into the F-16. The ultimate goal is to integrate high-speed internet onto the aircraft, to allow its systems to access data from a classified cloud resource.

The **US Navy** announced that it successfully completed its first test firing of the AGM-88G Advanced Anti-Radiation Missile – Extended Range (AARGM-ER) on July 19 at its Point Mugu Sea Test Range off the southern California coast. Developed by Northrop Grumman, the AARGM-ER was launched from an F/A-18 Super Hornet for the test. In addition to Super Hornet aircraft, the AGM-88G is slated for eventual use on the EA-18G Growler, as well as all variants for the F-35, which will carry it internally. The AARGM-ER program is expected to enter Low-Rate Initial Production in the coming weeks.

Australia's Department of Defence has established a new project to develop a ground-based space electronic warfare capability. Project 9358 was announced by Minister for Defence The Hon Peter Dutton, who's office said, "A Space Electronic Warfare capability, as part of the Australian Defence Force's approach to space control, seeks to detect and deter attempts to interfere with, or attack, our use of the space domain." Earlier this year, the chief of the Royal Australian Air Force announced that it would stand up a space force in 2022.

DARPA awarded two additional contracts for its Quantum Apertures program. **Honeywell** (Phoenix, AZ) won a $5.5 million contract, and **Northrop Grumman** (Woodland Hills, CA) received a $6.2 million award – the company's second for the program (see *JED,* August 2021, for earlier Quantum apertures award announcements).

ADVERTORIAL

Low-SWaP Comms Threat-Warner for Maritime Security Operations

By Chris Slack

Field Ops Specialist PROCITEC GmbH

This article explores the development of a software-app by PROCITEC GmbH to deliver a low-SWaP Communications Threat-Warner capability for use in the maritime space. The app enables "no warrant required" Electronic-Surveillance (ES) derived Indications & Warnings (I&W) for manned platforms such as Offshore Patrol Vessels (OPVs) & Fast Patrol Boats (FPBs), & Unmanned Surface Vehicles/Vessels (USVs) during Maritime Security Operations (MSOs).

◂ OPV mainmast showing example V/UHF communications & intercept antennas

Offshore in the Baltic Sea / Project DORNHAI Field-Trials radiating target emissions (UHF P/LMR & Satphone shown) ▸

Open-source reporting confirms that adversarial & criminal use of satellite telephones & Push-To-Talk (PTT) digital-speech handheld transceivers (HTs) is increasing in the maritime & littoral space around the globe.

PROCITEC markets our narrowband go2DECODE and wideband multichannel go2MONITOR-communications signals exploitation software applications for use by skilled & semi-skilled tactical & strategic communications surveillance specialists. Both applications automatically intercept and decode numerous communications signaling protocols including V/UHF complex data and digital speech emissions, and HF internet-protocol modems.

THE NEED

However, due to non-availability of suitably trained, skilled & administered communications surveillance specialists at their end-user units, a growing number of our customers are requesting fully automatic wideband intercept capabilities, but for use by non-specialist (i.e. general-service) personnel when operating from OPVs & FPBs.

This recurring customer-requirement is for a simple-to-use, Low-SWaP robust ES system which can classify, recognize and report close-range signal activations such as V/UHF digital-speech and UHF satellite telephones for I&W, but which does not process or decode signal content, and can therefore be deployed as a "no warrant required" general-service asset.

Project DORNHAI

To investigate our customers' needs & to close their capability-gap, the PROCITEC R&D Team initiated Project DORNHAI which employs proprietary software algorithms to process only detected signals' external parameters to enable automatic protocol-recognition and alerting in real-time, but which does not prosecute signal-content.

To develop and test the Project DORNHAI concept-of-operation, members of our R&D Team deployed to the Baltic Sea with DORNHAI trial systems comprising 3rd-party low-SWaP wideband intercept receivers, antennas, and a range of V/UHF targets including satellite telephones, digital speech handsets, and other transceiver types. The field-trial's results were very encouraging – speed & quality of automatic protocol recognition by the Project DORNHAI 'externals only' algorithms and range-to-target distances exceeded modelled expectations.

INTERCEPT RANGES

The DORNHAI R&D Team was aware that intercept ranges at sea will inevitably vary, depending upon a number of factors including (but not limited to) ambient weather conditions, sea-state, signal-type, radiated power & frequency, host-sensor/receiver sensitivity & intercept-antenna type & elevation.

However, using only low-sensitivity wideband receivers & antennas mounted on our DORNHAI platforms during our offshore trials at sea-states 2 to 3, we noted that satphone uplink activations could still be automatically prosecuted at operationally viable ranges.

DORNHAI USABILITY

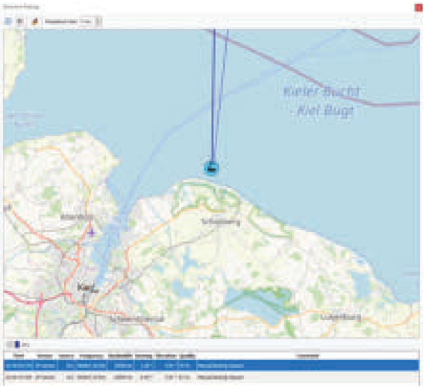
To satisfy the key customer-requirement for DORNHAI to be "trivially simple to use by general-service personnel", the application loads its mission-plan & auto-runs as soon as the host Laptop or Tablet PC is powered-on. The general-service user simply acknowledges each intercept and cancels the audio/visual alert via the laptop or tablet PC's touch-screen.

Prototype DORNHAI kit online & dismounted from host-FPB (DORNHAI app running live on Getac B300; 3rd-party proprietary Low-SWaP WB RXR hidden behind B300 lid)

DF INTERFACE OPTIONS?

Yes – interface options (e.g. 'CESMO') for automatic alert & cross-cue to 3rd-party Direction-Finding systems have now been developed here at PROCITEC HQ.

The DORNHAI DF-interface includes 'running-fix' algorithms enabling target geolocation & tracking from a single DORNHAI platform when in-transit.



For further information please just drop us an email to dornhai@procitec.com

EVENTS

…I'll be a Speaker at AOC Liverpool in October, and will be presenting a live demonstration of our Project DORNHAI capability developments which will include a variety of operational scenarios & use-cases, so I look forward to seeing you there..!

The Author

Chris is a former CESM Mission Supervisor with the Royal Navy; his most recent operational deployment was to Asia as a Radio Reconnaissance Team Leader with 30 Commando (IX) Group. Now based at PROCITEC GmbH in southwest Germany, Chris contributes to Research & Development initiatives for a range of data-signals exploitation software applications.

Hiding in Plain Sigh Concealment and D

By Andrew White

Israel's Fibrotex, which makes several types of multispectral camouflage for multiple applications and opened a new US facility in 2019, is currently manufacturing multispectral camouflage products for the US Army's UCLANS program. FIBROTEX

In the wake of the Great Power Competition between the United States, Russia and China, Europe's land forces are facing the realities of operating in a new and more dangerous battlespace. Over the past decade, Russia and China have been developing new sensor-to-shooter concepts that make use of multispectral ISR platforms, efficient battle networks that can rapidly move target data to commanders and weapons that can engage ground targets at much longer ranges. And they are exporting these capabilities to their allies across the globe. This development poses a new challenge for Europe's armies, which have spent the past 30 years operating in relatively permissive threat environ-

t – Camouflage, eception in the EMS

FIBROTEX

FIBROTEX

ments against adversaries that have been equipped mostly with Cold War era systems. While European armies must continue developing their own sensor-to-shooter networks, they must also focus on technologies, tactics and concepts that enable them to hide from an adversary's sensors.

OFFENSIVE BATTLE NETWORKS

The creation of modern offensive battle networks is hardly new. The US developed stealth aircraft designs, advanced ISR and targeting sensors, satellite communications, and space-based positioning, navigation and timing (PNT) in the 1970s and 1980s and then integrated these technologies as part of a new battle network concept to challenge the Soviet Union's armor advantage during the last decade of the Cold War. In 1991, the US relied on its nascent sensor-to-shooter network to defeat Iraqi ground forces in the Gulf War. Over the next two decades, China and Russia watched the US and its allies employ these sensor-to-shooter networks in Bosnia, Kosovo, Afghanistan and Iraq – tailoring the concept and leveraging new sensor and network technologies along the way.

Russia and China watched these developments, and by 2010 they were embarking on modernization programs that could take advantage of tactical unmanned aerial systems (UASs) fitted with compact EO/IR/RF sensors and RF jammers, faster data networks and information networks, precision standoff munitions to attack high value targets and very accurate long-range artillery (30 km - 70 km range) to break up enemy formations. These technologies have enabled Russia and China to develop new operational concepts for rapidly detecting, identifying, geolocating and engaging large numbers of ground targets and at much longer distances than ever before. In addition to meeting their own needs, Russia and China are selling these capabilities to other countries, who are in the process of developing their own sensor-to-shooter networks. From the standpoint of Europe's ground forces, this is a concerning trend for operations within Europe and expeditionary ops.

This Giraffe radar system is covered by Saab's Barracuda multispectral camouflage. Even with the radar antenna exposed, the rest of the vehicle is not clearly visible to EO, IR and radar sensors. SAAB

MULTISPECTRAL CAMOUFLAGE

According to Saab, today's high-tech battlefield is becoming increasingly sophisticated, making it "ever more challenging to avoid detection and identification and targeting." Company officials described camouflage, concealment and deception (CCD) concepts as a critical necessity for any modern force seeking to optimize their operational effectiveness.

