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November 2021 Vol. 44, No. 11

JED

Journal of Electromagnetic Dominance

EMSO for the Air Defense Fight – Part 2

- Technology Survey: ELINT Receivers
- Germany, Netherlands Contract for New COMINT Capability
- UK Invests in New DE Weapons Demonstrations

JED CONTENTS

Journal of Electromagnetic Dominance
November 2021 • Volume 44, Issue 11

US AIR FORCE RESEARCH LAB PHOTO

US Marines with 1st Battalion, 3rd Marines, monitor the signal environment during a Fire Support Coordination Exercise as part of Service Level Training Exercise 1-22 at Marine Corps Air Ground Combat Center Twentynine Palms, CA, on September 27. The exercise provided Joint Terminal Attack Controllers and Joint Fire Observers the opportunity to integrate air and ground assets to ensure 3rd Marines can process effective fires in any environment.

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AMD AND EMSO

This month's *JED* includes a feature story (the second part of two), by John Haystead about the US Army's Air and Missile Defense (AMD) enterprise. Last month, John focused on the command and control (C2) aspect of AMD modernization. This month, *JED* is taking a look at some of the new non-kinetic effectors, which are critical to defeating the growing set of airborne threats. The challenge posed by these new threats calls for a strategy that acknowledges EMSO as an essential part of the modern AMD enterprise.

The AMD mission, traditionally known as Ground-Based Air Defense (GBAD), has been characterized by an electromagnetic competition since World War II. The RAF's Dowding System, which included the Chain Home early warning radar network, was the first true integrated air defense system (IADS), proved its strategic value during the Battle of Britain and in the later stages of the war when Germany began launching V2 rockets.

From the 1940s to today, the AMD community has pursued very few technological pathways in terms of electromagnetic competition. Although IADS have evolved significantly to keep pace with jet aircraft and missiles, radars are still the main sensor of today's GBAD systems. In the 1960s and 1970s, EO/IR sensors were introduced, and short-range air defense systems began shifting from guns to IR-guided missiles. Overall, GBAD sensors and weapons have been able to evolve at a steady pace because air threats (aircraft and missiles) have stayed within a relatively limited performance envelope that AMD sensors, C2 systems and kinetic weapons could match.

Over the past decade, however, the air threat has started to change in two important ways. At the high-end (in terms of speed, at least), hypersonic-class weapons developed by Russia and China are posing new challenges for AMD sensors and C2 systems, as well as for the kinetic weapons that must intercept them. At the low-end, the advent of inexpensive commercial drones and the ability of potential adversaries to deploy them in swarms threaten to overwhelm GBAD systems that are primarily designed to attack smaller numbers of aircraft and cruise missiles.

Air defense planners are responding to these threat developments by pursuing strategies that expand the scope of electromagnetic competition. In the case of hypersonic missile defense, for example, the DOD is looking at ways that directed energy weapons might be used to complement kinetic interceptors. High Energy Lasers (HELs) and High-Power Microwave (HPM) weapons also have a role to play in defeating individual drones, as well as drone swarms. On the sensor side of the air defense equation, AMD forces will increasingly utilize passive RF sensors, such as radar ESM systems and passive coherent radars (or exploit the high-gain antennas on AESA radars), to take the pressure off active radars. Fusing these sensor inputs into unambiguous target tracks and sharing them across battle networks is another set of challenges that is being addressed by efforts such as CJADC2.

AMD is just one of many mission areas whose future depends on building stronger ties to EMSO. Fortunately, the EMSO community is also learning how it can support these missions, as well. – *J. Knowles*

JED
Journal of Electromagnetic Dominance

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Calendar *Conferences & Trade Shows*

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

JANUARY 2022

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

Asian Defense and Security (ADAS) 2022
January 19-21
Manila, Philippines
www.adas.ph

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

FEBRUARY

Modern Threats: Surface-to-Air Missile Systems Conference 2022
Secret / US Only
February 1-2
Redstone Arsenal, AL
www.crows.org

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

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

European Microwave Week
February 15-17
London, UK
www.eumweek.com

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

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

MARCH

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

World Defense Show
March 6-9
Riyadh, Saudi Arabia
www.worlddefenseshow.com

Dixie Crow Symposium 46
March 20-23
Warner Robins, GA
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Calendar *Courses & Seminars*

NOVEMBER

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www.crows.org

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

Basic Radar Concepts
November 16-18
Lake Buena Vista, FL
www.pe.gatech.edu

Fundamentals of Radar Signal Processing
November 16-19
Lake Buena Vista, FL
www.pe.gatech.edu

DECEMBER

AOC Professional Development Course: Machine Learning for Electronic Warfare
December 3-4
Washington, DC
www.crows.org

AOC Professional Development Course: Space Electronic Warfare
December 3-4
Washington, DC
www.crows.org

AOC Professional Development Course: Introduction to Satellite Communications (Satcom)
December 6-10 (3 sessions)
www.crows.org

Infrared Countermeasures
December 7-10
Atlanta, GA
www.pe.gatech.edu

JANUARY

Electro-Optic and Infrared Systems (Part 2)
January 10-14
Shrivenham, Swindon, UK
www.cranfield.ac.uk

GPS Spoofing – History and Prevention
January 13
1400-1500 EST
www.crows.org

AOC Virtual Series Webinar: Microwave Photonics Improving DRFM Capabilities Against a New Generation of Radars
January 27
1400-1500 EST
www.crows.org

Radar EW
January 31 – February 4
Shrivenham, Swindon, UK
www.cranfield.ac.uk

FEBRUARY

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

AOC Virtual Series Webinar: Tactical ESM
February 24
1400-1500 EST
www.crows.org

MARCH

Advanced Radar
March 7-11
Shrivenham, Swindon, UK
www.cranfield.ac.uk

AOC Live Professional Development Web Course: Microwave Photonics: Pushing EW Boundaries
March 7-28 (10 sessions)
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OCTAVE BAND LOW NOISE AMPLIFIERS

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

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

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

LIMITING AMPLIFIERS

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

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

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

LOW FREQUENCY AMPLIFIERS

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

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President's Message

SURVIVORSHIP BIAS AND THE EMS

I recently re-read an article that I had first come across about five years ago: "When Data Gives the Wrong Solution," which was about "survivorship bias." During World War II, the US Army Air Force (AAF) was trying to figure out how to better protect their bomber aircraft in Europe. They collected all available information – logging every bullet hole and other damage from every (AAF) bomber that they could examine after returning from a mission. Based on the data, the AAF analysts determined that the bombers' survivability would be improved if armor was added to the areas with the greatest concentration of bullet holes, such as the fuselage.

At Columbia University's Statistical Research Group, a mathematician named Abraham Wald (the most prominent of the 18 analysts in the group) was asked to look at the bullet hole data, and he noticed a problem with the analysis. The data was collected only from those bombers that returned from their missions. Focusing on this type of sample set is what is known as "survivorship bias." He asked a simple question about a missing data set: what about the bombers that did not return? Where were the bullet holes concentrated in those missing planes? By looking at the bullet hole data in a different way, Wald's observation led the AAF to realize that the returning aircraft had survived mainly because the bullet holes were *not* concentrated in sensitive areas, such as the engines, fuel systems, etc. Based on Wald's input, the AAF analysts came to realize that these sensitive areas were the locations where armor should be added to the bombers. Wald's analysis approach was extremely effective, and it continued to influence aircraft design through the Vietnam conflict.

You may ask, how does survivorship bias apply to EMSO and the Electromagnetic Spectrum? When we operate in the Spectrum, are we also focusing too much on what we can see, what we expect, and what we think the analysis shows? What information are we missing and what are the gaps? What are the spectrum "bullet holes" telling us? More importantly, what and where are the signals (and signal characteristics) that we are missing? Where can we afford to take "damage," and where do we need to increase our armor or Electromagnetic Protection (EP) in the congested and contested EMS maneuver space? The other piece that we must consider is how much do we really know about potential adversary EMS systems? Are we using "survivorship bias" (i.e., captured data) to analyze others, as well as our own systems?

Data can provide information, but incomplete data can lead us to the wrong solutions. We must understand the missing data to enable a more complete analysis and achieve the correct solutions.

I am looking forward to seeing you at the 58th Annual AOC Convention and Symposium in Washington, DC, at the end of the month. We will continue to reach out to you with opportunities to mentor, support STEM and grow the next generation of Crows. – *Glenn "Powder" Carlson*

GERMANY, NETHERLANDS CONTRACT FOR NEW COMINT CAPABILITY

Electronic systems and sensors house Hensoldt (**Taufkirchen**, Germany) is to supply new mobile COMINT systems to meet the tactical radio reconnaissance requirements of both Germany and the Netherlands. The Netherlands' Defence Material Organisation (DMO) has awarded a contract to the company's spectrum Dominance and Airborne Solutions Division on behalf of the two nations. Hensoldt said the order was "worth a two-digit million Euro sum."

Under the Elektronische Oorlogvoeringscapaciteiten (EOV) program, the DMO – acting through its Joint Informatievoorziening Commando IT division – has assumed responsibility for the procurement of a common solution to meet the joint German/Netherlands requirement. This followed an analysis of options by the DMO for the replacement of the existing Koninklijke Landmacht EOV system (also provided by Hensoldt).

A bilateral Letter of Intent for the joint EOV procurement was signed by the Netherlands and Germany in December 2018, with a Memorandum of Understanding detailing the terms of the collaboration following in October 2019. A supplementary project arrangement was signed in July 2021.

According to the DMO, the joint procurement model is intended to deliver economies of scale while also making knowledge sharing in the field of EOV easier. It is additionally designed to improve interoperability at the operational level, and enable common upgrades through-life.

Hensoldt, working with a number of sub-suppliers, will take turnkey responsibility for the delivery of the EOV program, which includes digital broadband receivers, compact direction finders and high-performance software for real-time signal evaluation. The core elements of the system will be integrated into armored vehicles, or could be designed for portability so that dismounted troops can be supported directly in the theater of operations and achieve early threat detection. – *R. Scott*

UK INVESTS IN NEW DIRECTED ENERGY WEAPON DEMONSTRATORS

The UK Ministry of Defence (MoD) is investing an aggregate US$100 million development of three new directed energy weapon (DEW) capability demonstrators for testing by the British Army and the Royal Navy (RN) from 2023.

Contracts have been awarded to Thales UK (Belfast, Northern Ireland) for the development of a maritime laser directed energy weapon (LDEW) and a land-based radio frequency (RF) DEW system. A third contract has been awarded to a team led by Raytheon UK for the delivery of a land-based LDEW prototype.

The experimental maritime LDEW demonstrator being developed by Thales UK is to be designed for use on an RN Type 23 frigate. This maritime LDEW program – known as Project Tracey – will be delivered by Thales from its Belfast site. The company's team also includes BAE Systems, Chess Dynamics, Vision4CE, and IPG.

The Project Tracey capability demonstrator will be integrated into an RN Type 23 frigate for user-experimentation trials, with the system to be integrated into the ship's combat system for the duration. Experiments will explore the full decision-making process for engaging threats and include detecting, tracking, engaging and countering unmanned air systems (UAS), as well as sea targets. According to the MoD, the design requirements are focused on providing user experience and are designed to allow the RN to de-risk operation of high-energy lasers in realistic environments.

Thales UK will also deliver a high-power RF DEW demonstrator for land-based testing. The company, leading a consortium including QinetiQ, Teledyne e2v, and Horiba Mira, will install the demonstrator system on a MAN SV truck for up to six months of user experimentation led by the British Army.

Under its contract, Raytheon UK – teamed with Frazier Nash Consultants, NP Aerospace, and Raytheon Technologies – will deliver a vehicle-based LDEW demonstrator to the British Army. The system will be installed on a Wolfhound six-wheeled armored vehicle, and user experimentation will address counter-UAS effects and the prosecution of land-based targets.

All three capability demonstrators, which form part of the MoD's wider novel weapons program, are being managed through a joint Defence Equipment & Support/Defence Science and Technology center of excellence for DEW known as Team Hersa. Experimentation will focus on operation and maintenance of the DEW systems and will provide knowledge, information, and experience to assess whether DEW can be fully embedded on other defense assets in the future, the MoD said. – *R. Scott*

US AIR FORCE SEEKS EW-RELATED SOLUTIONS FOR FIELD DEMOS

The Air Force Cryptologic Office Cyberspace Intelligence Surveillance and Reconnaissance and Multi-Domain Innovation (AFCO/CM) Division (Joint Base San Antonio-Lackland, TX) has issued a Commercial Solutions Opening (CSO) for technologies and services related to Electromagnetic Warfare (EW), Information Operations (IO), electromagnetic digital communications, and multi-domain innovation. Under this effort, AFCO/CM's goal is to "leverage mature technologies in novel ways for a field demonstration within a year through application of novel material approaches or innovative services."

Topic AFCO-CM-001 seeks innovative and novel material solutions for EW across electromagnetic attack (EA), electromagnetic warfare support (ES), and electromagnetic protection (EP). According to the solicitation, this includes "…EW data fusion, advanced signal processing, cognitive techniques such as artificial intelligence (AI)/machine learning (ML), EA waveform generation, EW battle management (BM), and other advanced concepts."

Topic AFCO-CM-002 addresses IO – "the ability to affect adversary and potential adversary decision making with the intent to ultimately affect their behavior in ways that help achieve friendly objectives. The decision-making process exists within the information environment and consist of three targetable dimensions: 1. informational, 2. physical, and 3. cognitive."

Under Topic AFCO-CM-003, which covers Electromagnetic Digital Communications, AFCO/CM is seeking "a method to achieve universal access no matter the networks' or material solution given basic information regarding the networks' physical configuration and protocol. Offerors may also propose methods for positively or negatively affecting (i.e. deny, disrupt, degrade, deceive) electromagnetic digital communications." In addition, the CSO states "Offerors may also propose methods for positively or negatively affecting (i.e. deny, disrupt, degrade, deceive) electromagnetic digital communications."

Topic AFCO-CM-004 seeks innovative material solutions for integrated multi-domain operations. According to the CSO, "This topic includes multiple systems in one domain generating effects and/or supporting operations in another domain. For the purposes of this CSO for AFCO/CM, multi-domain operations capitalize on deep integration of EW, cyberspace, ISR, and Information Operations to generate effects within the tactical environment that result in operational and strategic results. Multi-domain operations often rely heavily on automated functions and managers due to the tight synchronization required for successful execution to present multiple dilemmas to overwhelm an adversary at multiple levels from machine to higher leadership that requires seamless, dynamic and continuous integration of capabilities generating effects in and from all domains."