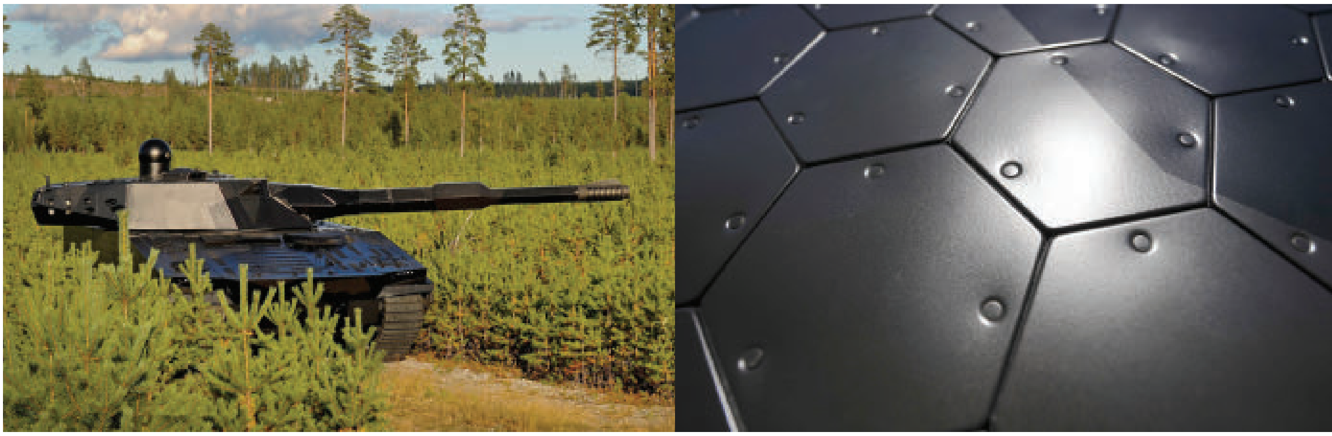
"Today, all peer armies have sensors in all parts of the spectrum," the company said. "There are no scenarios with no multispectral sensor threat. So modern signature management is one of few disruptive technologies that, together with deception and operational adoption, can break an enemy's overmatch in battlefield awareness, detection, target acquisition and long-range fires."

According to Saab's director of strategy and business development for the Barracuda business unit, Niklas Ålund, signature management provides the precondition for an armed force to win an engagement in a contested operational environment. "Technology and TTPs will allow an armed force to not become a target, hide its intentions, take the initiative and win an engagement," he said. "Deception is a state of mind. Deceive their minds, disrupt their sensors and destroy their chances to engage first."

Most ground-based weapons systems, from soldiers to APCs to main battle tanks, do not incorporate stealth design principles. In fact, they present significant visual, radar and thermal signatures when measured against the performance of today's radars and EO/IR sensors, including hyperspectral sensors. These signatures can be mitigated to some extent by multispectral camouflage systems, which have been available for more than two decades and can be applied as personal camouflage (ghillie suits), modular systems to cover various types of equipment and encampments, or can be applied directly to vehicles. One of the first products in this market was the Ultra-Lightweight Camouflage Netting System introduced in the 1990s by Saab Barracuda. Today, however, there are several other companies – many of them in Europe – offering multispectral camouflage systems. These include B.O.I.S. - FILTRY, spol. s r. o. (Blansko, Czech Republic), Lubawa S.A. (Ostrów Wielkopolski, Poland) and TDU Defense Systems (Torbalı-İzmir, Turkey), as well as Fibrotex (Petach Tikva, Israel), Jetcord (New Delhi, India) and Motley Exim Co. (New Delhi, India).

Another approach is to apply stealthy material directly onto a weapons system. In 2011, BAE Systems Hägglunds (Örnsköldsvik, Sweden) introduced its ADAPTIV technology, which can be applied to a ground vehicle's outer armor. First exhibited on a CV90120 tank, ADAPTIV provides a high degree of thermal camouflage. The individual modules can be heated or cooled to create different thermal patterns that can fool thermal sensors.

While multispectral camouflage can be added to ground systems, the long-term expectation is that high-value targets, such as tanks and APCs, will eventually incorporate stealth designs to limit their detection by multispectral sensors. In 2013, Research and Development Centre for Mechanical Appliances OBRUM Ltd. (Gliwice, Poland) and BAE Systems Hägglunds introduced a stealth concept design named PL-01 based on BAE's CV90120T light tank. While it never entered full-scale development, it represented a first look at some of the features that stealth tank designs might



Demonstrated on a CV90120T, BAE Systems' ADAPTIV technology reduces the ability of IR sensors to detect the thermal signature of the tank.

BAE SYSTEMS

incorporate, including clean and continuous surfaces and edges, radar absorbing material and a square-shaped covering over its main cannon.

ELECTROMAGNETIC CONCEALMENT

In addition to using passive means such as multispectral camouflage to mask the electromagnetic signature of a weapons system from EO/IR and radar sensors, today's ground forces must also become more adept at concealing their electromagnetic emissions – radar, communications and jamming systems – from an adversary's electronic support measures (ESM) and signals intelligence (SIGINT) systems. This can be a challenge for ground forces that depend on high-power radars for air defense or airborne surveillance. Most of the emissions from a ground force come from radios with omnidirectional antennas that are used for command, control and communications. A fighting force that employs a highly networked sensor-to-shooter kill chain necessarily sends and receives a lot of signals, and this activity provides a lot of opportunities for adversary EW and SIGINT operators to feed this emitter information into their own sensor-to-shooter kill chains. This is an area where Russia has focused its force modernization efforts, with the introduction of new UAS- and ground-based communications EW systems.

Zoran Dobrosavljevic, senior consulting engineer at Roke Manor Research (Romsey, Hampshire), described how western armies continue to rely upon communications networks to exchange information across a battlespace. "All that assumes a freedom of maneuver in the electromagnetic spectrum, but we don't think we can take that for granted anymore. The current electromagnetic environment and battlespace will be contested, congested and constrained, and all those things that go together with it," he said. "Adversaries can therefore try to deny parts of the spectrum, both actively and passively, to basically force NATO forces to use the radio spectrum in a way that is unfavorable to them," he added, referring to jamming command and control nodes and rebroadcasting stations for example.

According to Dobrosavljevic, peer/near-peer adversaries are able to deploy man-portable and vehicular ESM and SIGINT systems to confirm ranges of their opponents and detect emissions across the full range of frequencies, including HF, UHF and VHF. "They have sensors that are kind of focusing on specific types of communication systems. So on jammers, you have systems designed to suppress GPS and navigation, as well as a separate capability to exploit mobile cellular communications and systems to attack tactical communication networks," he said.

Studying ongoing operations in eastern Europe, Eric Herron, Roke's CEMA business development lead, suggested NATO forces must learn (and train) to emit as little as possible, relying upon tactical communications networks to deliver only critical messages, such as orders that are absolutely necessary to achieve mission effectiveness. "A battlegroup commander should have a good understanding of the risk associated with a certain activity, but on the ground," he said. "It is difficult to protect an entire formation which is often scattered across a battlefield. But there are lessons to be learned with [Russian] activities which are currently going on in Ukraine and Syria. These give us an idea of how our adversary operates – and it is very offensive. Now, that can be an advantage to us. And I think that there are probably ways to utilize that in the way we react. The enemy being active in the spectrum means they also expose themselves, which gives us an opportunity to counteract. And that's how the game goes," he explained.

Herron described how NATO forces in particular must revert to lessons learned during the Cold War. "We were very slick with our radio planning and radio silence when necessary," he said. "But it's something that isn't or hasn't been used, [at least] up until the last few years. So, there's a certain amount of skill fade and requirement to go back to basics. We have the ability to do it; it just hasn't been a priority. But we are doing stuff about it with future command and control systems being designed to reduce their signatures and to be resilient as much as possible to any electronic attack measures," he said.

According to Herron, the most suitable starting point to managing the electromagnetic signature of any ground force is awareness. "So first of all, we need to make sure that armies and industry are aware and decision makers are aware of the presence of threat and the importance of enemy capabilities as well. That links into us being aware what our electromagnetic signatures are," he explained. "How much do we really expose ourselves in the electromagnetic spectrum, particularly when we go about conducting our regular business doing command and control information exchange. So a ground force has to make sure what its signatures are and what they enable a potentially capable adversary to do."

Herron explained that decision support tools must also be made available to commanders on the ground, providing them with the ability to balance risk with effectiveness. "When they plan their operations, commanders must be aware of calculated risks in terms of setting up a course of action and whether they may or may not be exposed to certain electromagnetic spectrum risks," he said.

Ground forces will need to introduce more flexibility into their electromagnetic maneuver strategies. As Mat Willmot, EW sales director at Saab, explained, "Propagation prediction and spectrum management tools are nowadays deployed in dynamic mission planning, as opposed to the traditional pre-mission planning process."

Another aspect of concealing the electromagnetic signature of a ground force is for it to rely more on passive sensors, such as ESM and EO/IR systems, instead of using emitting sensors, such as radars, to build a situational awareness picture. A company official at Italy's Elettronica described how soldiers (particularly those conducting clandestine operations) must be capable of undertaking "passive engagement to the maximum extent" possible. "This provides the user with a tactical advantage with respect to the enemy," the company official confirmed before describing how, in general terms, passive engagement focuses on the exclusive use of passive sensors to provide ranging and complete situational awareness. "Both radio frequency (RF) and infrared/electro-optical (EO/

Inflatable targets are sometimes used as decoys. While not presenting much in the way of multispectral signatures and perhaps not very convincing up close either, their visual effectiveness usually increases with distance, especially if viewed through an electro-optic sensor.

TCH AND I2KMILITARY.COM

FROM LAB TO BATTLEFIELD

VIAVI Solutions

The VIAVI Ranger

Vector Signal Analyzer/Generator

The VIAVI Ranger Vector Signal Analyzer, Recorder, and Generator is the solution you need for design verification and testing of your next-generation EW, SIGINT, ECM/ECCM, and Tactical Radio systems. Ranger is a single-vendor, one-box solution that supports the complete lifecycle of your products, from conceptual design through field operational test and deployment. With deep memory and wide bandwidth, Ranger provides hours of full-bandwidth recording and playback capability, ensuring you will capture every sample of the RF environment and play it back with perfect fidelity. The VIAVI Signal WorkShop™ software provides signal analysis capabilities that can process a recorded RF environment sample-by-sample, breaking down individual signals and showing not only what happened but when and why it happened. RF environment simulation capabilities allow the Signal Workshop software to create synthetic signal environments, modify recorded signal environments, or both simultaneously, creating new RF signal environments using the generator. The VIAVI Ranger is the key to solving your next-generation RF problems.