AFCO/CM is soliciting proposals in two phases. Phase 1 proposals, which can be submitted through Sept. 30, 2022, will comprise a simple one-page "quad chart." Selected proposals will be invited to submit more extensive White Papers during Phase 2. For the purposes of this CSO, "All items, technologies, and services acquired using a CSO will be treated as commercial items." AFCO/CM expects to fund contracts in the range of $50,000-$50,000,000 over the full period of performance. The contracting point of contact is Ms. Carissa Heuertz, (201) 977-5457, e-mail carissa.heuertz@us.af.mil. Technical questions can be sent to 16AF.AFCOCM.BIZOPS@us.af.mil. – *J. Knowles*

ROHDE & SCHWARZ TO SUPPLY ESM FOR GERMAN F126 FRIGATES

Rohde & Schwarz has been contracted to provide its R&S KORA integrated communications-band and radar-band electronic support measures (ESM) for the German Navy's new F126 frigates.

In June 2020, a Damen-led team was awarded a €4.6 billion contract by Germany's Bundesamt fur Ausrüstung, Informationstechnik und Nutzung der Bundeswehr for the delivery of the F126 program. Under the terms of the contract, Damen will work with Thales (as mission systems integrator) and German shipyard partners to design and build four ships for delivery between 2027 and 2031; the contract includes an option for a further two ships to be delivered after 2032.

Rohde & Schwarz has now been awarded a mutual gain approach contract with Thales to deliver and integrate the R&S KORA communications/radar ESM on the new frigates. The company describes R&S KORA as a highly sensitive intercept and analysis system that detects, identifies and tracks complex and broadband radar emissions, as well as communications transmissions, at long range. – *R. Scott*

IN BRIEF

The Defense Advanced Research Projects Agency has awarded multiple contracts for its Waveform Agile RF Directed Energy (WARDEN) program. Awardees include **BAE Systems** (Nashua, NH) $6.9 million; **Communications and Power Industries** (Palo Alto, CA) $12.1 million); **Raytheon** (Tucson, AZ) received two awards for $2.9 million and $7.4 million; and **XL Scientific, LLC** (Albuquerque, NM) $4.9 million. DARPA's aim with the WARDEN program is to develop hardware, theory, and computational models to extend the range and wideband performance of High-Power Microwave (HPM) systems to attack targets with back-door attacks. WARDEN's three technical areas address the principal challenges to enhancing the range and effectiveness of HPM back-door attack which include 1) stable, high power, broadband amplification; 2) theory and computational tools to predict EM coupling into complex enclosures; and 3) predictive tools and agile waveform techniques enabling the identification and exploitation of electronic system vulnerabilities.

The Office of Naval Research has awarded three prototype development contracts to **D-TA Systems** (Arlington, VA), **Epiq Solutions** (Rolling Meadows, IL) and **Lockheed Martin Advanced Technology Laboratories** (Cherry Hill, NJ). Known as Project Neptune, the companies will work with Naval Surface Warfare Center-Crane (Crane, IN) to develop prototype subminiature RF signal processing payload subsystems for integration into an expendable unmanned maritime system that is being developed in parallel by ONR under a separate program. The Neptune payload will leverage commercial software defined radio (SDR) technologies (i.e., integrated wideband RF transceiver chipsets, FPGAs, ASICs, RFSoCs, and high-performance microcontrollers) but the payload will require varying levels of modification in terms of board shapes, connectors, power conditioning for battery power, tailoring of band-specific front ends, payload ruggedization for maritime operations, etc. According to a program description, "key technical objectives of the desired Neptune Payload Prototype subsystem include overall mechanical and electronic compatibility with the target platform, RF performance suitable for various maritime RF missions, and security of mission data / operational firmware / software."

Because the unmanned platform is expendable, the Neptune payload must also be a low-cost solution.

Cobham Advanced Electronic Solutions (CAES) (Arlington, VA) has acquired **Colorado Engineering, Inc.** (Colorado Springs, CO) for an undisclosed amount. Colorado Engineering develops boards and modules for EW, radar and communications applications. In recent years, it has moved into AI and ML technology for SIGINT applications.

The US Army's Program Executive Office for Intelligence, Electronic Warfare and Sensors (PEO IEW&S has entered into an $9.7 million Other Transaction Authority (OTA) agreement with **Lockheed Martin Rotary and Mission Systems** (Syracuse, NY) to support the next phase (Phase 2) of the Terrestrial Layer System - Brigade Combat Team (TLS-BCT). Under Phase 2, the program will enter a "fix test cycle" for TLS-BCT prototypes developed under Phase 1, and the company will provide prototypes ready for proof of concept of the SIGINT/EW/Cyber system, which is mounted on a Stryker vehicle. The award marks the downselection to one contractor.

The Navy's AN/ALQ-248 Advanced Offboard Electronic Warfare (AOEW) program, which is developing a helicopter-borne long-endurance anti-ship missile decoy, achieved Milestone C approval in September. Shortly afterward, Naval Sea Systems Command (Washington, DC) exercised a $17.8 million contract option with developer **Lockheed Martin Rotary and Mission Systems** (Syracuse, NY) to enter low-rate initial production (LRIP). NAVSEA is buying four units under LRIP Lot 1, with first deliveries scheduled in late FY2023. The Navy could buy four additional units under LRIP Lot 2 in FY2022.

Textron Systems (Hunt Valley, MD) won a $9.9 million contract from Air Combat Command (Joint Base Langley-Eustis, VA) for Synthetic Battlespace Enhancement with Force On-Force Reactive Tactical Readiness Integrated Air Defense System (IADS) Simulation (FORTRIS) services. The contract provides for the improvement of the Distributed Mission Operations Center IADS and electronic attack by a fully cognitive and automated IADS. Work will be performed in Hunt Valley and at Kirtland AFB, NM through September 2026.

The Naval Air Warfare Center – Weapons Div. (Point Mugu, CA) has awarded a $666,495 contract to **Synergent Technologies Inc.** (Frederick, MD) to deliver its Next Gen Frequency Agile Signal Simulator (NxGen FASS) and Recorder. The NxGen FASS is a software application that allows users to construct custom radar signal and digital communications signals to verify the response of airborne and ground-based receivers. According to a NAVAIR program description, "The Airborne Electronic Attack Integrated Program Team (AEA IPT) utilizes unique capabilities within the Electronic Warfare (EW) Unmanned Aerial Vehicle Simulation Lab to meet testing requirements for hardware and software. The EW hardware/software being developed by Naval Air System Command (NAVAIR) requires simulation of simultaneous pulse-on-pulse Radio Frequency signal from multiple threat emitters which the NAVAIR hardware/software will capture, analyze, and respond to. The Frequency Agile Signal Simulator (FASS) System and Recorder provides recording of the NAVAIR equipment response in addition to its own emissions, eliminating the need to purchase a separate recording system."

ARMTEC Defense Technologies (Coachella, CA) won a $6.9 million contract from Naval Air Systems Command (NAVAIR - PMA-272) to produce RR-198/AL chaff and RR-199/AL training chaff rounds for the F-35 program. The company will deliver about 24,000 rounds (combined) for US and international F-35 customers. The RR-198/AL is a new timed-release chaff expendable countermeasure with higher Radar Cross Section (RCS) and coverage into the millimeter-wave region. In related news, NAVAIR also awarded an $83.9 million contract to **Chemring Australia Pty. Ltd.** (Lara, Victoria, Australia) for production of MJU-68/B countermeasures flares for the F-35 program. Chemring Australia has been producing MJU-68/B flares for the past few years while it's sister division, Kilgore Flares (Toone, TN) works through an MJU-68/B order backlog.

Virginia Tech (Blacksburg, VA) has received a $1.5 million contract from the Office of Naval Research (Arlington, VA) for Advanced Spectrum Dominance and Research. Under the contract, Virginia Tech's Hume Center, Spectrum Dominance Division, will research software defined radio system architecture design, development and integration for

C2, ISR, EW and cyber effects; RF steganography techniques; and design and integration of compact multiband (HF through S-band) antenna system co-site interference mitigation techniques.

The Air Force Flight Test Center (Eglin AFB, FL), acting on behalf of the 350th Spectrum Warfare Wing, has awarded a $100 million indefinite-delivery/indefinite-quantity contract to **Northrop Grumman Amherst Systems** (Buffalo, NY) for Test Facilities Threat Simulators (TFTS) sustaining engineering services (SES) support; and a $530,744 task order for the 36th Electronic Warfare Squadron TFTS SES support. The contract will run through September 2031.

Lockheed Martin Rotary and Mission Systems (Owego, NY) won a $49.3 million contract from the Air Force Sustainment Center (Tinker AFB, OK) to overhaul an unspecified countermeasures receiver type on the B-52. This is part of a larger EW upgrade program for the B-52 program. In August, L3Harris Technologies (Clifton, NJ) won a $947.3 million contract from the EW Contracting Branch of the Air Force Life Cycle Management Center (Robins AFB, GA) for engineering services and modernization of the ALQ-172 jammer. This was awarded in support of Air Force Global Strike Command.

The Open Group Sensor Open Systems Architecture (SOSA) Consortium (San Francisco) published a new Technical Standard for SOSA™ Reference Architecture, Edition 1.0. The SOSA™ Consortium aims to create a common framework for transitioning sensor systems to an open systems architecture, based on key interfaces and open standards established by industry-government consensus. The open architecture supports airborne, subsurface, surface, ground, and space. The goal of The Open Group SOSA Consortium is to reduce development and integration costs and reduce time to field new sensor capabilities.

L3Harris Technologies (Melbourne, FL) announced that it has conducted the first flight of the EC-37B Compass Call jamming aircraft. L3Harris is the prime contractor with BAE Systems providing the EW mission suite.

HawkEye 360 (Herndon, VA), which provides space-based detection, identification and mapping of earth-based RF emitters, announced that it won a $10 million contract in July from the National Geospatial-Intelligence Agency (NGA) to help the agency develop emitter databases in support of Combatant Commands. The company will use its constellation of RF collection satellites to support a variety of analytics missions for NGA, including military activity and the trafficking of military, nefarious, non-state and transnational criminal (or illicit) activity. The contract, which includes $10 million for the base year, in addition to four one-year options, follows a one-year pilot program between the company and NGA. The company currently operates nine satellites, and has plans to launch 21 additional satellites by the end of 2022. It also wants to launch a second generation of 30 satellites by 2025.

Army Bringing EMSO to the Air Defense Fight – Part II

By John Haystead

The use of EMSO capabilities in the air defense fight is clearly well underway in terms of new non-kinetic countermeasures. These include the deployment of highly-powerful and sensitive GaN-based arrays in air defense radars and active jamming systems, as well as development (and soon deployment) of new Directed Energy (DE) weapons, such as High Energy Lasers (HEL) and High Power Microwave (HPM) for use in the AMD countermeasure role.

As described within Part I of this article, the Army's "Air and Missile Defense 2028" document provides the Army's overarching vision for the Air and Missile Defense (AMD) force and describes how the AMD force will achieve the Army's goal of preventing and defeating adversary air and missile attacks through a combination of deterrence, active and passive defense, and support to attack operations.

As he described at the time of the document's 2019 release, LTG James H. Dickinson, then Commander of US Army Space and Missile Defense Command (USASMDC) said, "We need integrated fires, both offensive and defensive, across domains, regions and missions, using multi-mission, high-demand, low-density assets. Our future architecture will be layered and integrated, utilizing the full suite of space, cyber, electronic warfare, as well as land and air sensors, to match the best shooter with the best sensor. Offensive and defensive integration during multi-domain operations will enable neutralizing enemy missile forces prior to launch."

Among AMD 2028's modernization initiatives and priorities are the Initial Maneuver Short Range Air Defense (IM-SHORAD) system, the Indirect Fire Protection Capability (IFPC), the Lower Tier Air and Missile Defense Sensor (LTAMDS) to replace the current Patriot radar; and, as previously discussed in Part I, the Integrated Air and Missile Defense Battle Command System (IBCS).

SHIELD PROJECT OFFICE

The Program Executive Office – Missiles & Space (PEO-MS), consisting of a number of project offices, is the home of these efforts. For example, the Short and Intermediate Effectors for Layered Defense (SHIELD) Project Office provides life cycle management for a number of countermeasure programs including IM-SHORAD and IFPC, and also provides transition management for short and intermediate DE air defense weapon systems. Its charter is to develop, test, acquire, field and sustain modernized kinetic countermeasures, as well as DE air and missile defense capabilities to counter tactical ballistic missiles, cruise missiles, unmanned aerial systems, rotary-wing, fixed-wing, and rocket, artillery and mortar (RAM) threats.

"We have to understand, at the fundamental level, that there is no one weapon system, offensive or defensive, that will solve all of our problems." – LTG Neil Thurgood

According to the program office, IM-SHORAD "fills a critical capability for the Army in providing air defense for maneuver forces. This year, a platoon of the 5th Battalion, 4th Air Defense Artillery Regiment, a subordinate unit under the 10th Army Air and Missile Defense Command, was the first unit in the US Army to field, test and receive four IM-SHORAD weapons systems. The Army's Rapid Capability and Critical Technologies Office (RCCTO) continues to mature high-energy lasers (HEL) and EW to increase M-SHORAD capabilities, and the Army will begin to integrate DE by fielding four DE-SHORAD prototypes in Fiscal Year 2022."

Within PEO MS, the Integrated Fires/Rapid Capabilities (IF/RCO) Project Office, is the lead office for transition of activities from the Army's Rapid Capabilities and Critical Technologies Office (RCCTO). The RCCTO is charged to field critical enabling technologies that address near- and mid-term threats. Together with RCCTO, IF/RCO provides the overall direction and guidance for the development, acquisition, integration, testing, training, fielding, product improvement, and interoperability of assigned Urgent Operational Needs (UONS)/Joint UONS (JUONS)/Directed Rapid Capability efforts.

The SHIELD program office reports that the "Indirect Fire Protection Capability System Increment 2 (IFPC Inc 2) remains on schedule to meet the Army's goal of having two batteries operational as directed by the SecArmy waiver." Enduring IFPC will be an industry-built solution for a launcher and an interceptor, incorporated in an All-Up Round Magazine (AUR-M) integrated with the IBCS as the fire control component, and the "Sentinel Radar" to provide the command and control and operational sensor. The Army is currently executing a competitive solicitation for the enduring IFPC capability to conduct US government, models and simulations, hardware-in-the-loop activities, and a live-fire shoot-off demonstration to determine the enduring IFPC capability. The Army submitted an Enduring IFPC Report to Congress in February of 2020 outlining the shoot-off.

STARE PROJECT OFFICE

The mission of PEO-MS's Search Track Acquire Radiate Eliminate (STARE) Project Office is to "deliver robust cyber security, advanced electronic countermeasures, and logistic systems and sub-systems, and to support the managed and controlled sale of radar and sensor capabilities to allies and international partners." It manages Army air defense and field artillery sensors, supporting and improving fielded sensors by developing capabilities to address current and future threats, as well as integrating with the IBCS network. Among the programs within its purview is the Lower Tier Air and Missile Defense Sensor (LTAMDS). LTAMDS, is designed to defeat advanced and next-generation threats including hypersonic weapons.

According to information provided by the Missile Defense Advocacy Alliance (MDAA) (Alexandria, VA), LTAMDS is a multi-band, 360-degree, multi-mission sensor with a high degree of cross-functionality, interoperability, and modularity. It is the first sensor designed specifically for operations within the Army's Integrated Air and Missile Defense architecture. It is intended as a replacement for the current AN/MPQ-53/65 radar in use with the Patriot missile system and uses Gallium Nitride (GaN) technology to provide greater signal strength and sensitivity for longer-range target detection.

According to the STARE program office, the LTAMDS rapid prototyping program has been running since September, 2018 with a $384 million contract awarded to Raytheon for six prototype radars in October, 2019. Prototype deliveries are being made between December 2021 and July 2022, with developmental testing commencing in March 2022 and continuing to April 2023. Operational demonstration is planned for June-July 2023, with an Urgent Materiel Release (4 radars) planned for September 2023 and a milestone C decision in December. Low Rate Initial Production (LRIP) is planned for the 2024-2028 timeframe and full rate production from 2028-2034.

DIRECTED ENERGY WEAPONS

The Army is pursuing a variety of directed energy weapons including HELs and HPM systems. Among these is a Directed Energy-Maneuver Short Range Air Defense capability, or DE-MSHORAD, that it plans to field at the platoon level by fiscal year 2022. According to LTG Neil Thurgood, Director of Hypersonics, Directed Energy, Space and Rapid Acquisition at RCCTO, "the new capability will provide brigade combat teams with a 50-kW laser aboard a Stryker combat vehicle in support of air defense artillery operations." In addition, Thurgood says the Army is looking to field a 300-kW Indirect Fire Protection Capability-High Energy Laser, or IFPC-HEL, and IFPC-High Powered Microwave, or HPM, at the platoon level in support of brigade air defense artillery operations. The

Army plans to deliver four operational, 300 kW-class IFPC-HEL prototypes integrated on tactical vehicles to a platoon by FY2024, while initially demonstrating the 300 kW-class capability in FY2022. The effort stems from a science and technology program, the High Energy Laser Tactical Vehicle Demonstrator (HEL-TVD), which featured a 100 kW-class laser.

The Army has also invested in the Air Force Research Laboratory's (AFRL's) Tactical High Power Operational Responder (THOR) system program in support of the Army's efforts to provide a prototype Indirect Fire Protection Capability-High Power Microwave (IFPC-HPM) system.

Developed at the AFRL Directed Energy Directorate (Kirtland AFB, NM), THOR is a prototype HPM weapon intended to disable the electronics in drones, and specifically engineered to counter multiple targets such as drone swarms. According to AFRL, the technology is housed in a 20-foot-long shipping container that can be stowed in a military cargo plane and assembled by just two people.

As observed by the General Thurgood, "Directed energy weapons are considered more cost effective in the fight against low-cost weapons found on the modern battlefield. High energy lasers kill one target at a time, and high powered microwaves can kill groups or swarms, which is why we are pursuing a combination of both technologies for our Indirect Fire Protection Capability rapid prototyping effort. Our partnership with the Air Force Research Laboratory gave us a running start on the HPM mission, and as brigades move to a more fixed location, personnel can leverage the IFPC-HEL and IFPC-HPM technology. Users will have the option to sequentially destroy a series of single targets through a high-powered laser, or take out a group of targets through a "cone" of high-powered microwave energy. Moving forward, the Army aims to equip its maneuver elements with HPM microwave capabilities, but to accomplish that, we must wait for current technology to improve and decrease in size."

Ultimately, says Thurgood, "We have to understand, at the fundamental level, that there is no one weapon system, offensive or defensive, that will solve all of our problems. And so in pursuing that, what you get is different types of technologies that we apply in the battlespace, in a layered defense in this case, things that can reach really far, things that can reach midrange, and things for really close. Missiles don't do that in all cases, nor does DE or HPM. Also, these technologies are at different levels of maturity, so linking them into an integrated battle command system at the right time and place is critical. This is why the Army, with its modernization strategy, is pursuing multiple technologies – kinetic kill, DE, HPM, and HEL. At the end of the day, some of those might not work like we want them to, or we may not be able to resource them at the pace we want, and the way we solve that is to create multiple ways that our soldiers on the battlefield can provide a defensive structure for the things that they are trying to protect by creating multiple dilemmas for an adversary – multiple problems for them to solve if they want to put offensive pressure onto us."

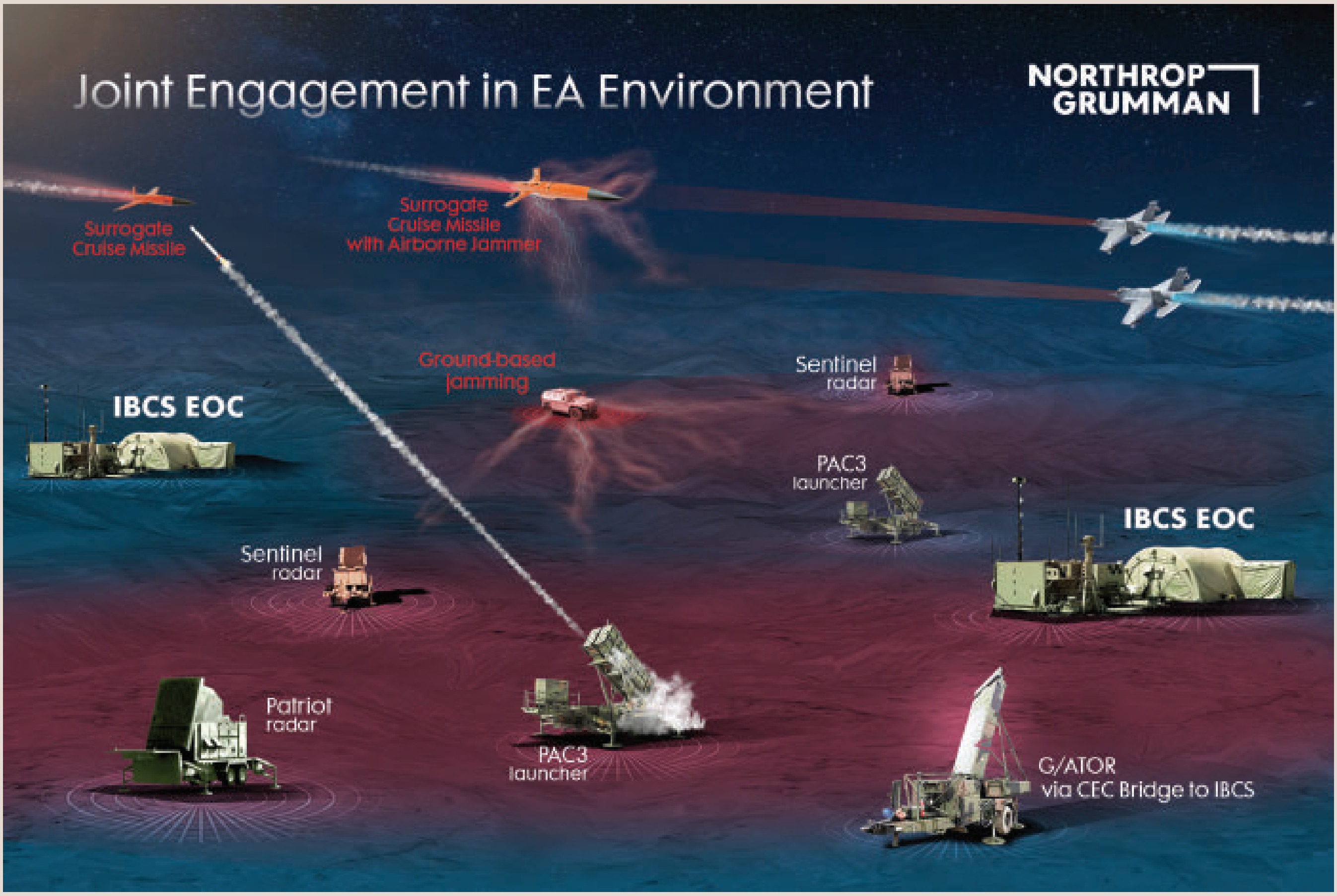
Continued on page 25

IBCS DELIVERS FORCE MULTIPLICATION TO ARMY AMD

Dr. Nicholas Paraskevopoulos, Chief Technology Officer and Sector Vice President, Emerging Capabilities Development, Northrop Grumman Mission Systems (Linthicum, Maryland), identifies finding, fixing, tracking, targeting, engaging and assessing airborne threats – from traditional ballistic and cruise missiles to novel drone swarms, jammers, stealthy platforms and high-speed, maneuvering weapons – as one of the Nation's most pressing challenges. "Scanning the electromagnetic spectrum for threat signatures is not new," he says, "but the sophistication of the sensors and their ability to detect new types of phenomenology has accelerated in recent years as technology has improved, miniaturized and proliferated within the commercial and defense sectors. The multifaceted challenge of picking out these sometimes faint and elusive signals among the background noise and clutter of the RF spectrum requires us to bring together the best minds in science and engineering." In particular, Paraskevopoulos points to work on "defining the possible" with regard to the ability of active and passive sensing of the EMS to detect air and missile threat emissions and signatures.

In terms of defining the possible, and as discussed in Part I of "US Army Brings EMSO to the Air Defense Fight," (*JED*, October 2021) the key to successful AMD is integration and sharing of information from all available sources and technologies. This is as true on the effectors side as it is with sensors. This is where the Northrop Grumman's (Huntsville, AL) Integrated Air and Missile Defense (IAMD) Battle Command System (IBCS) comes into play. IBCS is the Army program of record to represent what the DOD is envisioning for its DOD-wide Combined Joint All Domain Command and Control (CJADC2) initiative. As described by Mark Rist, Northrop Grumman's IBCS Program Director, "IBCS takes information from all available sensors and uses that information to form what is called a 'composite track,' for operators. As opposed to a multitude of different sensor feeds, they receive a single, unified, integrated air picture, which is often even better than the sum of the parts. And, it does the same thing on the effectors side, allowing you to network to a multitude of effectors, and given the integrated air picture, you can start selecting the best effector for any particular target."

Rist points to the recent Army developmental test of IBCS as an example of how the system is already performing in the CJADC2 role. Conducted at White Sands Missile Range (NM) in July, the successful test included a wide variety of sensors from multiple Services including a Marine Corps AN/TPS-80 Ground/Air Task-Oriented Radar (G/ATOR) system, a Sentinel radar, a Patriot radar, and two Air Force F-35 fighter aircraft. The test also featured a highly-contested electromagnetic environment. Two surrogate



The threats in the IBCS test at White Sands Missile Range in July included adversary jammers and cruise missiles. US ARMY PHOTO cruise missiles were launched in the test, one performing EA and the other flying a threat attack profile.

The backbone network for IBCS is the Integrated Fire Control Network (IFCN), an IP-enabled network with meshing radios. As noted by Rist, "One of the things in terms of electronic attack as demonstrated in the flight test was that, though the IFCN network was actively jammed, because we have a diversity of radios we were still able to get signals through and conduct the mission. This is one area where we have electronic resilience. In some ways we are radio agnostic, since the IFCN is not bound to any particular radio."

Rist notes that another discriminator of the IBCS and IFCN, is that "it's the same set of equipment deployed at the battery level where the actual missions are conducted, and all the way up to the battalion level. It's a distributed system with a common set of hardware and software, and all echelon levels have the same visibility." Rist says individual operators are able to configure their user interface into the system to see the information that is specific to their task, whether sensor management or weapons monitoring and control. "It's really at the tactical level as far as deciding how to set up a particular defense design. Down the road, as the system continues to expand with additional sensors and effectors, you can create roles that are very specific to a particular activity, such as electronic attack, which may be a very different set of controls than those for a missile response."

IBCS received Milestone C approval in January of this year, transitioning from Engineering and Manufacturing Development (EMD) to Low-Rate Initial Production (LRIP). In terms of its test schedule, IBCS entered the Initial Operational Test & Evaluation (IOT&E) phase in September. IOT&E will run through February of 2022. According to Rist, the target date for first-unit-equipped is the 3rd quarter of FY2022, with Initial Operational Capability (IOC) planned for April 2022.

Rist says the power of a networked system like IBCS is that it provides several benefits for the warfighter. "You get resilience, such as resistance to electronic attack. You also give the warfighter a single integrated air picture with much better situational awareness. This is really a force multiplier creating deeper magazines of effectors by being able to choose the best effector to any particular threat and the ability to defend a larger area." – *J. Haystead*

Northrop Grumman provided an IBCS Engagement Operations Center (EOC) and Interactive Collaborative Environment (ICE) for the July test at White Sands Missile Range, NM. US ARMY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CHALLENGES AHEAD?

As pointed out by Riki Ellison, MDAA President and Chairman, although both DE and electromagnetic jamming are being pursued for missile defense, "Particularly with DE, we are challenged by the doctrine piece of this more so than the technology right now, and the Army is struggling with that. If we can't have a doctrine to deploy these things, we will not be able to. I think we're ahead of the game in the development of some of these capabilities, but there is no way they will deploy them without a doctrine. This is the big missing link that is keeping this technology in perpetual R&D and not getting it out to the warfighters. It is absolutely critical that it be resolved."

In this regard, says General Thurgood, "If the question is 'Are we slowing technology because of the development of doctrine,' I would say absolutely not. The reason I say this is two-fold. First of all, our Secretary and our Chief, along with Army Futures Command, has been very focused on the Army's modernization. That strategy is tied to two fundamental constructs. Number one is adapting technology early and bringing soldiers on early, or what we call 'soldier-centered design.' We are no longer waiting for the perfect doctrine and the perfect solution. That mindset is not really what the Army's modernization strategy is about. It's about finding technologies and bringing soldiers in literally as early as we begin thinking about the 'back-of-the-envelope' design. It's no longer a sequential event; the modernization strategy is about parallel activities and providing that at a single point in time where the technology and doctrine can come together. It is a new way to think about how we modernize our Army, and that's the value of why the Army set up Futures Command to think about overall modernization at the same time that the materials side is working on the technologies. It's no longer a sequential set of events, it's a parallel set of events."

BG Brian Gibson, Director of the Air and Missile Defense Cross Functional Team (CFT) at Army Futures Command (Ft. Sill, OK), thoroughly agrees. "Here at Fort Sill, we are literally in the heart of AMD doctrine land. I can attest to the linkages that General Thurgood described. One of the good things that hopefully reinforces the point I made earlier, is that, while the CFT itself is only about 30 people, and General Thurgood's office is a small set of people, and the acquisition community is focused on those pure acquisition actions that need to occur, the linkages between us and also the user community are strong and everyone is out and about doing the things that we need our Army to do. The 'secret sauce' part to this is the linkages, the teamwork, and the relationships that our leadership have directed us to move out on and not allow perfect to be the enemy of good-enough. We cannot be exclusively focused on the technology in and of itself. Yes, it's about injecting technology when it is mature enough to do so, but that cannot be the point that we start thinking about what that means to operational employment. That means getting soldiers involved as soon as possible in developing the solutions to employ the kit that all of us are working to develop."