The VIAVI Raptor

SCA Development Platform

The VIAVI Raptor is an all-integrated solution for accelerating the development process, from concept to battlefield, of products that are based on the Software Communications Architecture (SCA) standard. Its open standard, modular and configurable design approach lets you emulate any tactical radio, radar, electronic warfare, signal intelligence and robotics system platform. Its multiple processors (i7, ARM, FPGA), high speed data bus, and instrument grade RF front end will exceed nearly any signal processing requirement. Raptor is fully integrated and compliant with SCA v4.1 (including Core Framework and SCA devices) to help kickstart application design, implementation, and testing. And for that, Raptor offers a complete Integrated Development Environment (IDE) to model SCA applications and target platforms, to automatically generate all of the SCA artifacts code, to test different software deployment strategies on the various processors, and to introspect, in real time, the signal processing chain for debug and test purposes. Quickly design, implement and test your SCA application on the VIAVI Raptor system and efficiently port it to your target platform, drastically reducing development cost and time to market.

IR) sensors can be used effectively. In fact, the real-time cooperation between passive sensors adopting RF data links allow for an effective geo-location capability. Then, both passive RF and EO/IR sensors can perform ranging on the back of low probability of intercept/low probability of detection data links. This approach can be integrated into overall electromagnetic spectrum operations (EMSOs), including spectrum operations that require dynamic spectrum management (DSM)," the official said.

GROUND DECOYS

Just as some companies, such as Saab, are developing materials to meet multispectral camouflage requirements, so others are utilizing new materials, inexpensive commercial electronics and autonomous vehicle technologies to develop maneuvering multispectral decoys that are designed to deceive adversary ISR sensor operators.

In the past, employing ground decoys that could mimic a tank, an artillery piece or a surface-to-air missile (SAM) system usually meant fooling an adversary mainly in the visual realm. During World War II, wooden and inflatable decoys were utilized in large numbers as part of the Allies' "Ghost Army" in southeast England leading up to the D-Day invasion of France. In the 1990s, Serb forces used very basic materials (lumber, wooden boxes and sheets in some cases) to create decoy tanks and air defense systems that in at least some cases successfully fooled NATO strike aircraft.

Not a whole lot has changed. Most of the "decoys" available today are basically inflatable targets operating in the visual spectrum and are mainly used for training applications. Many companies across Europe, as well as Russia, China and India, manufacture several types of these inflatable targets, although some are used as decoys. The Russian Army's 45th Separate Engineer-Camouflage Regiment, nicknamed the "inflator" regiment according to some Russian news reports, makes extensive use of these inflatable devices.

However, simple visual decoys are losing their effectiveness against today's multispectral sensor capabilities. Western ground forces will need a new generation of decoys that present a more realistic signature, including radar return, radio activity and thermal characteristics.

Roke's Dobrosavljevic expressed optimism about the problem: "I'm not aware of specific off-the-shelf [decoy] solutions at the moment, to be honest, but I've seen systems that are being developed. And they're quite good. I think the technology is pretty much in research and development at the moment, and a number of countries are working on it because there's a lot of interest in it. But it's one of the more complicated things to achieve when you're trying to mimic an entire battlegroup. And unless it is absolutely nailed on, even down to the modulation types and the timings, then a capable adversary will realize that a decoy isn't real. We're not talking about simple jammers here." He went on to say, "However, decoys could basically congest the electromagnetic environment from our side, confusing and keeping the adversary busy over an extended period of time and prolonging their decision loops. That's one way to maintain the tactical advantage."

Echoing the thoughts of Saab, Dobrosavljevic also described how disruptive technologies must also be supported by suitable concepts of operation and TTPs: "It's never just technology itself. You also want to build behaviors, skills and capabilities and ways of working."

FUTURE

Looking to the future, Roke believes electronic support measures will permeate all the way down to the lowest tactical level, with every soldier on the ground becoming a multi-sensor node in a wider battlefield network. Benefiting from smaller, lighter, more agile and highly capable solutions, soldiers will be more informed, benefiting from the ability to track their own forces and exploit all of that information. "That's a double-edged sword," Dobrosavljevic warned. "If they're all sensors at the edge, that's creating a huge signature for potential prosecution by the enemy. But if you have a haystack, which piece of straw is the one you need to stop? So it's all about either not exposing themselves in the electromagnetic spectrum or creating even more signatures to confuse the enemy across the entire battlespace."

Saab's Ålund said, "We think that multispectral deception capabilities are the next big thing. In a potential multi-domain conflict, the most advanced sensors are feeding AI-controlled kill-networks with global reach ... Deception will never be obsolete. An 80% reduction of a sensor's capability to detect is still 50% even when the sensor ranges evolve. We see customers investing to implement a capability now, at the same time as incremental development of technology and doctrine are prioritized in parallel. The future is now. A majority of the customers need state-of-the-art capabilities available now. The threat is not only evolving; it has already been here for a while. The requirement is for a system provider that can deliver incremental developed capacities ahead of the sensor threat."

Czech company Inflatech Decoys makes inflatable decoys, such as the SA-8 and T-72 above, that feature thermal and radar signatures.

INFLATECH DECOYS

AI Is Changing EW...Fast

By Barry Manz

Artificial Intelligence (AI) is a term that most people find difficult to understand. The more you try, the more questions you have, and the answers are extraordinarily complex. Even AI aficionados have trouble explaining it clearly and simply. Nevertheless, AI is everywhere, from search engines to smartphones and digital assistants to streaming services that decide what you might want to watch. Inevitably, one of the next targets for AI is EW, which desperately needs it for many reasons, not the least of which is that the AESA radars of adversaries already use it. Although late to the game, EW and SIGINT are perfect applications for AI and its subsets – machine learning and deep learning. Together, they are forming a concept known cognitive EW.

Cognitive systems, in general, are designed to sense, learn, and reason from the data they ingest and provide recommendations to people who can make decisions based on what the data reveals. As this applies to EW, the concept focuses on the ability to detect and categorize signals of an adversary and use machine learning algorithms to automate the currently lengthy process of building countermeasures. AI can analyze massive amounts of data infinitely faster than humans and identify signals of interest for further analysis and exploitation so countermeasures could be ready for use very quickly. And as cognitive EW technology matures, it will be embedded in forward-strike platforms to better sense, identify, and deliver information about the electromagnetic environment with electromagnetic battle management systems where further AI can be used to build a larger EMS picture for commanders.

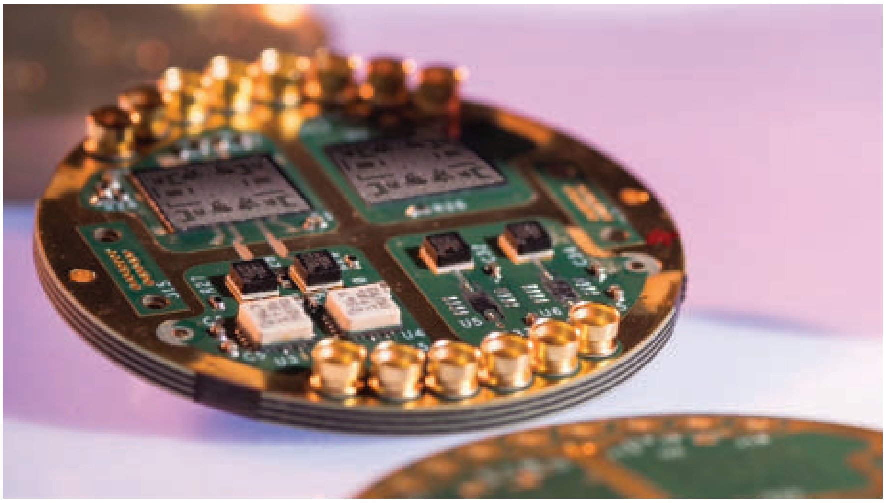
"The cost of processing information into intelligence is becoming more expensive because there are more and more waveforms out there and more congestion along with higher frequencies," notes Chris Rappa, product line director for RF electronics and cyber at FAST Labs, BAE Systems' R&D center. "That is, AI and machine learning need to be enabled directly at the sensor, as well as the sensor resource manager, the control center, and where back-end exploitation of adversaries waveforms is performed. It's not enough for that to be in just one place, and we believe that bringing AI and machine learning into different stages of the processing chain is the true secret to inverting that cost curve."

In general, the most advanced cognitive systems can make decisions and execute actions autonomously, completely removing the "human in the loop." However, cognitive EW systems won't take these steps – at least not in the foreseeable future – until they are proven to work. This is because weapons system operators must trust the AI in an EW system to make life or death decisions – their life or death, that is – especially in end-game countermeasures situations. And it will take a while for AI to gain that level of trust, just as it did for the automated EW systems that largely replaced "back-seat" EW officers on fighter aircraft 40-50 years ago. But the objective, for now, is less ambitious than it may seem. For one thing, AI-enabled self-protection systems are just one application of many for AI in EW. There are many other EW applications, from threat analysis to force training to electromagnetic battle management, in which AI can make significant contributions. And when AI is used in these types of EW applications, it will not be like flipping a binary switch on and off. In fact, the most effective cognitive systems combine the computational and analytic capabilities of AI with the unique capabilities of humans who can provide insight and creativity well beyond what a machine can provide. The result is less "human in the loop" and more of a "human on the loop" process.

"A person – or even several people – can only consume so much information," says Scott Kuzdeba, chief scientist at BAE Systems' FAST Labs R&D center, "and that is why you need AI to help with that intelligence process so that the humans are only getting the relevant information they need when they need it to take action."

"It's not enough for [AI] to be in just one place, and we believe that bringing AI and machine learning into different stages of the processing chain is the true secret to inverting that cost curve."

– Chris Rappa



Developed by BAE Systems' FAST Lab, the Multiple Array Technology for Reconfigurable Integrated Circuits (MATRICs) transceiver uses RFSoC technology and can enable EW systems to be reprogrammed in the field and on the fly. BAE SYSTEMS

"AI is not a panacea but rather a support tool to help the operator make real-time informed decisions," says Joe Ottaviano, Lockheed Martin's director of Maritime & Air Cyber/Electronic Warfare. "The operator is still needed to engage effectively." Carl Nardell, Principal Engineering Fellow and Technical Director, Electronic Warfare Systems at Raytheon, agreed. "I don't see this job [electronic warfare operator] going away; we're just giving them a tool so they can automate their workflow and scale so they can look at more data."