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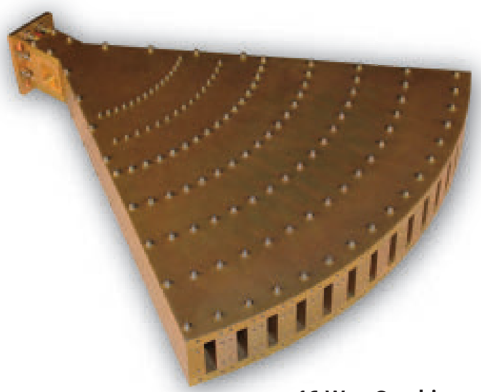

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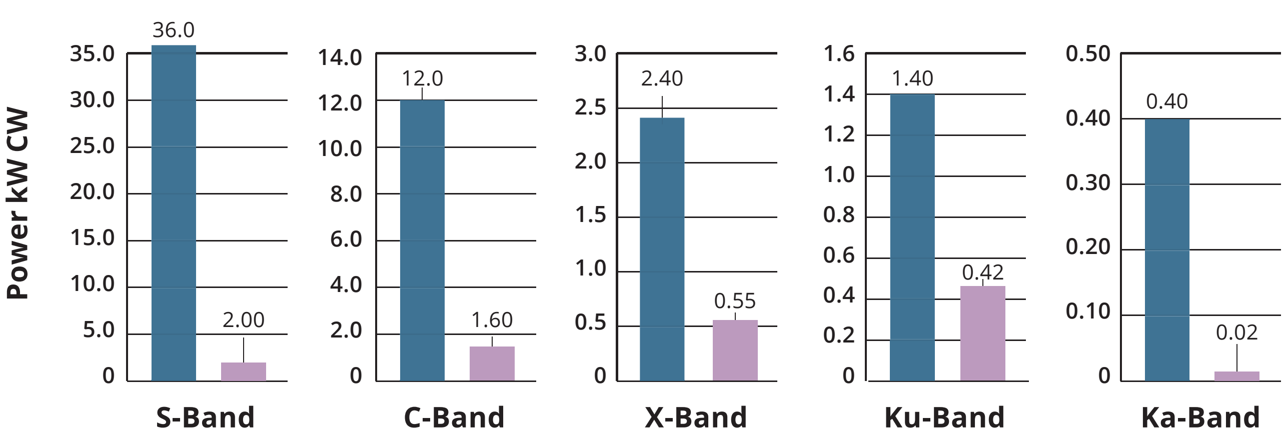
Whereas an N-Way Radial Combiner design is limited in CW output power due to the diameter of the central output coaxial section (based on TEM Mode Operation), the E-Plane Combiner is limited only by the CW power rating of the respective waveguide size. This results in an N-Way Combining architecture which handles multiples higher in power at respective frequencies.

- Higher CW Power and Higher Duty Cycle
- High Power Density and Low Loss
- Space Efficient, Planar Structure
- Ideal for S, C, X, Ku, Ka Bands

CW Power ■ E-Plane Combiner vs. ■ Radial Combiner



Werlatone, Inc. 17 Jon Barrett Road Patterson, NY 12563 845-278-2220 sales@werlatone.com www.werlatone.com

TECHNOLOGY SURVEY
A SAMPLING OF ELINT RECEIVERS

By Barry Manz

Turkey's National Intelligence Organization (Millî İstihbarat Teşkilatı – MİT) operates an Anka-1 UAS fitted with an extensive COMINT/ELINT suite.
TURKISH AEROSPACE INDUSTRIES

The goal of electronic intelligence (ELINT) receivers is to detect radar signals and produce data of the high fidelity required to accurately identify the target. These tasks have become extraordinarily difficult for a variety of reasons, not the least of which are major advances in radar technology that make them far more difficult to detect and validate by matching to a threat library. Their most significant challenge by far is coming to grips with the increasing use of low probability of intercept (LPI) techniques in radars. These elusive targets employ complex waveforms, transmission bandwidths greater than 1 GHz, extremely low sidelobes, the ability to simultaneously transmit on multiple frequencies and have extremely low RF output power.

The latter metric alone sets them apart and allows LPI radar performance to leapfrog over pulsed counterparts. When using FMCW pulse compression, for example, their detection capabilities can equal those of a high-power radar while transmitting with only a few watts of RF power. FM allows enhances the range resolution of CW signals to make their detection by narrowband receivers extremely difficult.

For example, LPI maritime radars can now routinely detect and track several hundred targets with resolution of less than a meter up to 100 km, even with an RF output power of less than 2 W and in some cases one-tenth of that. All these capabilities make the mission of an ELINT receiver far more difficult today than a decade ago and it is very likely to become even more challenging in the future.

Practically speaking, what this means is that ELINT receivers must discriminate between the very weak signals emitted by LPI radars that may occupy the same frequencies as other emitters. A similar challenge occurs when the signal from a high-power radar is located in the same bandwidth as an LPI radar. In this case, the receiver can be desensitized, requiring attenuation that has the unfortunate attribute of increasing the noise floor and further obscuring the LPI signals of interest.

ELINT TECHNOLOGY

Fortunately, ELINT receivers benefit from many of the same technologies driving LPI and other types of radars, thanks in large measure to the digitization of their front ends and the use of FPGAs directly behind the analog-to-digital converter. What's more, today's ELINT receivers can span HF frequencies through at least 40 GHz with instantaneous bandwidths matching those of the radars they are seeking. These receivers also benefit from high levels of functional integration, machine learning, high-speed and solid-state storage. When integrated with the receiver, high-speed processors and FPGAs allow near-real-time analysis to be performed locally to reduce latency, as sending information to the cloud and back for analysis is typically not an option.

Comparing the systems in this year's survey with those in our previous survey from December 2019, it's evident that ELINT receiver technology continues to evolve, in some cases combining ELINT and COMINT detection and analysis capability in the same platform. Achieving this makes it possible to dramatically reduces the size, weight, and power consumption required to perform these functions. This allows them to be placed on smaller platforms than ever before without necessarily sacrificing performance. Larger systems used in labs and on test ranges cover the entire electromagnetic spectrum up to at least 100 GHz and combine RF detection with IR.

Formidable signal analysis software is not relegated purely to the lab, and many programs can run on a laptop or embedded computer, and this software is often available from the receiver manufacturers themselves as well as other sources, including test equipment companies and a growing number of open-source resources that can be modified to suit the needs of ELINT.

ELINT RECEIVERS

MODEL	RECEIVER TYPE	OPERATING FREQ.	INST. BANDWIDTH	INSTALLED SENSITIVITY	TOTAL DYNAMIC RANGE	INST. DYNAMIC RANGE
ASELSAN A.S.; Ankara, Turkey; +90-312-592 1000; www.aselsan.com.tr						
Wide Band	IFM	S to Ku Band	*	*	*	*
Chordell Systems; Adelaide, Australia; +61 431753484; www.chordell.com.au						
WOLVERINE	Digital	0.5-100 GHz	30 GHz	CRLB +0.2dB	140dB	*
D-TA Systems; Arlington, VA, USA; +1 571-527 - 4915; www.d-ta.com						
DTA-9590N-2R	Superhet	0.5-18 GHz (40 opt.)	500 MHz (1 GHz opt.)	80 dBm	90 dB	63 dB
DTA-9590N-4R	Superhet	0.5-18 GHz (40 opt.)	500 MHz (1 GHz opt.)	80 dBm	90 dB	63 dB
DTA-9590-6R	Superhet	0.5-18 GHz (40 opt.)	500 MHz (1 GHz opt.)	80 dBm	90 dB	63 dB
DAS Photonics; Valencia, Spain; +34 963 556 150; www.dasphotonics.com						
RESM/ ELINT Receiver	*	0.5-40 GHz	40 GHz	*	*	*
Digital Receiver Technology, Inc.; Germantown, MD, USA; +1 301-916-5554; www.drti.com						
DRT-OPX3 QT1-FE	Superhet	1.5 MHz - 18 GHz	2 GHz (500 MHz x 4 channels)	NF 6 dB typ. with preamp; 11 dB typ. bypass	130 dB	>80 dB in 25 kHz BW
Elbit Systems EW and SIGINT - Elisra; Bene Beraq, Israel; +972-3-6175411; www.elbitsystems.com						
WBR	*	0.5-40 GHz	0.5-40 GHz	*	> 75 dB	> 60 dB
Elettronica Group; Rome, Italy; +39 0641541; www.elt-roma.com						
ELT/1000	Digital direct RF sampling	E to J + D Band	1GHz min	*	60 dB	50 dB
ELTA Systems Ltd.; Ashdod, Israel; +972-8-857-2312; www.elta-iai.com						
ELL-8385 ESM/ELINT Digital Receiver	Superhet, digital (direct sampling)	0.5-18 GHz	> 500 MHz	-80dBmi	80 dB	60 dB
ESROE Ltd.; Fareham, Hampshire, UK; +44 (0)1329 237285; www.esroe.com						
MicroESM 1t	Digital/Analog hybrid	2-18 GHz	10 GHz	-55 dBm (pulsed)/-70 dBm(CW)	50dBm	-
FEI-Elcom Tech, Inc.; Northvale, NJ, USA; +1 201-767-8030 ext 271; www.fei-elcomtech.com						
SIR-4001-8-9	*	0.5-18 GHz; 0.5-26.5 GHz; 0.5-40 GHz	Up to 2 GHz	At L Band 500, 1, 2 GHz; 160 MHz 1, 5, 10, 20, 40, 80 MHz	65 dB (Including non-carrier related spurious, carrier prelated, IP3, IP2) per 1 MHz BW	IP3 > 0 dBm; NF < 15 dB
HENSOLDT Sensors GmbH; Ulm, Germany; +49 731 392 0; www.hensoldt.net						
HENSOLDT Kalætron® 4C-EDRx	digital	0.5-40 GHz	≥ 2 GHz	Depending on used antenna front-end ≥ -95 dBm for high-gain antenna	*	60 dB
iRF - Intelligent RF Solutions; Sparks, MD, USA; +1 443-595-8510; www.irf-solutions.com						
iUR-7400/7800 UltraRail	Superhet, search/set-on tuner or receiver	20MHz - 18 GHz	500MHz/1GHz/2GHz/16GHz	100 dB @1 MHz	60 dB	60 dB
iWR-6500 WideRail	Superhet; stepped sweeper	450 MHz - 26.5 GHz, up to 44GHz	500 MHz @ 1 GHz IF; 100 MHz @ 140 MHz IF	95 dB @1 MHz	65 dB	65 dB
SMR-7522 LiteRail	Superhet; stepped collection	800 MHz - 26.5 GHz, up to 44GHz	95 MHz @ 140 MHz/160 MHz IF	94 dB @ 1 MHz	50 dB	50 dB
Kratos General Microwave Israel Ltd.; Jerusalem, Israel; +972-2-5689444; www.kratosmed.com						
WBR-0518-MOD	Superhet	0.5-18 GHz	1 GHz	-58 dBm	60 dB	59 dB

SUPPORT DF	CHANNELS	POWER (W)	SIZE (HxWxL inches/cm)	PLATFORM	WEIGHT (lb/kg)	FEATURES
Amplitude	4	< 300W	*	Air, grd, shp	< 20 kg	Full capability against modern threats (high sensitivity, precise parameter measurement)
TDOA, FDOA, Phase	1 to 4	300W	15U	Air, grd, shp, sub	120Kg	One chan. Staring, detects at vastly negative SNR to CRLB +0.2dB
Amplitude, Phase	2	100W	10 x 7.5 x 12.5 in.	Air, grd-mob, grd-fix, shp	20 lb	Phase-coherent ELINT/ESM receiver is antenna agnostic and processor agnostic, input protection, blanking, frequency selective front-end frequency selective filtering
Amplitude, Phase	4	160W	12 x 7.5 x 12.5 in.	Air, grd-mob, grd-fix, shp	30 lb	See above
Amplitude, Phase	6	220W	15 x 7.5 x 12.5 in.	Air, grd-mob, grd-fix, shp	40 lb	See above
Yes	*	*	*	*	*	360 deg coverage; DF accuracy 1 deg RMS
Amplitude, Phase, and Time w/ off module processing	4 tuners to 6500 MHz with 2 block converters to 18 GHz	83W	VITA 48.2 1-inch 3U conduction-cooled form factor (3.937 in. x 1.0 in x 6.299 in.)	Air, grd-mob, grd-fix, shp, sub, stratosphere	1.80 lb	SW selectable IF filters of 40 MHz, 80 MHz, and 500 MHz supports both COMINT and ELINT
Amplitude	Multiple	400W	44 x 72 x 77(D) cm	*	60 kg	>99% POI, digital map, remote control.
*	4	200W typ.	3U x 12 Modules typ.	Air, grd-mob, grd-fix, shp	12 kg typ.	Radar emitter measurement and technical parameters extraction.
Amplitude, phase, time	Multichanel (4 channels)	400W	11.4 × 8.26 × 18 in.	Air, grd-mob, grd-fix, ship, sub	25 kg w/o antennas	SDR with automatic system process, optionally integrated with company's radars for complete active and passive situation picture
Amplitude	4	<20W	18 x 18 x 9.6 cm	Grd-fix, grd mob, air, ship, sub	1.5 kg (main unit); 1 kg (tablet); 0.62 g (9Ah battery)	Automatic processing, can report and identify 100 simultaneous emitters. Continuous recording of PDW data. Graphical plotting of PDW data.
No	1	95 - 265 VAC, 47-440 Hz, 150W	19-in. Rack 1U	*	20 lb	ELINT, RWR, EW, SIGINT
Amplitude and phase DF	4	≤ 500W	32 x 19.4 x 32.4 cm	Air, grd-mob, grd-fix, ship, sub	20 kg	Software upgradable; continuous IQ raw data recording and spectrum analysis; PDW recording; operator tasking online; offline supported by AI technologies
Yes	4 channels, expandable to 8 channels	40+ W	3U VPX, brick	air, grd-fix, shp, sub	2+ lb	High density microwave tuner or receiver w/ superior phase noise and signal fidelity configured to support external and internal RFSoC processing
Yes	Single/Multi	45 W	brick	air, grd-fix, shp, sub	< 5 lb	SDR housed in rugged mini chassis, designed to support SIGINT collection, N-channel DF, user programmable FPGA resources available on-board
Yes	Single/Multi	25+ W	brick	air, grd-fix, shp, sub	3.5 lb	Housed in rugged mini CD-ROM enclosure, supports OFDM/PCM satellite backhaul and ELINT applications
Yes	1	50W	220 x 440 x 40 mm	air, grd-fix, grd-mob, shp, sub	5.5 kg	*

ELINT RECEIVERS

MODEL	RECEIVER TYPE	OPERATING FREQ.	INST. BANDWIDTH	INSTALLED SENSITIVITY	TOTAL DYNAMIC RANGE	INST. DYNAMIC RANGE
L3Harris Technologies – Surveillance Solutions; Van Nuys, CA, USA; +1 818-988-2600; www.L3Harris.com						
ES-5080	Superhet, digital	To Ka Band	500 MHz	Depends on high-gain antenna; to -95 dBmi typ.	> 75 dB	60 dB
Lockheed Martin Rotary and Mission Systems; Owego, NY, USA; +1 607-751-7089; www.lockheedmartin.com						
Advanced Digital Receiver Processor (ADRP)	Superhet, digital	*	*	*	*	*
Mercury Systems; Andover, MA, USA; +1 978-967-1401; www.mrcy.com						
RFM3202	3U Single Slot Transceiver	100 MHz - 18 GHz	Downconverter: RF Input Frequency: 0.1-18GHz Upconverter: IF Input Frequency: 3.4-5.4GHz RF Output Frequency: 0.1GHz-18GHz	*	2-18GHz tunable RF range	*
Midwest Microwave Solutions Inc.; Hiawatha, IA, USA;+1 319-393-4055; www.mms-rf.com						
WRX-126G-D	Superhet RF digitzer	1-26GHz	500MHz per channel	14 dB NF (typ)	>60 dB (1MHz BW)	60 dB
Patria; Tampere, Finland; +358-20-4691; www.patriagroup.com						
ARIS	Digital	0.5-18 GHz (optional 20 MHz - 40 GHz)	Variable 0.1-500 MHz	-130 to -80 dBm depending on BW and resolution settings	130 dB	56-81 dB
Raytheon Deutschland GmbH, Freising, Germany, +49 (0)8161 902 0, www.raytheon.com						
ARDS	Digital	1-26 GHz (opt. 0.5-40 GHz)	1 GHz	> -80 dBm	> 90 dB	> 60 dB
Rohde & Schwarz GmbH & Co.KG; Munich, Bavaria, Germany; +49-89-4129-0; www.rohde-schwarz.com						
R&S®WPU2000	Superhet, digitizer and pulse analyzer (full Nyquist sampling)	8 kHz - 18 GHz (opt. to 40 GHz)	Digital; from 2.5 kHz to 2000 MHz in 8000 steps	Max. -120 dBm (DANL)	> 110 dB	> 72 dB
Saab AB; Järfälla, Sweden; www.saab.com; +46 8 580 840 00						
Sirius Compact EPS-50 Mk3	Digital channelized receiver	0.5-18 GHz	500 MHz	-65 dBm over 0.5-2 GHz -75dbm over 2-18 GHz	> 75 dB	> 45 dB
Sierra Nevada Corporation; Sparks, NV, USA; +1 775-331-0222; www.sncorp.com						
AE-4500	Superhet, digital	0.5-18 GHz 0.5-40 GHz	500 MHz	*	>75 dB	60 dB
Space and Defence Technologies (SDT); Ankara, Turkey; +90 312 210 10 15; www.sdt.com.tr						
Wideband Microwave Receiver	Superhet	0.1-18 GHz	1 GHz	*	> 60 dB at- 30 dBm input	*
Systems & Processes Engineering Corporation (SPEC); Austin, TX, USA; +1 512-479-7732; www.spec.com						
ADEP Blade	Superhet, channelizer, IFM	20 MHz - 3.6 GHz	128 MHz	*	70 dB	40 dB
Teledyne Defence Limited; Shipley, West Yorkshire, UK; +44-1274-535147; www.teledyne.com						
DR068	CV IFM	2-18 GHz	16 GHz	*	65 dB	65 dB
TUALCOM ELEKTRONİK A.Ş.; Ankara, Turkey; +90 312 485 22 85; www.tualcom.com.tr						
TUAL-ELINT	IFM and superhet	2-18 GHz	16 GHz	*	65 dB	45 dB
Wide Band Systems Inc.; Rockaway, NJ, USA; +1 973-586-6500; www.widebandsystems.com						
IFM	IFM	50 MHz - 18 GHz	*	*	> 70 db	> 60 dB

SUPPORT DF	CHANNELS	POWER (W)	SIZE (HxWxL inches/cm)	PLATFORM	WEIGHT (lb/kg)	FEATURES
High gain, spinning DF	2 standard	< 1kW	Varies with installation	grd-mob, grd-fix, shp, air	*	Detect, ID FMCW radars; supports many operators (local or remote over TCP/IP)
*	Multiple	350W	6 x 7.7 x 10 in.	*	29 lb	Open architecture, high performance digital receiver for RWR, ESM, ELINT applications
*	2 Tx channels, and 2 Rx channels	.=125W Typ. 140W Max	*	*	2 lbs ±0.25 lb	High spectral density rugged, compact, and open-systems compliant (OpenVPX, VITA 65) and SOSA aligned, user-selectable built-in LO generation or user-supplied LOs via external inputs
FDOA, TDOA	2	<50W (9-16V)	5.0 x 6.9 x 2.5 in.	air, gnd, ship, sub	4.25 lb	40GB ethernet, I/Q streaming, Software defined, 40GHz option
Amplitude, Phase monopulse and spinning DF	2 independent microwave channels and 2 V/UHF channels feeding digital channelizers	1200W	10U + 4U 19-in. rack mount chassis	Grd-fix, grd-mob, ship, air (opt.)	69 kg	Remote operable, spectrum surveillance, interception and recording. Real-time and offline I/Q and pulse analysis with channelized pulse processor
Phase	2x5 DF channels, 4 measurements simultaneous per side	1700W	Downconverter 3/4 ATR, Receiver 1/2 ATR	Air, grd-mob, grd-fix, shp	160 kg (entire system)	DF accuracy < 1 deg, ELINT, SIGINT, fast localization, I/Q Recording, remote controllable, fully automated and library based, ITAR free
Spinning dish	8	250-400W	426mm x 176mm x 450mm (4HU, 19”)	Grd-fix, grd-mob, air, shp, sub	44 lb	Superhet tuner, digitizer, digital channelizer and pulse analyzer in one device, digital signal processing for CW and LPI radars.
Phase	2	< 160W	1/2 ATR	Air	16 kg	Support RWR function
Phase, TDOA	4	250W @ 28 VDC	6.25 x 14.5 x 9.4 in.	Air, grd, ship	27 lb	Phase interferometer provides monopulse precison DF and geolocation. Mature, TRL 9 turn-key system
*	*	*	6U, 19-in. rack mount	Grd-fix, grd-mob, air, shp, sub	40 kg	Extendable up to 40 GHz; Eremote programming via Ethernet 1000 Base-T
No	1	28 VDC, 15W	5 x 7.9 x 0.89 in.	Air, grd-mob, grd-fix, shp	<2 lb	16-bit ADC/DAC; radar emitter detection, discrimination and identification.
*	1	< 40W	2 6U VME slots	*	1.5 kg	Can also include switched multiplexer preselecter to manage dense signal environments.
Yes	4	2.5 A @ 28 VDC	*	Air, grd, ship	5 kg	Compact and user friendly
Amplitude, Phase	Single, Multiple DF	50W	15 x 10 x 6.5 in. max	Air, grd, ship	25 lb max.	Provides digital output of RF frequency, RF amplitude, RF envelope pulse width, and time of arrival; options include angle of arrival, frequency modulation onpulse, phase modulation on pulse.

SURVEY KEY – ELINT RECEIVERS

MODEL
Product name or model number

RECEIVER TYPE
Superheterodyne, Channelizer, IFM, etc.
- CV = crystal video receiver
- IFM = instantaneous frequency measurement
- Superhet = Superheterodyne

OPERATING FREQUENCY
Indicated in kHz, MHz or GHz

INSTANTANEOUS BANDWIDTH
Includes selectable bandwidths if more than one.

INSTALLED SENSITIVITY
Indicated in dBm or dBmi
CRLB = Cramer-Rao Lower Bound
DANL = Displayed Average Noise Level
NF = Noise Figure

TOTAL DYNAMIC RANGE
Total dynamic range, indicated in dB, dBm or dBc

INSTANTANEOUS DYNAMIC RANGE
Instantaneous dynamic range, indicated in dB or dBm
- BW = bandwidth

SUPPORT DF
Does it support DF and with what technology and accuracy?
- FDOA = frequency difference of arrival
- RMS = root mean square
- TDOA = time difference of arrival

CHANNELS
Single channel receiver, multiple channels or single expandable to multiple?

POWER
Power dissipated in Watts

SIZE
H x W x L in inches/cm
- ATR = Air Transport Rack

PLATFORM
Host platform
- air = airborne
- grd-fix = ground-fixed
- grd-mob = ground-mobile
- ship = shipboard
- sub = submarine

WEIGHT
Weight in lb/kg

FEATURES
Additional features
- CW = continuous wave
- FMCW = frequency-modulated continuous-wave
- POI = Probability of Intercept
- PDW = pulse descriptor word

OTHER ABBREVIATIONS USED
- < = greater than
- > = less than
- min = minimum
- max = maximum
- deg = degree
- freq = frequency

** Indicates answer is classified, not releasable or no answer was given.*

STEM Competition Now Open!

The AOC STEM Program invites students in grades 9 through 12 to submit a 1 to 5-minute video for the **chance to win $2,000** for their group and gain access to member benefits to enhance their future career goals. AOC recognizes the importance of educating and guiding the next generation of scientists, technologists, engineers, and mathematicians using an interdisciplinary and applied approach.

Competition Opens: October 1, 2021
Competition Closes: November 30, 2021

This contest aims to encourage and support student STEM groups to consider the electromagnetic spectrum (EMS) in their studies. The competition is a chance for your School or STEM team to work on a fun project with an AOC Mentor, learn about the Electromagnetic Spectrum (EMS) and how it applies to everyday life and a future career. In addition, this competition is an opportunity to win a significant financial award for your school/group and a chance to be informative, inventive, artistic, scientific, technical, and creative in a short video.

Find Out More at crows.org/STEM.

ASSOCIATION OF OLD CROWS

WASHINGTON D.C.

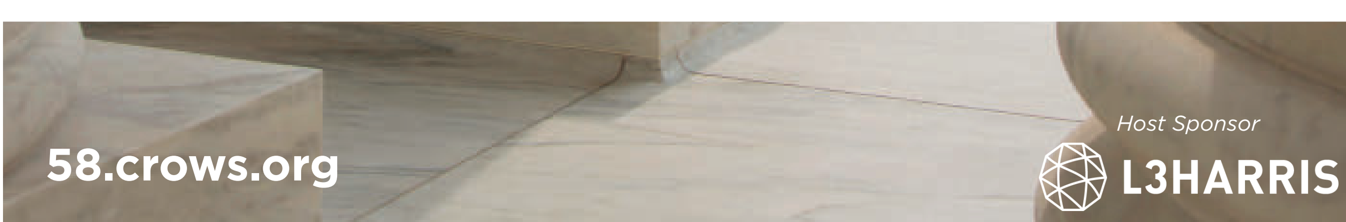
58TH

AOC INTERNATIONAL SYMPOSIUM & CONVENTION

NOV. 30-DEC. 2, 2021

PREVIEW

REGISTER NOW AT 58.CROWS.ORG!



THEME

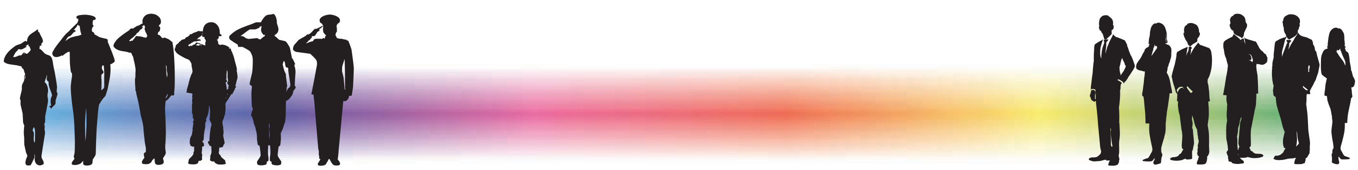
All-Domain Operations - Integrating Effects Across the Spectrum

The importance of electromagnetic spectrum operations cannot be over-emphasized; it empowers All-Domain Operations, an integrated and synchronized application of capabilities across all warfighting domains. Awareness and understanding of the electromagnetic spectrum, its properties, and the need to command and control effects within it are necessary to strategize thoroughly, plan, and decisively execute any mission anywhere in the world.

An advantage in the electromagnetic spectrum is foundational to successful All-Domain Operations.

WHO SHOULD ATTEND

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



ACTIVE DUTY TO VETERAN

No matter what your mission, you need an advantage in the spectrum. A better understanding of the invaluable role of spectrum in military operations is imperative for success.

The importance of electromagnetic spectrum operations cannot be over emphasized; it empowers All-Domain Operations, an integrated and synchronized application of capabilities across all warfighting domains.

You cannot win the fight without an advantage in the EMS. **By attending AOC 2021, you gain that advantage.**

JUNIOR ENGINEER TO PRINCIPAL ENGINEER

You are the technology makers, the rapidly evolving designers. Through research and development, you are solving the problems and providing the solutions to the war fighters.

The importance of electromagnetic spectrum operations cannot be over emphasized; it empowers All-Domain Operations, an integrated and synchronized application of capabilities across all warfighting domains.

Technology is ever evolving, and you are part of that. **By attending AOC 2021, you will help influence the mission.**

CASUAL TO PRO

The spectrum is part of your world and touches everything you do. You need to join our mission in order to gain the knowledge you need to drive decisions in your organization.

By engaging a broader community, you become more informed and can take your place among stakeholders in the defense industry. **By attending AOC 2021, you will learn our mission and add your voice to a larger audience.**

SUPPORT OUR MISSION • INFLUENCE OUR MISSION • LEARN OUR MISSION

#CROWS2021

REGISTRATION INFORMATION

Master Pass

The 'Master Pass' includes access to keynote sessions, all symposium sessions Tuesday–Thursday, the Welcome Reception; the exhibit hall, lunches and happy hours, First-Time Attendee Orientation, and to all recorded keynote sessions and all briefings as released by the speakers. *Registration does not include access to the Program Manager Briefing Series or post-convention courses.*

	~~By 8/31~~	9/1-11/5	11/6-On-Site
Industry (Member)	~~$695~~	$795	$895
Industry (Non-Member)	~~$895~~	$995	$1095
Academia*	~~$445~~	$545	$645
Young Crows (35 and younger)*	~~$445~~	$545	$645
Government Civilian*	~~FREE~~	FREE	FREE
Military in Uniform**	~~FREE~~	FREE	FREE

*Must present proper ID for discounted price, see 58.crows.org for more information.
**Duty uniform must be worn each day. If not, a fee of $100 will be assessed.