Removing The Bottleneck

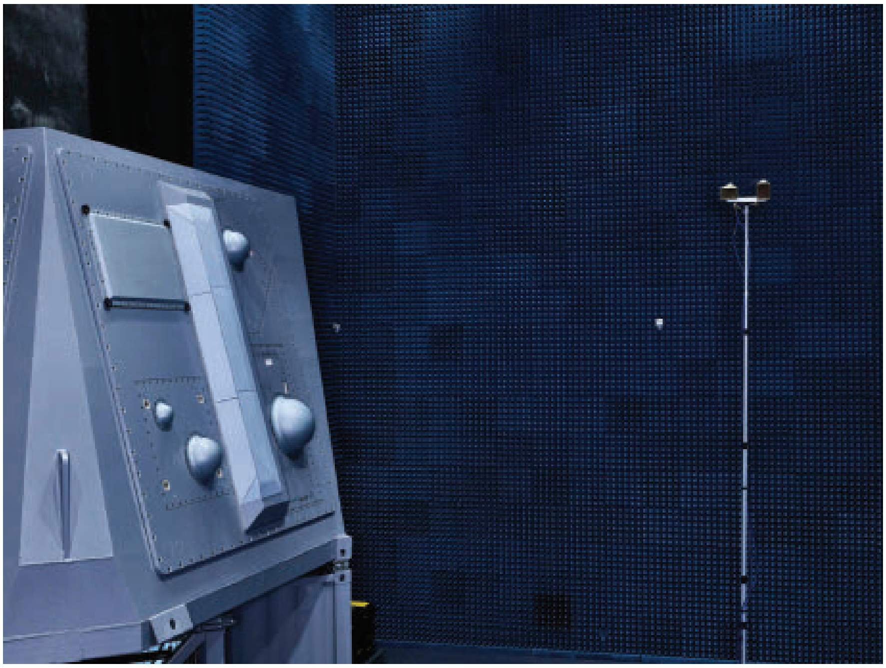
For the weapons system operator, time is critical when countering a threat. Classic EW systems normally detect a signal of interest – from an enemy radar or radio, for example – and try to identify it by matching it to a known signal in the system's threat library. If the signal is recognized, the jammer can immediately select a pre-loaded countermeasures algorithm that is optimized to disrupt or deceive that particular radar or radio receiver and immediately transmit that jamming signal.

Peer competitors, such as China and Russia, use AI to enhance the cognitive performance of their radars, EO/IR sensors and communications systems, and this poses a new challenge for EW systems. Cognitive radars and radios can transmit, receive and process novel waveforms that are constantly changing. This presents a problem for a classic EW system because it cannot optimally match a jamming algorithm to a radar or communications signal it does not easily recognize.

For an EW system, adversary radar and radio signals are part of a complex electromagnetic environment that is densely populated with friendly and neutral emitters, all of which are using new and changing signal types. This means that these novel signals from an enemy radar or radio can hide as an "unknown" signals within an immense blanket of RF energy that spans from HF through microwave frequencies and well into the millimeter-wave region.

Cognitive EW technology helps to solve this problem by applying a combination of AI algorithms, computational and analysis capabilities and deep learning that tries to detect threat systems within the EM environment based on their behaviors, while keeping the friendly weapons system operator "on the loop" to if they are needed to make final decisions. However, the computational capability required to achieve this was until recently limited to remote data centers and their hundreds of thousands of servers, all powered by immensely powerful processors that can analyze large quantities of information and make decisions almost instantaneously. But as these data centers are hundreds or thousands of miles away, even under ideal circumstances, it takes too long for the data to travel from the platform on which it originated to the data center where it is processed and then send and countermeasure algorithm back to the original weapon system.

A solution is to split the EW data processing between the platform and the



The SLQ-32(V)7, developed under the Navy's Surface EW Improvement Program (SEWIP), will eventually utilize AI to help protect surface combatants against advanced anti-ship cruise missiles. The array, seen above as it undergoes testing in Northrop Grumman's High Bay Integration Lab (Baltimore, MD), integrates Lockheed Martin's digital ESM system (in the array's upper left quadrant) and an AESA-based jamming suite developed by Northrop Grumman. NORTHROP GRUMMAN operations center. This process is nearly identical to what is being deployed throughout the industrial, medical, and other sectors, for the same reasons that are of interest to EW. There are two primary factors driving it. The first is the long round-trip latency between the platform where the data is generated by sensors to the cloud data centers, and the second is that the amount of data being transferred is overloading the data links that are transmitting the data.

Both issues can be remedied by dividing the tasks between the cloud and the "edge" of the network. Using this approach as applied to EW, the problem of latency is eliminated because processing functions required for real-time applications reside on the platform, not the cloud data center. Only data of use to analysts is sent onward, which dramatically reduces the load on DOD's already overwhelmed data links and networks. In addition, by keeping critical information on the platform, it can be continuously updated and is not as likely to be intercepted and corrupted.

That said, implementing this concept is not trivial. For example, while ships and some vehicles have the required space and DC power for AI hardware, many airborne platforms have little of either to spare. Developing cognitive EW systems for aircraft requires the highest possible power efficiency in the smallest possible form factor. Fortunately, several significant technological advances have taken place in recent years that go a long way toward utilizing available space in constrained environments.

The first of these is the so-called "digitization" of RF that is being accomplished by direct RF sampling in which the analog input signal is digitized near as possible to the antenna in the signal chain. This eliminates the need for RF and microwave components, such as mixers and local oscillators, which along with the elimination of their undesirable attributes, reduces the footprint required for RF functionality.

Once the signals are in the digital domain, the system benefits from the inherent advantages of digitization, with processing performed in a Radio Frequency System-on-Chip (RFSoC) or General-Purpose Graphics Processing Unit (GPGPU). The former, introduced several years ago by Xilinx and since enhanced, integrates the formerly external analog-to-digital converter within the FPGA package that, along with an FPGA's programmable logic, adds an ARM processor in significant I/O. The GPGPU combines the performance of a traditional scalar central processing unit (CPU) with the unique capabilities or graphics processor (GPU). Both types of processing engines are used for AI, and collectively they have dramatically reduced the footprint of the signal processing chain while also reducing the power they consume.

A recent example of this in the EW and SIGINT market is BAE Systems' Hedgehog, a software-defined radio (SDR) that is reconfigurable in real-time and whose RF front-end consists of Multiple Array Technology for Reconfigurable Integrated Circuits (MATRICs) transceivers that were developed with funding from DARPA and are about the size of a dime. The signal sources allow tuning from DC to 40 GHz with switching speed in the nanosecond region. Digitization and processing are provided by a Xilinx RFSoC, which allows the transceivers to digitize up to 16 channels, each with 2 GHz of instantaneous bandwidth.

BAE Systems is using the Hedgehog radio within its Controllable Hardware Integration for Machine-learning Enabled Real-time Adaptivity (CHIMERA) program, also being funded by DARPA, that provides a reconfigurable hardware platform for machine learning algorithm developers to make sense of radio frequency (RF) signals in crowded electromagnetic environments. The contract complements the efforts within the DARPA Radio Frequency Machine Learning Systems (RFMLS) program dedicated to development of machine learning algorithms.

The company demonstrated its small-form-factor capabilities on an unmanned aerial system (UAS) to test Hedgehog's ability to sense signals and congested and contested electromagnetic environments. The demonstration was part of DARPA's Distributed RF Analysis and Geolocation on Networked System (DRAGONS) research initiative, whose objective is to integrate signal identification and geolocation capability. "Our goal is to deliver the ability to proliferate very-small-geometry products so there can be more sensors in more places with more capability and then integrate," notes Rappa. "With the available processing power along with advanced data exploitation, I think we're on the cusp of a major sea change in our ability to exploit real-time data."

Streamlining the Process

The traditional way countermeasures have been developed is becoming increasingly untenable because, like processing itself, the traditional countermeasures development process has inherent latency. Once a new threat signal is collected by

Cognitive EW will play a significant role in future operational concepts that rely on unmanned combat aircraft and expendable drones. In March, the Air Force demonstrated how the XQ-58A Valkyrie (from Kratos) could deploy the ALTUS-600. Both types of aircraft could be fitted with AI-enabled EW payloads. US AIR FORCE

a signals intelligence (SIGINT) platform, it must be sent to analysts in operational data centers to perform signal forensics, piecing together collections of data that have been captured from other SIGINT missions. The signal data is analyzed and countermeasures are been developed over the course of weeks and sometimes months. Once developed, the threat data, as well as the corresponding countermeasures techniques can be sent to operational units and uploaded into EW systems, as needed. This has been the approach for decades, but as adversaries modernize their IADS with cognitive radars and datalink systems, this process has become far too slow.

"It can take a long time and is very labor-intensive," says Raytheon's Nardell. "The time between when you see a novel threat and the time you have to do something about it is not measured in days, weeks, or months but in seconds or minutes. AI and machine learning will let us shorten this latency."

An EW system's most basic function is to receive signals in the electromagnetic environment, recognize signals of interest – typically from enemy radars, threats and communications systems – and jam them, if necessary. For a classic EW system, this process relies on data collection (i.e., SIGINT), which helps with programming the EW system to recognize the signals of interest. With an AI-enabled EW system, data collection takes on a whole new value, because lots and lots of data from the EM environment is needed to train the AI models to recognize patterns of behavior from emitters of interest.

"Modern radars are very adaptable, and the way they behave can be changed instantly within an FPGA, which makes waiting for a countermeasure problematic," says Lockheed Martin's Ottaviano. "However, by reducing the data with AI and seeing how these radars behave you can provide recommendations on how to engage in a brief time. It is a huge help in data reduction."

Connecting the Dots

While AI can offer tremendous benefits to EW at the system level, it is also creating an impact for EW in other areas. For example, the DOD has initiated the Joint All-Domain Command and Control (JADC2) effort that aims to enable distributed sensor inputs to be rapidly collected, analyzed and shared with weapons delivery platforms. The DOD envisions a cloud-like JADC2 environment for all forces to share sensor data, transmitting across many communications networks to enable faster decision-making. Nardell affirms this, saying that "the roadmap is being applied differently in each of the Services with their own initiatives, and the fact that an F-22 can't talk to an F-35 today is an indicator of how big that gap is."

With JADC2, the DOD intends to give commanders better decision-making power by collecting data from an enormous number of sensors with the aggregate data being used by AI to identify targets, then recommending the optimal kinetic or non-kinetic weapon to engage the target. The concept allows commanders to access information to enable simultaneous operations using surprise and the rapid and continuous integration of capabilities across all domains.

No Shortage of AI Capability

There appears to be no lack of hardware and software available to integrate AI in both existing platforms and new ones. "We have the horsepower now.

We have RFSoC capability that helps, but we are certainly looking to the next generation that further expands it," says Nardell. "I don't think training machine learning is what we want to do in tactical-focused platforms, but you can still provide a level of AI and machine learning that helps the mission. We are using AI multiple systems, from submarines to service and airborne, and they're all getting increased benefits from AI and machine learning."

"So while the core capability out there now is adequate," Nardell explains, "the challenge becomes putting it into a tactical system where organization, environmental qualification, and reliability need to be tackled. But we've done that before, so the processes exist, and we just need to make the investment. There are really very few technical barriers that are preventing it from happening today.

"AI in some form has been around for decades," he says, "and I think most times when people think of it is in relation to neural networks, but that's only one part of the AI tool kit. You already have heuristics, algorithms and neural approaches, and it's just now that we're starting to apply them to EW problems. And actually, a lot of the tools available do not really require a lot of expertise and information science to use. We're using algorithms that have been out there awhile and applying them to our problems."

"I see machine learning as an opportunity to extract as much capability as we can from our already very capable sensors and effectors," Nardell continues. "But we have not been able to use them to their fullest advantage because of the algorithms that join the two. So, I see AI and machine learning as an opportunity to extract more value from the things we already have."

Retrofitting AI

While designing AI capability into new EW systems in the future is assumed, there is also a need to integrate it into as many legacy EW systems as possible, some of which mostly use analog technology and are several decades old. "We're putting AI in systems that were designed 10 years ago because it's not a complete overhaul, as there are standard interfaces we can leverage to get the data we need," says Nardell. "It depends on how to open the system is and how well it was designed."

"What I consider a legacy platform is not an F-22 but an F-16 or an F-18," Nardell continues. "We are already looking at sixth-generation platforms, and we're starting to see what they may look like – and they all have AI capabilities. The problem is that it's going to be a long time before those birds are flying, and since the fourth-generation footprint is enormous, there is a huge opportunity now to add AI capability to these platforms in a shorter time frame at a lower price. It's going to get even easier to put FPGAs, tensor processors and GPGPU's into legacy platforms as the industry increasingly adopt open standards."

What the Future Holds for Cognitive EW

Less than a decade ago, cognitive EW was more a dream than a reality. But that has changed dramatically thanks to extraordinary developments in the field of

Under DARPA's Adaptive Radar Countermeasures (ARC) program, Leidos and L3Harris Technologies have been integrating AI into the ALQ-214 RF countermeasures system, which is used on the US Navy's F/A-18E/F Super Hornets. US NAVY

AI, as well as the software and hardware required to enable it.

"One of the messages I think the EW community needs to be aware of is that implementing this capability into our systems today is definitely possible," notes Rappa. "We can extract a lot more value from our fourth-generation platforms by installing AI in them – and the barrier is not terribly high. As budget pressures increase, DOD needs to get a lot of value for their money, and AI is an extremely efficient use of resources." BAE Systems' Kuzdeba points out that his company already has the ability to generate near-instantaneous responses to unknown threats. "We can do it, although its readiness for use across [an air] wing or fleet varies greatly. We will get there, but at the moment it's aspirational.

"We're seeing more and more incorporation of AI and machine learning," says Ottaviano, "in both fixed-wing and rotary aircraft, and I think the next big step will be to reduce latency, or as I like to put it, we need to get this stuff working at the speed of RF. We are taking steps to reduce the processing latency on GPGPU-type platforms, and while they are terrific, they do have some latency. But if you told me four years ago we'd be where we are today, I'd probably have given you a strange look, so we are obviously moving forward rapidly."

"In our development programs," says Rappa, "we're focusing on bringing AI closer to the edge, and one of our primary efforts is bringing the machine learning coprocessor right next to the transceiver where it could be offloading instructions, which is much more power-efficient than using a CPU or an FPGA. But you can only take advantage of that if you have a definitive edge processing strategy designed for EW. It's the major lynchpin in what we are trying to do with partnerships in the commercial sector."

Once all of these capabilities are deliverable, the next question is whether or not the system should be autonomous – a topic of considerable interest not just as it concerns EW but throughout the DOD, as well. "There are many questions about the ethical use of AI," notes Kuzdeba. "When you start to get where you can do it in real-time, those questions begin to come up, such as if you have an autonomous system creating a countermeasure, can you safely verify that it is going to keep the pilot safe?"

"It really comes down to trust," Kuzdeba explains, "because the pilot has to determine whether he is going to stake his life on having the [EW] system work autonomously and whether it will perform as is it supposed to. You have to get buy-in from the stakeholders so that they turn it on. Because if they don't have confidence, they might turn it off. Of course, this is hardly the first time warfighters were required to have faith in new technologies, of which stealth is an excellent example. In the end, they have."

Kuzdeba sums the challenge up succinctly: "In the end, it's about speed, because our adversaries are trying to bring AI into their systems as well, so we're either fast, or we lose. It's that simple."

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AOC Webinars has been a tremendous asset providing the AOC's audience with learning, advocacy, and the exchange of information. Register today to hear from subject-matter experts on all things EW!

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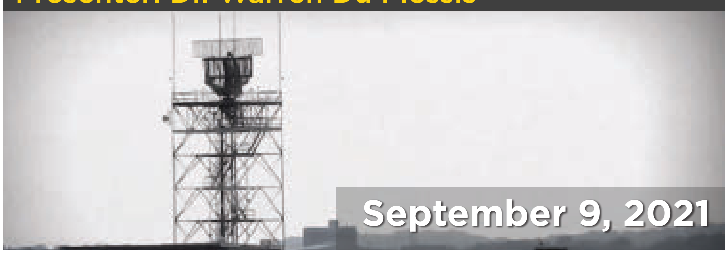

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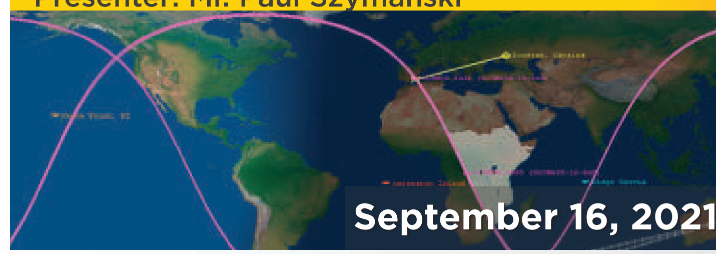
Presenter: Mr. Paul Szymanski



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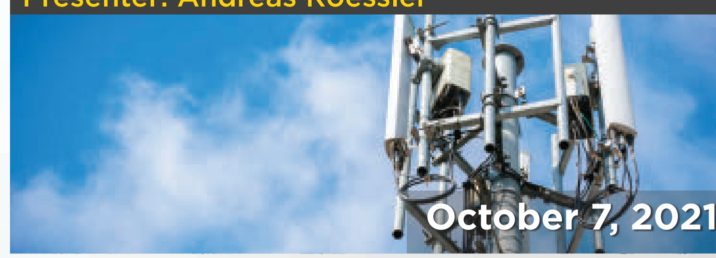
Presenter: Dr. Thomas Withington

5g for Critical Communications
Presenter: Andreas Roessler



What SOSA™ Means to the Warfighter
Presenter: SOSA Panel

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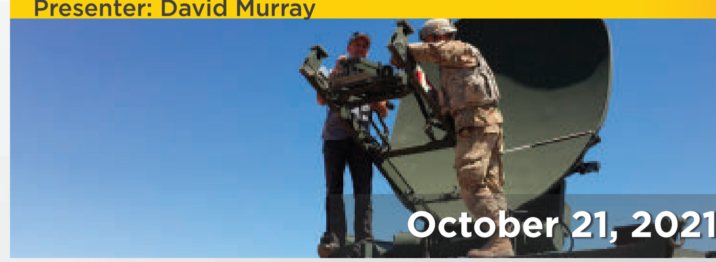
Presenter: David Murray



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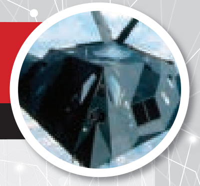

Renan Richter

Mondays, Wednesdays & Fridays
1:00 – 4:00 PM ET | September 13 – 29, 2021
This course introduces students to Radar Cross Section (RCS) engineering and its basics fundamentals inside the modern EW context. Stealth technology will be addressed by presenting current challenges and future perspectives.

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Dr. Patrick Ford

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This course will cover the core material required for participants to understand and discuss basic Satcom theory and operations.

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EW EUROPE 2021

Dr. Clayton Stewart

Saturday & Sunday | 09:00 – 17:00 BST
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This course is intended for an audience that has some familiarity with electronic warfare (EW) but wants to gain additional depth and breadth in the subject. We will begin with a historical perspective and introduce use of radar, integrated air defense system, early electronic attack (EA) functions and conclude with an overview of modern EA, electronic support (ES), and electronic protection (EP).