Need help justifying your attendance?
We have resources for you to use at crows.org/JustificationLetter

Exhibition Only Pass

This complimentary registration type provides access to the Welcome Reception, keynote sessions and the exhibit hall. *It does not allow access to all other symposium sessions, Program Manager Briefing Series or post-convention courses.*

Exhibition Only	~~FREE~~	FREE	FREE

HOTEL INFORMATION

AOC has negotiated special rates for AOC attendees during their stay in DC with the **Courtyard/Residence Inn by Marriott Downtown/Convention Center**. Housing deadline fast approaching, book your room by November 8.

Book your room now at crows.org/2021HotelTravel

VACCINE / NEGATIVE TEST VERIFICATION

Prior to picking up your badge on-site and receiving access to the event, all individuals must show:

A valid government-issued ID (driver's license, military ID, or passport) and either:

- Proof of being fully vaccinated* against COVID-19 or
- Proof of a negative test** for COVID-19 within 72 hours of check-in to the event

Please refer to our Health and Safety page at crows.org/COVID-19HealthSafetyInformation for all the policies and requirements in place for our event.

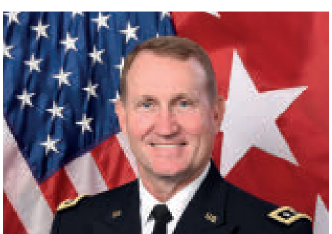
58.crows.org

KEYNOTE SPEAKERS

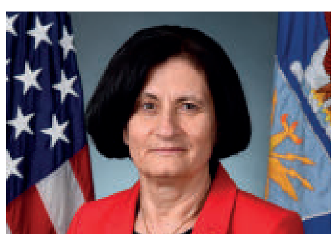
Lt. Gen. S. Clinton Hinote
Deputy Chief of Staff for Strategy, Integration and Requirements, U.S. Air Force

Dr. Kelly Fletcher
Performing the Duties of Chief Information Officer, Department of Defense

SPOTLIGHT SPEAKERS



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 & Managing Partner WestExec Advisors

The Honorable Heidi Shyu
Chief Technology Officer Under Secretary of Defense for Research & Engineering (OUSD(R&E))

View the full list of our prestigious speakers at crows.org/2021Speakers

#CROWS2021

SCHEDULE AT-A-GLANCE

MONDAY, NOVEMBER 29

Noon, 12:30, 1:00, 1:30, 2:00, 2:30, 3:00, 3:30, 4:00, 4:30, 5:00, 5:30, 6:00, 6:30, 7:00, 7:30, 8:00, 8:30, 9:00

On-site Registration Open
(Badge Pick-up and Registration)
Hall A Concourse of the
Walter E. Washington Convention Center

Welcome Reception
Hosted by L3Harris

TUESDAY, NOVEMBER 30

7:00, 7:30, 8:00, 8:30, 9:00, 9:30, 10:00, 10:30, 11:00, 11:30, Noon, 12:30, 1:00, 1:30, 2:00, 2:30, 3:00, 3:30, 4:00, 4:30, 5:00, 5:30, 6:00

Onsite Registration Open

Exhibit Hall & Crows' Nest Open

Symposium Morning Coffee

Opening Keynote Session

Program Manager Briefing Series

Lunch

Program Manager Briefing Series

Spotlight Session - Strategic Opportunities and Emerging Technologies

Program Manager Briefing Series

Program Manager Briefing Series

Symposium Session – The Speed of Data and Decisions in the Next Fight

Symposium Session – Vision, Initial Efforts, Integration Across the Joint Force

Exhibit Hall Happy Hour

As of October 11, 2021. Subject to change.
All events occur at Walter E. Washington Convention Center unless otherwise noted.

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SCHEDULE AT-A-GLANCE

WEDNESDAY, DECEMBER 1

- 7:30–6:00 Onsite Registration Open
- 9:45–6:00 Exhibit Hall & Crows' Nest Open
- 7:45–8:45 Symposium Morning Coffee
- 8:30–9:45 Keynote Session
- 10:00–10:45 Program Manager Briefing Series
- 10:00–11:30 Symposium Session – Enabling to Rapid Development and Fielding
- 10:00–11:30 Symposium Session – The Criticality of EMS Interoperability/ Compatibility
- 11:00–11:45 Program Manager Briefing Series
- 11:30–1:00 Lunch
- 11:30–12:00 Assembly of Delegates
- 12:00–12:45 Program Manager Briefing Series
- 12:30–2:00 Symposium Session – How Space Force Is Developing Guardians To Build High-Performance Teams
- 12:30–2:00 Symposium Session – Implementing EMSO for the Future Fight
- 1:00–2:30 Program Manager Briefing Series
- 3:00–3:45 Program Manager Briefing Series
- 3:00–4:00 Spotlight Symposium Session
- 4:30–6:00 Happy Hour Reception

THURSDAY, DECEMBER 2

- 8:00–2:00 Onsite Registration Open
- 9:45–2:00 Exhibit Hall & Crows' Nest Open
- 7:45–8:45 Symposium Morning Coffee
- 8:30–9:45 Keynote Session
- 10:00–10:45 Program Manager Briefing Series
- 10:00–11:30 Symposium Session – Critical Enabler or Vulnerability?
- 10:00–11:30 Symposium Session – Industry Panel
- 11:00–11:45 Program Manager Briefing Series
- 11:30–1:00 Lunch
- 1:00–2:30 Closing Spotlight Symposium Session – All-Domain Operations - Integrating Effects Across the Spectrum

Post-Convention Courses

Extend your convention experience by signing up for a post-convention AOC professional development course. These courses are taught by our subject matter experts.

Friday, December 3 – Saturday, December 4

Space Electronic Warfare
Presented by: Dave Adamy

Friday, December 3 – Saturday, December 4

Machine Learning for EW
Presented by: Kyle Davidson

Get more information online at crows.org/2021Courses

Separate registration required.

PODCAST

This year AOC launched two hugely successful podcasts: "From the Crows' Nest" and "The History of Crows". Our host, Ken Miller, will be recording live with many of our speakers from a studio located on the show floor during the event. Start listening now and be sure to tune in for his daily recaps right from the show.

Find out more at crows.org/podcasts.

SCAN ME

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CROWS' NEST

CONGREGATE | CAFFEINATE | COLLABORATE

At the center of our bustling exhibit hall is the AOC Crows' Nest! Open during official show hours, the Crows' Nest has lounge areas for attendees to relax and network. It is also the site of the AOC membership area and store, AOC Sales Office, Meet & Greet events, raffles, JED desk, device charging stations, and coffee service.

This year, we will be hosting "meet and greets" in the Crows' Nest so attendees can find out more about new AOC programs.

Crow Career Builder - Learn about AOC's newly launched mentorship program directly from mentors who helped develop the program.

Certification Program – Meet with the education and certification committee members to learn more about AOC's new certification program.

Powered by L3HARRIS™

PROGRAM MANAGER BRIEFING SERIES

PROGRAM MANAGER BRIEFING SERIES

WHERE GOVERNMENT & INDUSTRY MEET

AOC is thrilled to host our third Program Manager (PM) Briefing Series during AOC 2021. The PM Briefing Series offers a technology interchange in a series of 45-minute sessions comprised of presentations from PM offices across the military services and audience Q&A. During this program, exhibitors will hear directly from their government customers on the status of key programs and activities under their leadership, opportunities and milestones on the horizon, and how government and industry can strengthen collaboration. *This program is only open to 2021 exhibiting companies.*

Tuesday, November 30

1:00 - 1:45 PM: **Mr. Cleve Eason,** Surface Cryptologic and Electronic Warfare Branch Head, OPNAV N2N6W2

Wednesday, December 1

10:00 - 10:45 AM: **COL Kevin Chaney,** Program Executive Officer, IEWS Aircraft Survivability Equipment

11:00 - 11:45 AM: **Col. Gregg Jerome,** Senior Material Leader, AFLCMC/WNY (EW & Common Avionics)

12:00 - 12:45 PM: **CAPT David Rueter,** Program Manager, NAVAIR PMA-234 (AEA)

1:00 - 2:30 PM: **Mr. Adam Nucci / MG Dustin A. Shultz,** Deputy Director of Strategic Operations, Office of the Deputy Chief of Staff, G - 3/5/7 / Director of Strategic Operations (IMA), Office of the Deputy Chief of Staff, G - 3/5/7

2:00 - 2:45 PM: **Mr. Randall Walden,** Director and Program Executive Officer, Department of the Air Force Rapid Capabilities Office, Office of the Assistant Secretary of the Air Force for Acquisition, Technology and Logistics

Thursday, December 2

10:00 - 10:45 AM: **Mr. Kenneth Strayer / COL Daniel Holland,** Project Manager, Army Electronic Warfare and Cyber / Army Capability Manager- Electronic Warfare, Capability Development Integration Directorate, Cyber Center of Excellence

11:00 - 11:45 AM: **CAPT Jesse Mink,** Principal Assistant Program Manager, Surface Ship Electronic Warfare and Electro-optic Infrared Systems (PEO IWS 2E)

**Schedule as of 10/11/21 (Subject to Change)*

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SYMPOSIUM AGENDA

TUESDAY, NOVEMBER 30

Opening Keynote Session
8:30 - 10:00 AM I Main Stage, Exhibit Hall

SPOTLIGHT SESSION
Strategic Opportunities and Emerging Technologies
12:30 - 2:00 PM I Main Stage, Exhibit Hall
This session will focus on the implications of technology to our national defense and how strategy & policy can be used to drive innovations and technology into defense programs, particularly EMSO programs. By providing a tops-down view, investment and prioritization of technologies show the expectations of senior government leaders when they invest in a particular area expecting a strategic, operational, and/or tactical overmatch through our technology. The panel will discuss how the US Dept of Defense and Air Force are bringing the best scientific and technical minds to solve their challenges. The panel discussion is expected to provide context of the ecosystem differences between the US and nation-state competitors. Additionally, this panel will provide an initial look at strategic, organizational, and priorities that are expected to come to fruition in the next several years.

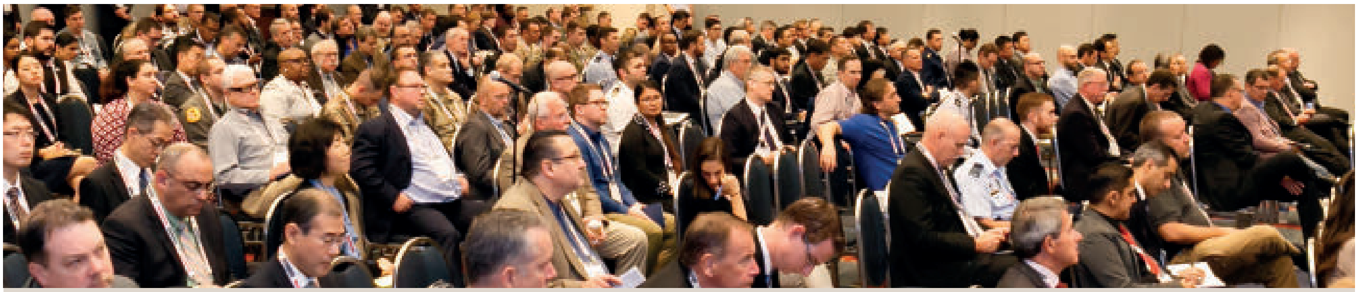
SPOTLIGHT SPEAKERS:
Dr. Victoria Coleman, Chief Scientist, United States Air Force
The Honorable Heidi Shyu, Under Secretary of Defense for Research and Engineering (OUSD(R&E))

SESSION MODERATOR:
Dr. Richard Wittstruck, DISL, Senior Intelligence Advisor, Assistant Secretary Acquisition, Logistics, Technology (ASAALT)

BREAKOUT SESSION
[AI and Autonomy] The Speed of Data and Decisions in the Next Fight *(brought to you by Young Crows)*
Students in aerospace engineering will present a project in which they designed and flew a Cubesat (CACTUS-1). The presentation focuses on Software Defined Radios and Machine Learning on an autonomous float being built for the Labor Day parade, a practical application of emerging autonomy efforts. The components include multiple swarming ground robots and sensors on various quad-copters on a student-designed float.

SESSION MODERATOR:
Dr. Guna Seetharaman, Chief Scientist for Computation NRL , Navy Senior Scientist (ST) for Advanced Computing Concepts at U.S. Naval Research Laboratory

SESSION PRESENTERS:
Mr. Rishabh Maharaja, Capitol Technology University
Dr. Sean O'Rouke, USAF AFMC AFRL/RYAP
Dr. Sean Kaiser, Chief Engineer, EMW S&T, NSWC Crane



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BREAKOUT SESSION

[Air Force Spectrum Warfare Wing] Vision, Initial Efforts, Integration Across the Joint Force

This panel will cover the recently activated 350th Spectrum Warfare Wing in the United States Air Force. Following activation in June 2021, the 350th SWW is focused on integrating with all Numbered Air Forces (NAFs) to support the Air Force Core Functions. Mainly, the panel will talk about the organization, strategy, and ongoing efforts in the SWW. Additionally, a leadership perspective on how the SWW integrates with the different NAFs will be discussed. The panel will blend deterrence strategy, operational integration, tactical art, and technological innovation.

SESSION PRESENTERS:

Gen. Stephen W. "Seve" Wilson (Ret), former Vice Chief of Staff of the U.S. Air Force
Brig. Gen. Tad D. Clark, Director, Electromagnetic Spectrum Superiority HQ Air Force (HAF/A5L)
Col. William E. "Dollar" Young, Jr., PhD, Commander, 350th Spectrum Warfare Wing

WEDNESDAY, DECEMBER 1

Keynote Session

8:30 - 9:45 AM I Main Stage, Exhibit Hall
Dr. Kelly Fletcher, Performing the Duties of Chief Information Officer, Department of Defense

BREAKOUT SESSION

[MBSE Digital Environment and Engineering] Enabling to Rapid Development and Fielding

This facilitator-led panel brings the evolving Models Based Systems Engineering (MBSE) methodology and concepts into focus as an enabler for accelerated development in meeting the challenges of the electromagnetic spectrum. The scope will include the tools and methods to accelerate development, updates, and fielding to meet operational needs. The panel will also bring the contrast of integration new systems versus legacy systems and the fiscal realities that impact MBSE evolution.

SESSION MODERATOR:

Mr. Ed Wolski, Strategy & Advanced Development Programs, Precision Engagement Sector, L3Harris Technologies

SESSION PRESENTERS:

Mr. Patrick H. Mason, SES, Deputy Program Executive Officer for Aviation
Dr. Jim Moreland Jr, Deputy VP, Strategy and Transformation
Mr. Dave Shelley, Director, F/A-18 & EA-18G Mission Systems, Boeing

BREAKOUT SESSION

[JADC2] The Criticality of EMS Interoperability/Compatibility

Joint All-Domain Command and Control (JADC2) is the Department of Defense's (DOD's) concept to connect sensors from all of the military services—Air Force, Army, Marine Corps, Navy, and Space Force—into a single network, a far leap from the service-centric stovepiped systems currently in use. However, as most of our sensors use the electromagnetic spectrum, understanding the EMS is critical to achieving this goal. This panel brings together leaders in electronic warfare, spectrum, and C2 from all services to discuss a vision on how this integration might be achieved.

SESSION MODERATOR:

MG (Retired) Pete Gallagher, SVP, Technology & Solutions National Security & Innovative Solutions, CACI

SESSION PRESENTERS:

BG Paul G. Craft, Commandant and Chief of Cyber, U.S. Army Cyber School
BG Charles R. "Rob" Parker, J-6 Deputy Director for Joint All-Domain Command and Control, The Joint Staff

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AOC Assembly of Delegates
featuring Outstanding Military Unit and AOC Chapter Commendation

11:30 AM - 12:30 PM I Main Stage, Exhibit Hall

Please join us for an annual meeting of our members. The Assembly of Delegates will include a report from President Glenn "Powder" Carlson on the strategic and financial future of AOC, a review of notable activities for the year, and swearing in of the 2022 Board of Directors. A highlight of the year in review will be a presentation of our Chapter of the Year winners and Military Unit Recognition Awards. Come and show your support for the outstanding service and contributions of this year's winners!

BREAKOUT SESSION

[EMSO] Implementing EMSO for the Future Fight

This session will be an in-depth discussion on the Electromagnetic Spectrum Superiority Strategy's Implementation Plan (EMSSS I-Plan) and how the Department of Defense is taking decisive action to achieve the Strategy's vision of "freedom of action in the electromagnetic spectrum, at the time, place, and parameters of our choosing." Key stakeholders from across the Department of Defense, including U.S. Strategic Command and the Office of the Chief Information Officer will be brought together to reinforce the importance of working together as a community to build upon the progress and success of the EMSO Cross-Functional Team (EMSO CFT). The session will be a follow-up to the morning Keynote Session with Mr. John Sherman, Acting Chief Information Officer, Department of Defense.

SESSION MODERATOR:

Brig. Gen. Darrin P. Leleux, Deputy Director, EMSO CFT

SESSION PRESENTERS:

Brig. Gen. AnnMarie K. Anthony, Deputy Director, Operations for Joint Electromagnetic Spectrum Operations & Mobilization Assistant, Director of Operations, U.S. Strategic Command
Ms. Vernita Harris, Director, Spectrum Policy and Programs Directorate, Office of the Chief Information Officer (CIO)
Mr. David Tremper, SES, Director Electronic Warfare, OUSD (A&S)A/Platforms & Weapons Portfolio Management (P&WPM)

BREAKOUT SESSION

[Talent Challenges] How Space Force Is Developing Guardians To Build High-Performance Teams

This panel will focus on the human capital strategy, and talent management approaches being pursued by USSF to allow commanders to build high performance teams within squadrons to secure and defend US interests in space. Given the relatively small size of the USSF and the very limited number of individuals brought into the Service each year, the USSF must take a new, tailored, and individualized approach to cultivate the competencies necessary to fulfill its portion of the joint warfighting mission. Also, a candid discussion and debate of the challenges of balancing breadth and depth (i.e., specialization), "free market" approaches to career pathways, creating high-performance teams, new approaches to assessing performance and promotion readiness, and crafting a new culture to meet the needs of the Service.

SESSION MODERATOR:

Mr. Jason B. Lamb, NH-04, DAF, USSF/S1 Talent Strategist

SESSION PRESENTERS:

Brig. Gen. Shawn W. Campbell, USSF/S1 Deputy
Col. John "PY" Thien, Delta 3 Commander, U.S. Space Force
CMSgt Amber Mitchell, USSF/S1 Senior Enlisted Leader

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SPOTLIGHT SESSION

A Conversation Ms. Michèle Flournoy

3:00 - 4:00 PM I Main Stage, Exhibit Hall

SPOTLIGHT SPEAKER:

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

SESSION MODERATOR:

Mr. Ken Miller, Host of From the Crows' Nest and Creator of History of Crows podcasts

THURSDAY, DECEMBER 2

Keynote Session

8:30 - 9:45 I Main Stage, Exhibit Hall

Gen. S. Clinton Hinote, Deputy Chief of Staff for Strategy, Integration and Requirements, U.S. Air Force

BREAKOUT SESSION

[5G Networks] Critical Enabler or Vulnerability?

Military and government agencies worldwide are eying 5G for its potential to revolutionize their communications. However, while the immense advantages are clear, many obstacles need to be considered to bring about new technological advances while securing communications. And no one wants their forces to be left behind in new technology adoption.

Join us for the AOC 5G panel discussion to learn how 5G will revolutionize military and government organizations. Our speakers will discuss 5G's impact on communications, advances, security, and logistics. Hear our panelists of military, industry, and test and measurement experts discuss:

- The current state of 5G for military and government
- Examples of new, advanced use cases
- 5G challenges and how to mitigate them
- The future: 6G

SESSION MODERATOR:

Dr. Raymond Shen, Business Unit Manager of Keysight Technologies' Field Test and Spectrum Monitoring Group

SESSION PRESENTERS:

Mr. Bryan Clark, Senior Fellow, Hudson Institute
Mr. Daniel Rice, Lockheed Martin, Vice President, 5G Programs
Dr. Melissa Midzor, National Institute of Standards and Technology (NIST)
Mr. R. Scott "Sherm" Oliver, Chairman of Board of Advisors, RVJ Institute, former Chief of Staff of the Secretary of Defense Electromagnetic Spectrum Operations Cross Functional Team
Mr. Vince Nguyen, Keysight Technologies, General Manager of Aerospace Defense Solutions

SYMPOSIUM AGENDA

BREAKOUT SESSION

Building the Future All-Domain Force – A Bottom's Up Technical Perspective

This panel will provide an opportunity for the industry to discuss emerging technologies and opportunities. The scope will include emerging commercial technologies, advanced integration, and processes to increase technology adoption. In addition, the department's budgetary realities will inform the discussion, and the strategic challenges nation-state competitors are putting on our EW & EMSO capabilities as we build the All-Domain Force of the Future.

SESSION MODERATOR:

Mr. Patrick Antkowiak, President, CEM Technology Advisors LLC Former Corporate Vice President and Chief Technology Officer, Northrop Grumman Corporation (retired)

SESSION PRESENTERS:

Mr. Ivo Bolsens, Senior Vice President Advanced R&D and CTO, Xilinx
Dr. Victoria Coleman, Chief Scientist, United States Air Force
Dr. William Conley, Chief Technology Officer, Mercury Systems
Dr. Bo Marr, Chief Technology Officer, Eperis

SPOTLIGHT SESSION

[Project Convergence 21] Linking Land, Air, Sea, Space, and Cyberspace

12:30 - 2:00 PM I Main Stage, Exhibit Hall

SPOTLIGHT SPEAKER:

LTG Thomas H. Todd III, Deputy Commanding General for Acquisition and Systems, Army Futures Command

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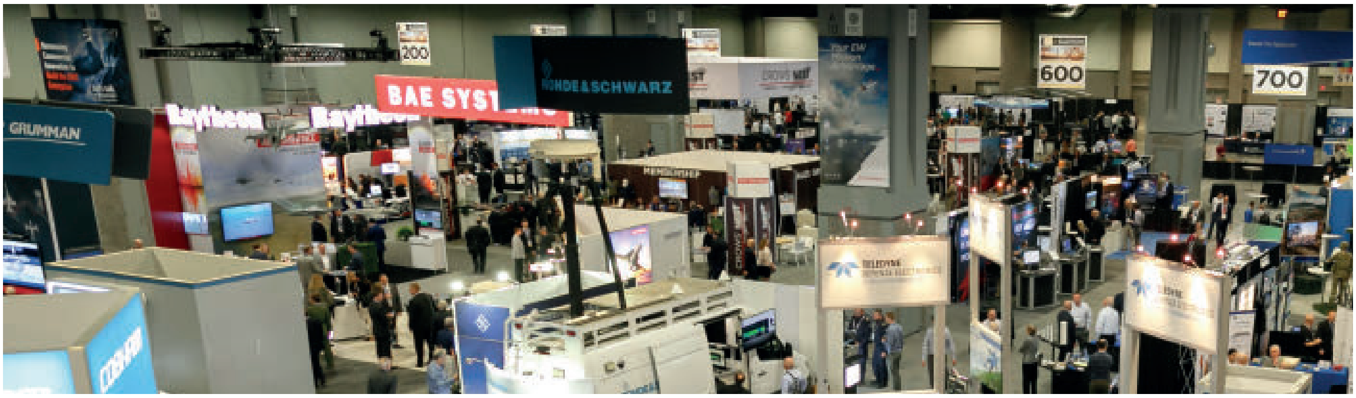
As of 10/11/21 (Subject to Change)



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CHECK OUT WHO WILL BE AT AOC 2021!

3dB Labs
Booth 133
9050 Centre Pointe Dr.,Suite 340
West Chester, OH 45069
United States
http://www.3db-labs.com
3dB Labs delivers powerful, customizable, digital signal processing solutions capable of realtime and offline spectrum and temporal analysis, signal detection, demodulation.

Advanced Test Equipment Rentals
Booth 350
10401 Roselle Street
San Diego, CA 92121
United States
http://www.atecorp.com
Advanced Test Equipment Rentals (ATEC) is the global leader for EMC and signal analysis test instrument rentals, sales and calibrations.

Aethercomm
Booth 325
3205 Lionshead Avenue
Carlsbad, CA 92010 United States
http://www.aethercomm.com
Aethercomm designs and manufactures high power RF amplifiers, subsystems and systems for use in radar, electronic warfare, communication systems, space, test and measurement and any other system that requires high power in a robust and package.

Alaris USA LLC
Booth 308
33R Main Street
Windham, ME 04062
United States
http://www.alarisusallc.com
Alaris USA is based in Windham, Maine, USA and is a proud supplier of high quality antenna solutions for the EW spectrum monitoring and communications market and operates as part of mWAVE Industries LLC.

American Microwave Corporation
Booth 829
7309-A Grove Road
Frederick, MD 21704
United States
Since its founding by Raymond L. Sicotte in 1973, American Microwave Corporation (AMC) has led the way in the production of DC to 40 GHz Solid State Control Components and is a key supplier of goods to the Global Defense Electronics Industry.

American Standard Circuits
Booth 513
475 Industrial Drive
West Chicago, IL 60185
United States
https://www.asc-i.com
ASC manufactures rigid, metal-backed, RF/microwave, HDI, flex, and rigid-flex Printed Circuit Boards. We are capable of providing a wide variety of technologies in a time-critical environment. Our certifications include AS9100D and MIL-PRF-31032.

Ampex Data Systems
Booth 344
26460 Corporate Ave.
Hayward, CA 94545
United States
http://www.ampex.com
Ampex delivers full-spectrum data acquisition systems for Electronic Warfare needs. We build secure, rugged solutions, employed in any domain. We capture/process EW/ISR, video/imagery, telemetry, mission data, & more in an open-architecture platform.

AmpliTech Incorporated
Booth 704
620 Johnson Avenue
Bohemia , NY 11716
United States
http://www.amplitechinc.com
AmpliTech designs, develops and manufactures custom leading-edge RF Low Noise Amplifiers and components for the Commercial, SATCOM, Space, and Military markets. These designs cover frequencies from 50 kHz to 44 GHz.

Analog Devices
Booth 823
3 Technology Way
Norwood, MA 02062
United States
Analog Devices, Inc. is the leader in the design and manufacture of high-performance integrated circuits and complete RF solutions. ADI is enabling the next generation of Electronic Warfare systems with a complete DC to 100 Gigahertz offering.

Annapolis Micro Systems, Inc.
Booth 605
190 Admiral Cochrane Dr.
Ste 130
Annapolis, MD 21401
United States
https://www.annapmicro.com/
Founded in 1982, Annapolis Micro Systems manufactures COTS FPGA-based Boards and Systems for challenging data acquisition, digital signal processing, and data storage applications. High-performance products are 100GbE-capable & SOSA™-aligned.

Anritsu Company
Booth 613
490 Jarvis Drive
Morgan Hill, CA 95037
United States

AQYR Technolgies
Booth 729
12 Murphy Dr, Unit D1,
Nashua, NH 03062
United States
http://ara-inc.com
ARA provides an array of antenna and RF systems, including VSAT Systems, SATCOM, RADAR, Electronic Warfare (EW) components, supporting the military and commercial markets. Our processes are ISO 9001:2015 compliant.

This exhibitor is participating as part of the Small Business Showcase.

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AOC Europe 2022
Booth 248
Clarion Events Ltd
Fulham Green, 69-79 Fulham High Street, London SW6 3JW
United Kingdom
https://www.aoceurope.org/
The next edition of AOC Europe will take place in Montpellier, France from 10-12 May 2022. Meet our team to discuss how you can take part in the 26th annual edition of the AOC's flagship European event.

CONTRIBUTING SPONSOR
API Technologies Corporation
Booth 232
400 Nickerson Rd
Marlborough, MA 01752
United States
API Technologies combines engineering expertise, innovation and manufacturing excellence to enable mission-critical solutions. API solutions enable high quality product performance in the military and government, space, commercial, and more.

ApisSys
Booth 312
Archamps Technopole
60 rue Douglas Engelbart
Building ABC 1, A
74160 Archamps
France
http://www.apissys.com
ApisSys is "The Partner" dedicated to deliver best in class OpenVPX COTS products with very high speed data conversion and signal processing solutions for Electronic Warfare and Radar applications. ApisSys provides also customs solutions and services

ASELSAN A.S
Booth 127
Mehmet Akif Ersoy Mahallesi 296. Cadde No: 16, Y enimahalle Ankara 06370
Turkey
http://www.aselsan.com.tr
ASELSAN is the largest defense electronics company of Turkey whose capability/product portfolio comprises communication and information technologies, radar and electronic warfare, electro-optics, avionics, command and control systems.

Atlanta Micro, Inc.
Booth 342
3720 Davinci Court, Suite 400
Peachtree Corners, GA 30092
United States
https://www.atlantamicro.com
Atlanta Micro strives to simplify RF system design by providing integrated, chip-scale solutions that significantly reduce size, weight, power and component count. Our components range from single-function RFICs to complete RF tuner solutions.

PLATINUM SPONSOR
BAE Systems
Booth 347
144 DW Hwy
MER-24-1216
Merrimack, NH 03054
United States
http://www.baesystems.com
Our dedication shows in everything we deliver, from electronic systems to cyber operations and intelligence analysis, from combat vehicles to naval weapons to ship modernization. We give our customers a critical advantage where it counts.