WASHINGTON D.C. 58 AOC INTERNATIONAL SYMPOSIUM & CONVENTION

Space Electronic Warfare

Dave Adamy
Friday & Saturday
08:00 AM – 5:00 PM EST | December 3 – 4, 2021

Machine Learning for Electronic Warfare

Kyle Davidson
Friday & Saturday
08:00 AM – 5:00 PM EST | December 3 – 4, 2021

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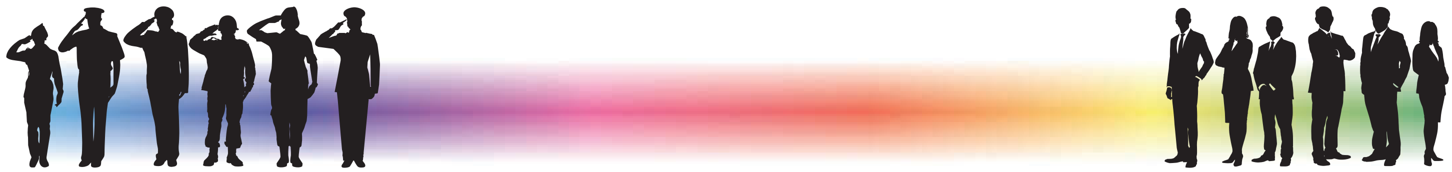
AOC 2021, the Association of Old Crow's International Symposium & Convention, brings together the *full spectrum of people* working in electromagnetic spectrum operations.



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Symposium Sessions

- [5G Networks] Critical Enabler or Vulnerability?
- [Air Force Spectrum Warfare Wing] Vision, Initial Efforts, Integration Across the Joint Force
- [EMSO] Implementing EMSO for the Future Fight
- [JADC2] The Criticality of EMS Interoperability/ Compatibility
- [MBSE Digital Environment and Engineering] Enabling to Rapid Development and Fielding
- [Project Convergence 21] Linking Land, Air, Sea, Space, and Cyberspace
- [Government and Industry Perspectives] Strategic Opportunities and Emerging Technologies
- [Talent Challenges] How Space Force Is Developing Guardians To Build High-Performance Teams
- [AI and Autonomy] The Speed of Data and Decisions in the Next Fight *(brought to you by Young Crows)*

Learn more about our theme and session details at **58.crows.org**

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SPEAKER SPOTLIGHT

LTG Thomas H. Todd III
Deputy Commanding General
Acquisition and Systems Management

Dr. Victoria Coleman
Chief Scientist
United States Air Force

Ms. Michèle Flournoy
Co-Founder and Managing Partner
WestExec Advisors

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5G Communications – Part 6

More ISR Applications of 5G

By Dave Adamy

Last month, we discussed some of the applications of 5G to intelligence, surveillance and reconnaissance (ISR). This month, we will look at some more ISR applications.

ISR is clearly moving into an increasing level of net-centric operation, with many sensors and many users sharing information about enemy activity. 5G technology is attractive for ISR applications because it allows the cooperative operation of large numbers of users. Open literature states that 5G allows up to a million users in 38 square miles. This compares to 2000 for 4G operation. Consider that there are many users present, competing to use the electromagnetic spectrum. The high density of users available on 5G assures that the necessary number of ISR users will be able to gain access as required. This means that 5G will significantly improve the performance of ISR networks.

With a 5G network, the information collected by intercepting hostile emissions can be efficiently moved to the locations where analysis can be performed on large numbers of intercepts from dispersed fixed and mobile receiving sites. The resulting analysis can then be applied to locations where countermeasures can be optimally initiated.

SWARMS OF SENSORS

Figure 1 shows a swarm of airborne sensors operating cooperatively. For simplicity, the swarm is pictured with only a few sensors; actually, there will be significantly more – each member of the swarm operates semi-independently in close proximity to other members. If they are connected by 5G links operating across millimeter-wave frequencies, the swarm can cover most of a 1x1 kilometer-wide area with excellent connectivity and with high-quality, low-latency, high-data-rate links.

The shortcoming of using millimeter wave links is that they are subject to high losses in heavy rain, which will require closer proximity of individual sensors in bad weather to shorten the links. However, if data is forwarded from member to member of the swarm, data can be collected from optimally spaced sensors and passed to ground control and processing assets using multiple-hop transmissions, if necessary.

It may be best for the members of the swarm to use high-band links for maximum data transfer rates from platform to platform, but the links from the swarm members to the control stations may need to use mid-band links, which can operate over longer distances. If the control and data links need the

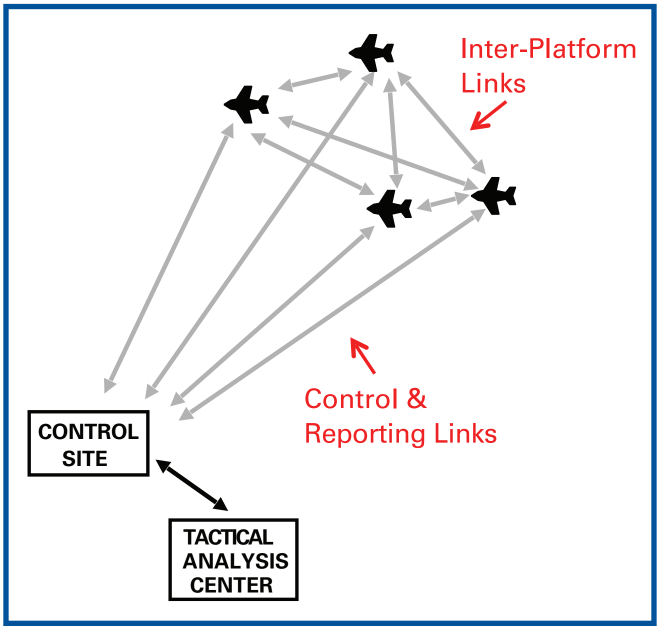


Fig. 1: Swarms of semi-independent sensors in the atmosphere can connect to pass data and perform station keeping. They will also need to be connected to a control site for direction and reporting but may transmit through other members of the swarm to reduce link distances.

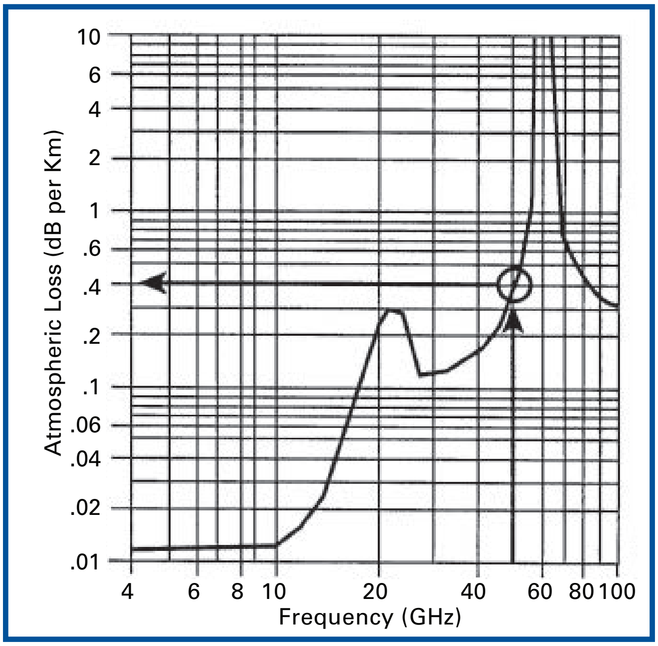
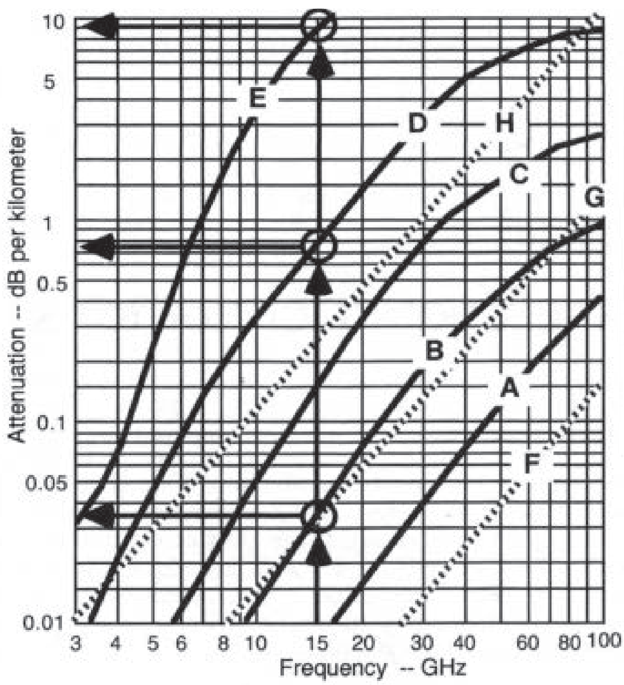


Fig. 2: Atmospheric attenuation is very low at mid-band frequencies, but it is much higher at high-band frequencies. At 60 MHz, it is about 20 dB per kilometer.

Rain Loss



RAIN	A	0.25 mm/hr	.01 in/hr	Drizzle
	B	1.0 mm/hr	.04 in/hr	Light Rain
	C	4.0 mm/hr	.16 in/hr	Moderate Rain
	D	16 mm/hr	.64 in/hr	Heavy Rain
	E	100 mm/hr	4.0 in/hr	Very Heavy Rain
FOG	F	0.032 gm/m^3	Visibility greater than 600 meters	
	G	0.32 gm/m^3	Visibility about 120 meters	
	H	2.3 gm/m^3	Visibility about 30 meters	

Fig. 3: *Rain loss in the atmosphere can be very significant at 5G high-band frequencies.*

wider high-band bandwidth, they may be required to employ intermediate platforms for range extension.

As shown in **Figure 2,** the atmospheric attenuation is very high at high-band 5G frequencies. A 50 GHz link will suffer 10 dB loss at 25 km, but only 0.4 dB over a 1 km distance.

As shown in **Figure 3,** the loss from rain is a function of the signal frequency, the rainfall rate and the length of the signal path through the rain. For example, the loss in a 28-GHz link in heavy rain is 3.3 dB per kilometer, which is 82 dB over a 25-km link.

SWARMS OF SATELLITE-BORNE SENSORS

There is no rain in space, so a swarm of sensors can operate under any weather conditions. **Figure 4** illustrates the operation of a swarm of small satellites. Again, the figure shows only a few satellites, but the swarm can be considerably larger.

First, let's consider how the members of the swarm communicate with each other for data transfer and station keeping. Because it is challenging and because it provides security against ground-based intercept and jamming, we will assume 60-GHz link frequency.

The following discussion draws on information presented in the May and June 2021 EW 101 columns. Let's consider a high-band 5G link operating in space with a 100-watt transmitter, a 1-MHz bandwidth and a 256-element antenna array (both transmit and receive), with less than a 15-degree offset from boresight in each array. Each antenna is oriented toward the other satellite to an accuracy of 5°. Each link receiver has a 2-dB noise figure. At 60 GHz, the link space loss is 182 dB at 500 km spacing of the satellites. The antenna gain for each antenna is 25 dB (for both transmit and receive).

Here is the satellite-to-satellite link equation:

Transmitter power = 100 watts (50 dBm)
Antenna gain is 25 dB (each for transmit and receive).
Antenna loss from misalignment is 7.8 dB for each antenna.
Link frequency is 60 GHz.
Link range is 500 km.
The received power is:

$$P_R = P_T + G_T - \text{misalignment error (both antennas)} - \text{space loss} + G_R$$
$$= 50\text{ dBm} + 25\text{ dBi} - 15.6\text{ dB} - [32.4 + 20\log(60{,}000) + 20\log(500)] + 25\text{ dBi}$$
$$= 50\text{ dBm} + 25\text{ dBi} - 15.6\text{ dB} - [182\text{ dB}] + 25\text{ dBi} = -97.6\text{ dBm}$$

Now consider the receiver sensitivity, which is a function of the receiver noise level (kTB), the receiver noise figure and the pre-detection signal to noise ratio (RFSNR).

kTB is the thermal noise in the receiver. At 280°K, it is -114 dBm in a 1-MHz bandwidth. The receiver in a satellite may be colder than this, and if so kTB may be lower. Since we don't know that temperature, we will assume the receiver is at the 280°K temperature of the Earth's atmosphere. The noise figure of the receiver is 2 dB.

$$\text{Sensitivity} = kTB + \text{Noise figure} + RFSNR$$
$$= -114\text{ dBm} + 2\text{ dB} + RFSNR$$
$$= -112 + RFSNR$$

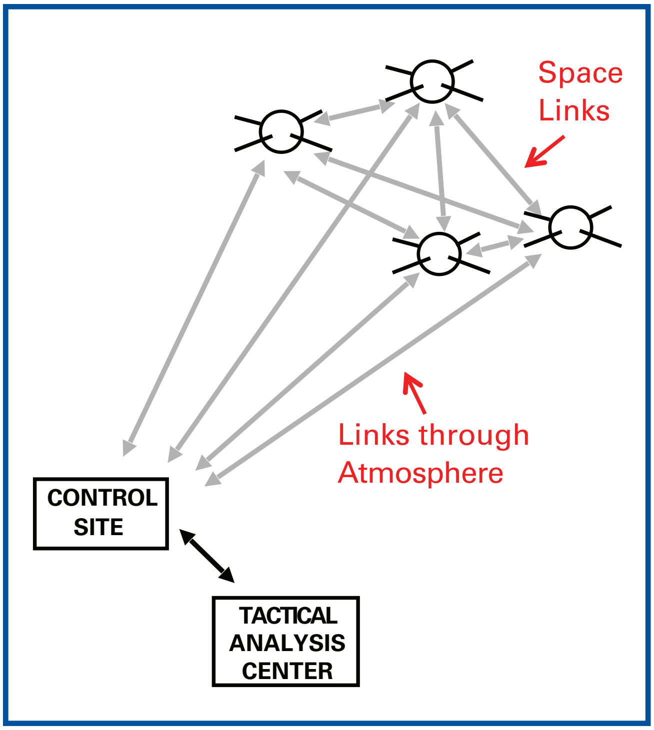


Fig. 4: Swarms of semi-independent sensors in space do not face atmospheric or rain loss between members of the swarm, but they must pass through the atmosphere to reach a control site on the Earth's surface.

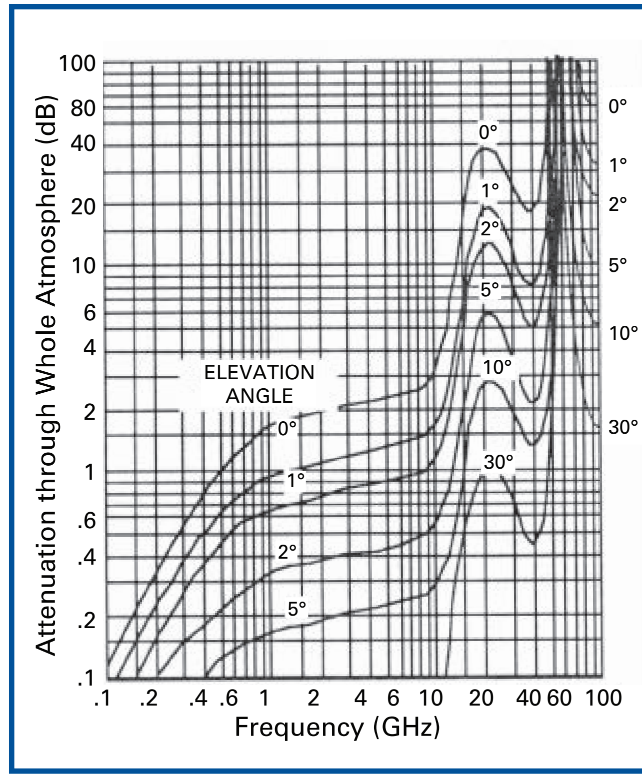


Fig. 5: Loss from atmospheric attenuation through whole atmosphere is a function of elevation angle from the ground station to the satellite and the frequency.

The RFSNR in the link receiver is the difference between the received power and the sensitivity. Thus, the pre-detection signal to noise ratio at a range of 500 km is:

-97.6 dBm - (-112 dBm) = 14.4dB

This means that the satellites can be 500 km apart and the signal-to-noise quality would be a very respectable 14.4 dB for satellite-to-satellite links. If they are deployed closer, the quality of transferred signals would be even better.

Now, consider the links from the swarm satellites to the ground. The space loss will depend on the distance from the satellite to the ground station. But because the ground station can have a large antenna, the link should provide proper connectivity. However, we must consider the atmospheric and rain losses over the portion of the satellite to ground link that is in the atmosphere.

Figure 5 shows the loss through the whole atmosphere as a function of elevation to the satellite and frequency. For example, at 28-GHz, a link with 30° elevation to the satellite would have about 0.8 dB loss. It should be noted that at 60 GHz there is so much loss that the signal will never get there.

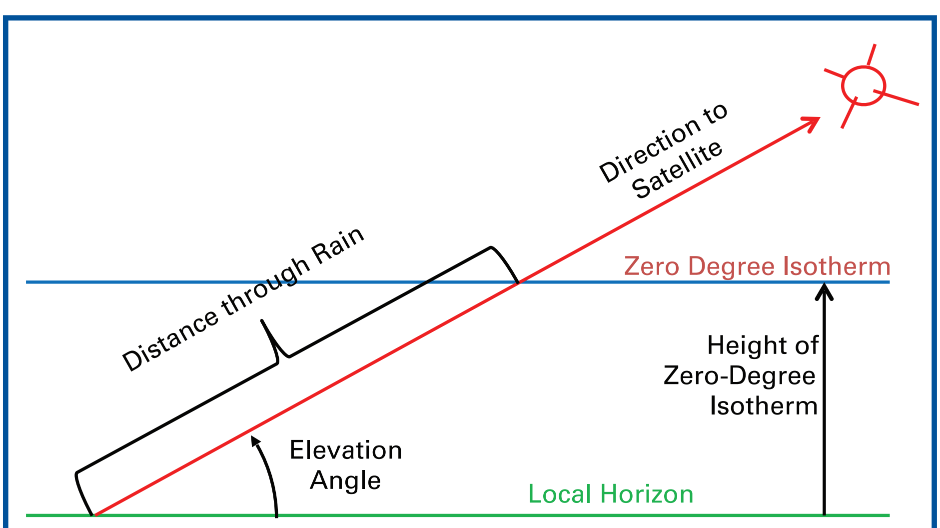
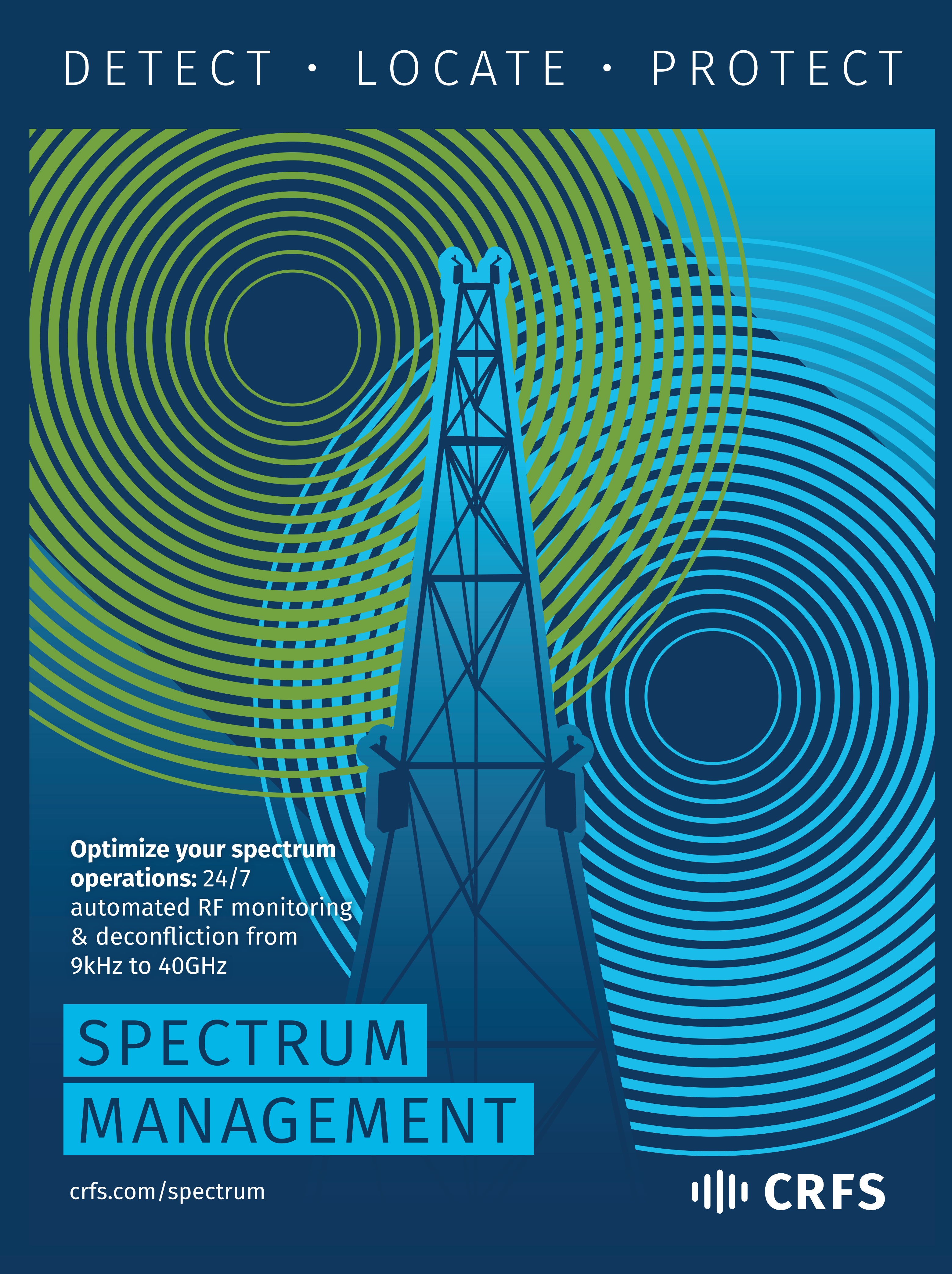


Fig. 6: Because rain falls from the zero-degree isotherm, the length of the signal path through the rain is a function of the elevation angle to a satellite.

Figure 6 illustrates that the distance through rain depends on the elevation to the satellite. Rain falls from the zero-degree isotherm (i.e., the freezing altitude) so the distance through the rain is the elevation of the zero-degree isotherm divided by the sine of the elevation angle. Over this calculated distance, the rain attenuation can be determined from the frequency and rain density in Figure 3.

WHAT'S NEXT

Next month, we will continue our discussion of military applications of 5G. For your comments and suggestions, Dave Adamy can be reached at dave@lynxpub.com.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Epiq Solutions has introduced its Sidekiq NV100, a very small software defined radio (SDR) that is suitable for mobile EW, SIGINT and other C5ISR applications. The module, which can be used in any small compute platform, such as a laptop or tablet, leverages Analog Devices' wideband transceiver RFIC (ADRV9004), The result is a 22 x 80-mm unit that delivers an RF tuning range from 30 MHz to 6 GHz (with extended RF access down to 10 MHz); flexible bandwidths between 12 KHz and 40 MHz per channel; 16-bit A/D and D/A converters; and two U.FL antenna ports supporting the following modes: 1Rx + 1Tx (FDD or TDD), 2x independently tunable or phase coherent Rx, or 2x independently tunable or phase coherent Tx. Platform development kit is available supported by the company's standard libsidekiq software API and FPGA reference design. *Epiq Solutions; Rolling Meadows, IL, USA; +1 (847) 598-0218; www.epiqsolutions.com*

VIDEO CAPTURE AND SIGNAL PROCESSING CARD

Abaco's GRA115V is a rugged 3U VPX form factor graphics/GPGPU/video capture processing card that is based on NVIDIA® TuringTM architecture using the NVIDIA RTX3000TM platform. It operates as an all-in-one solution for video capture, process, encode, decode, stream, and display and is well suited for image and signal processing applications, such as EW, SIGINT, digital signal processing and degraded visual environments (DVE). By utilizing the NVIDIA RTX3000TM, the GRA115V has 6 GB GDDR6 graphics memory, 1920 CUDA® cores, 240 Tensor cores, 30 RT cores, and delivers up to 5.3 TFLOPS floating-point performance with CUDATM and OpenCLTM support. It also takes full advantage of the NVIDIA GPUDirectTM RDMA to minimize latency for real-time video and data streaming. The 3G-SDI I/O can be configured as HD-SDI & SD-SDI if required. The card is available in air cooled or conduction cooled with thermally efficient heatsink technology and rear I/O. *Abaco Systems; Huntsville, AL, USA; +1-866-652-2226, www.abaco.com.*

AOC FORT WORTH CHAPTER ('COWTOWN CROWS') 2021 ANNUAL SCHOLARSHIP GOLF TOURNAMENT

The Association of Old Crows (AOC) Fort Worth Chapter ("Cowtown Crows") Scholarship Golf Tournament was held on Friday, June 11 at the Squaw Creek Golf Course located in Willow Park, Texas. The tournament drew participants from industry and professional organizations.

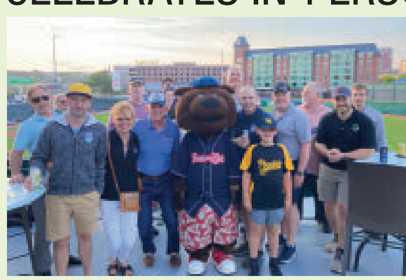
After registration from 10:30 a.m. to 11:30 a.m., the tournament was started with a catered barbeque luncheon with all of the trimmings, which included cole slaw, baked beans as well as tasty cupcakes from Sam's Club for dessert.

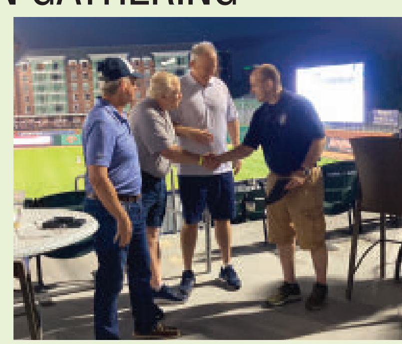
The tournament drew 48 golfers divided into 12 four-person team squabbles. Industry golf participants were represented by Rohde & Schwarz, INCOSE, IEEE Fort Worth Section, Golf Etc., Test Equity, Lockheed Martin and BAE Systems. Tee time commenced at 1 p.m. with consecutive teams following at eight-minute intervals.

The golfers competed for first, second and third place bragging rights. The first-place winner was Team Golf Etc. followed by Team Huncharek in second place and Team Auld winning third. Each team was awarded placement trophies in the form of tumblers. The tournament ended with awards recognition, giveaways and a raffle. Each golfer who participated received a goody bag upon registration.

Everyone had fun and walked away either with a raffle prize or giveaway. Many thanks to our volunteers, sponsors and golfers who made our 2021 Scholarship Golf Tournament fundraiser a success.

GRANITE STATE ROOST CELEBRATES IN-PERSON GATHERING AT THE FISHER CATS





The Granite State Roost Crows held its annual summer outing on July 21 at the New Hampshire Fisher Cats Delta Dental Stadium in Manchester, New Hampshire.

Approximately 26 Crows, families and friends attended the event, including AOC President Glenn "Powder" Carlson and Northeast Regional Director Myles Murphy. The First Base Party Deck was reserved, which has a large, private suite area and a new BIG TOP tent over the deck. The weather was a bit windy but warm and sunny to "play ball"! Everyone enjoyed delicious ballpark fare.

The Fisher Cats took the initial lead in the second inning with two runs. It was an exciting game with the lead changing hands four times throughout the game. The game lasted nine innings, and fans watched the Fisher Cats score a two-run homer in the bottom of the ninth to bring the final score to 6-7. Unfortunately, the visiting team – the Reading Fightin' Phils – pulled out the win … this time.

Steve Tourangeau, president of the Granite State Roost, presented Skip Stolz, former vice president of GSR, with a certificate of appreciation and a GSR coin to thank him for his service to the GSR. Stolz's family was in attendance to see this ceremony.

We were very honored and glad to host Myles Murphy, who drove up from his home in New Jersey to attend the game. Granite State Roost was also fortunate to have "Powder" Carlson in attendance. The GSR wishes to thank Carlson for essentially pulling "double duty," serving both our chapter and the AOC International.

Granite State Roost continues to energize its chapter activities. GSR and Rohde & Schwarz are co-hosting technical Lunch & Learns and planning evening socials at the Nashua Country Club, who we thank for the privilege of holding board meetings and IEEE technical events at their facility.

Granite State Roost works to strengthen electronic warfare, electromagnetic spectrum operations and cyber warfare in the Northern New England area. GSR provides scholarships to local colleges and university students majoring in engineering and science-related fields of study and who plan to pursue a career in EW and EMSO.

For more information about the Granite State Roost, contact Melinda Tourangeau, secretary and social chair, Granite State Roost - AOC, at (603) 459-3151 or mtourangeau@rvjinstitute.org.

AOC JAPAN CHAPTER 10TH EW RESEARCH GROUP CONFERENCE

The AOC Japan Chapter hosted the 10th EW Research Group Conference on May 13 online. The event was co-sponsored by the IEICE (The Institute of Electronics, Information and Communication Engineers) Japan, Technical Committee on Space, Aeronautical and Navigational Electronics (SANE).

The EW Research Group of the AOC Japan Chapter holds its annual conference to promote the exchange of new ideas and information in the fields of EW and related areas.

At the conference, AOC Japan Chapter President Shigeo Kazama, an AOC Silver Award recipient, welcomed the 70+ attendants from Japanese industries, academia and government and promoted AOC membership.

AOC Japan Chapter President Shigeo Kazama's speech

The keynote speeches were on radar cross-section evaluation and mathematical forms of stealth. They were presented among the technical session presentations of researchers, engineers and students. The AOC Japan Chapter officers and keynote speakers gathered carefully at Sogo Electronics Inc. in Tokyo, where the AOC Japan Chapter originated, and sent out messages to the attendees.

Japan Chapter officers and keynote speakers at Sogo Electronics Inc.

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