BRONZE SPONSOR
CAES
Booth 413
2121 Crystal Drive Suite 800
Arlington, VA 22202
United States
https://caes.com/
Electronic Warfare Components, Subsystems, and Test Solutions

Colorado Engineering Incorporated
Booth 604
1915 Jamboree Drive, #165
Colorado Springs, CO 80920
United States

Communications & Power Industries LLC
Booth 725
811 Hansen Way
Palo Alto, CA 94304
United States
http://www.cpii.com
CPI is the world's leading manufacturer of microwave tubes, generators, power grid devices and components, including TWTs, CCTWTs, klystrons, microwave windows, couplers and filters.

Comtech PST
Booth 243
105 Baylis Rd
Melville, NY 11747
United States
http://www.comtechpst.com
Comtech PST Manufactures solid state high power amplifiers and control components. Amplifier frequency ranges are from 1MHz to 18GHz and pin diode switches, limiters, attenuators and multifunction assembly frequency ranges are from 1MHz to 40GHz.

Conduant Corporation
Booth 649
1501 South Sunset Street, #D
Longmont, CO 80501
United States
http://www.conduant.com
Conduant Corporation designs and manufactures real-time high-speed record/playback systems capable of transferring 1TB (8Tb) of data every 50 seconds. The systems are designed for use in industrial and military applications.

Crane Aerospace & Electronics
Booth 130
16700 13th Avenue West
Lynnwood, WA 98037
United States
Crane Aerospace & Electronics delivers mission-critical and innovative components, systems, and services for commercial aircraft, defense, and space markets.

CRFS
Booth 541
4230-D Lafayette Center Dr
Chantilly, VA 20151
United States
http://www.crfs.com
CRFS's rugged deployable systems provide actionable real time RF spectrum situational awareness. Products include spectrum management, signal classification, DF & TDOA geolocation, RF recording/signal analysis, TSCM, & UAS passive detection/tracking.

dB Control
Booth 209
1120 Auburn Street
Fremont, CA 94538
United States
http://www.dbcontrol.com
dB Control designs and manufactures reliable high-power TWTAs, MPMs and high voltage power supplies for radar, EW, ECM, and data link applications. We offer specialized contract manufacturing, BTP and repair depot services of HVPS and TWTAs.

Decodio AG
Booth 712
Technoparkstr. 1 Zurich CH-8708
Switzerland
Decodio AG specializes in spectrum baselining, SIGINT, EMCON training systems, TDoA/AoA emissions Localization, and spectrum management. We tailor low-profile to large training range solutions for warfighters to increase their Electronic Protection.

Digital Receiver Technology (DRT)
Booth 126
12409 Milestone Center Drive
Germantown, MD 20876
United States
http://www.drti.com
DRT designs and manufactures SDR solutions. Leading supplier of RF and DF hardware and embedded signal processing algorithms. Modular, scalable, multi-channel SDRs for manpack, mobile, large-system operations spanning the air, land and sea.

Directed Energy Professional Society (DEPS)
Booth 244
7770 Jefferson St NE, Suite 440
Albuquerque, NM 87109
United States
http://www.deps.org
Non-profit that fosters the research, development, and transition of Directed Energy technologies for national defense and civilian applications through professional communication and education.

Be sure to check out everything happening in the hall this year including the current floor plan online at 58.crows.org

This exhibitor is participating as part of the Small Business Showcase.

D-TA Systems
Booth 315
2500 Lancaster Road
Ottawa, ON K1B 4S5
Canada
http://www.d-ta.com
D-TA is a sensor interface and processing company, pioneering the 10-Gigabit Ethernet as data back-bone, for high speed data transfer between signal acquisition and processing. Handles high-bandwidth, high channel-counts and seamless synchronization.

Elbit America
Booth 406
EW, intelligence and communications comprehensive solutions for air, ground and naval applications, operational worldwide in all theaters and conflict zones of the last five decades.

Electro-Metrics Corporation
Booth 710
231 Enterprise Road
Johnstown, NY 12095
United States

Elite RF
Booth 505
2155 Stonington Avenue, #217
Hoffman Estates, IL 60169
United States
Elite RF is a Global Total Solutions Provider for all your RF Amplifier and Test Equipment Needs. We strive in delivering advanced technology to virtually every industry sector in quantities ranging from quick turn to large volume production.

Empower RF Systems
Booth 548
316 West Florence Ave
Inglewood, CA 90301
United States
https://www.empowerrf.com
High Power RF and Microwave Pulse and CW Amplifiers for Electronic Warfare Applications. From 100KW+ Liquid Cooled Systems to Compact Man Pack modules, Empower RF is Tactically Deployed and Operating on Multiple Levels in Support of DOD Missions.

Epiq Solutions
Booth 401
3740 Industrial Ave
Rolling Meadows, IL 60008
United States
http://www.epiqsolutions.com
Epiq Solutions expands the limits of RF technology with innovative software defined radio (SDR) platforms and sensors that address our customers' challenging SWaP requirements while providing competitive advantage and reduced time to market.

EWA
Booth 511
13873 Park Center Road
Herndon, VA 20171
United States
A Veteran-Owned, Small Business with less than 500 employees, providing technical and engineering solutions while working closely with the customer to understand and refine system requirements to achieve the best outcome.

Georgia Tech Research Institute
Booth 245
250 14th Street, NW
Atlanta, GA 30318
United States
Georgia Tech Research Institute (GTRI) provides the US and international military communities systems engineering and technical solutions for current and future EW and Cyber Warfare requirements.

Giga-tronics
Booth 717
5990 Gleason Dr
Dublin, CA 94568
United States
http://www.gigatronics.com
Giga-tronics Real-Time-Control, Agile, Wideband, Coherent, multi-channel RF/Microwave Up & Down Conversion instruments provide integrated solutions for addressing test and evaluation of the worlds next generation Radar and Electronic Warfare Systems

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Booth 220
1211 Air Way
Glendale, CA 91201-2497
United States
https://www.glenair.com/
Glenair provides a variety of products addressing EMI, Shielding, Filtering, wire management and interconnect solutions. Full engineering support through all aspects of the design and Implementation. 100% USA Engineering and Manufacturing.

Gowanda Electronics
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5G Communications – Part 8

Review of Propagation Formulas

By Dave Adamy

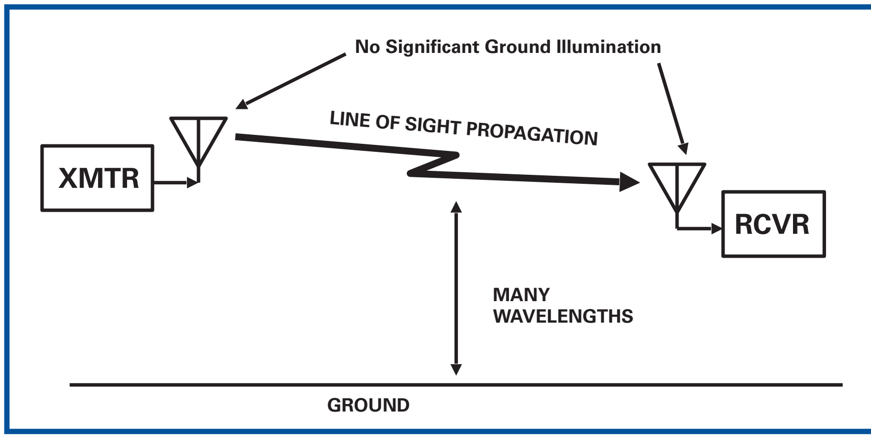

Fig. 1: If both the transmitter and receiver are many wavelengths above the ground or if the antenna beams are narrow enough to exclude significant energy to and from the ground, the line-of-sight propagation model is appropriate.

This month and next, we are taking a slight detour in our discussion of 5G communication to review some important propagation formulas which were presented in a series of columns 14 years ago. Although these formulas are presented as though they apply to communication links, they apply just as well to radar or data transmissions.

RADIO PROPAGATION LOSS

We are concerned here with the loss between the transmitting and receiving antennas. Each of these formulas assumes that both antennas are isotropic (i.e., 0 dB gain and spherical coverage). Thus, we can add antenna gains and geometry as a later step in each application. The propagation losses are called line-of-sight, two-ray and knife-edge diffraction. **Table 1** shows the circumstances in which each applies.

There are complex computer-generated models that require a model of the environment in which communication takes place. By analyzing every signal path, including all reflections and their interactions, you can generate a very accurate propagation loss. In electromagnetic warfare (EW), however, the situation tends to be quite dynamic, and when either the transmitter or receiver moves, the model must be rerun. It is common practice to use approximating formulas that are accurate as opposed to precise – thus giving results that are generally accurate to within about a dB and allow the practical solution of practical problems. Here are the descriptions of the three most important models; those included in Table 1.

Table 1: Selection of Appropriate Propagation Loss Formula

<table>
<tr><td rowspan="3">Clear Propagation Path</td><td rowspan="2">Low frequency, wide beams, near ground</td><td>Link longer than Fresnel zone distance</td><td>Use two-ray model</td></tr>
<tr><td>Link shorter than Fresnel zone distance</td><td rowspan="3">Use line-of-sight model</td></tr>
<tr><td colspan="2">High Frequency, Narrow Beams, far from ground</td></tr>
<tr><td>Propagation path obstructed by terrain</td><td colspan="2">Calculate additional loss from knife-edge diffraction</td></tr>
</table>

LINE-OF-SIGHT PROPAGATION

Line-of-sight (LOS) propagation loss is also called free-space loss or spreading loss. It applies in space and between transmitters and receivers in any other environment in which there are no significant reflectors and the ground is far away in comparison with the signal wavelength. See **Figure 1.**

The formula for LOS loss comes from optics.

$$\text{Loss} = (4\pi)^2 R^2 / \lambda 2$$

Where R is the transmitter to receiver range and λ is the wavelength. Both the range and the wavelength are in the same units (typically meters). The convenient dB version of this formula is:

$$L\ (\text{dB}) = 32.44 + 20\log10(R) + 20\log10(F)$$

Where R is the link distance in kilometers (km) and F is the transmit frequency in megahertz (MHz).

TWO-RAY PROPAGATION

When the transmitting and receiving antennas are close to a single dominant reflecting surface (i.e., the ground or water) and the antenna patterns are wide enough to allow significant illumination of that surface, the two-ray propagation model (as shown in **Figure 2)** must be considered. As we will see, the transmitted frequency and the actual antenna heights determine whether the two-ray or line-of-sight propagation model applies.

Two-ray propagation is also called "40 log d" or "d⁴" attenuation, because the loss varies with the fourth power of the link distance. You will note that (unlike line-of-sight attenuation) there is no frequency term in the two-ray loss expression. In non-logarithmic form, the two-ray loss is:

$$L = d^4 / (hT^2 \times hR^2)$$

Where: d = the link distance,
h_T = the transmitting antenna height, and
h_R = the receiving antenna height.

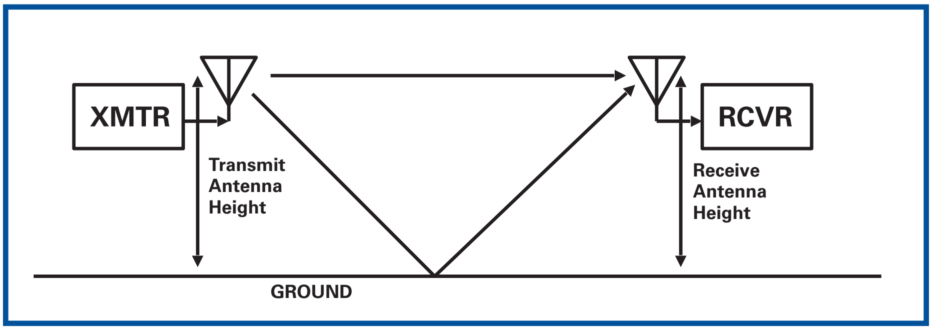

Fig. 2: *In two-ray propagation, the dominant loss effect is the phase cancellation between the direct and reflected signals.*

The link distance and antenna heights are all in the same units.

The dB formula for the two-ray propagation loss is:

$$L = 120 + 40\ \mathrm{Log}(d) - 20\ \log(h_T) - 20\ \mathrm{Log}(h_R)$$

Where: d = the link distance in kilometers
h_T = the transmitting antenna height in meters
h_R = the receiving antenna height in meters

MINIMUM ANTENNA HEIGHT

Figure 3 shows minimum antenna height for two-ray propagation calculations vs. transmission frequency. There are five lines on the graph, they are for:

- transmission over sea water
- vertically polarized transmission over good soil
- vertically polarized transmission over poor soil
- horizontally polarized transmission over poor soil
- horizontally polarized transmission over good soil

"Good soil" provides a good ground plane. If either antenna height is less than the minimum shown by the appropriate line in this graph, the minimum antenna height should be substituted for the actual antenna height before completing the two-ray attenuation calculation.

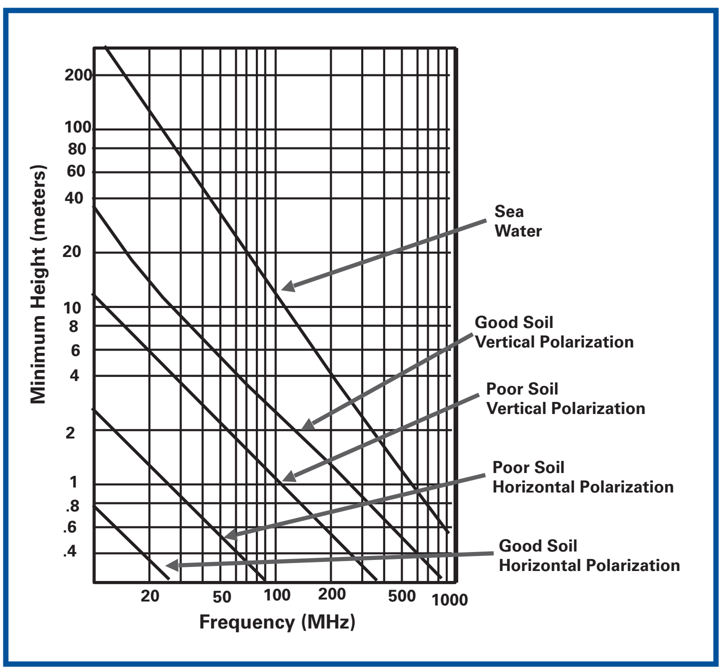

Fig. 3: *If antennas are below the minimum height shown in this graph, use the indicated minimum height in the two-ray propagation loss calculation.*

COMPLEX REFLECTION ENVIRONMENT

In locations with very complex reflections – for example when transmitting down a valley (see **Figure 4**), it is suggested in the literature that the line-of-sight propagation loss model will give a more accurate answer than the two-ray propagation model.

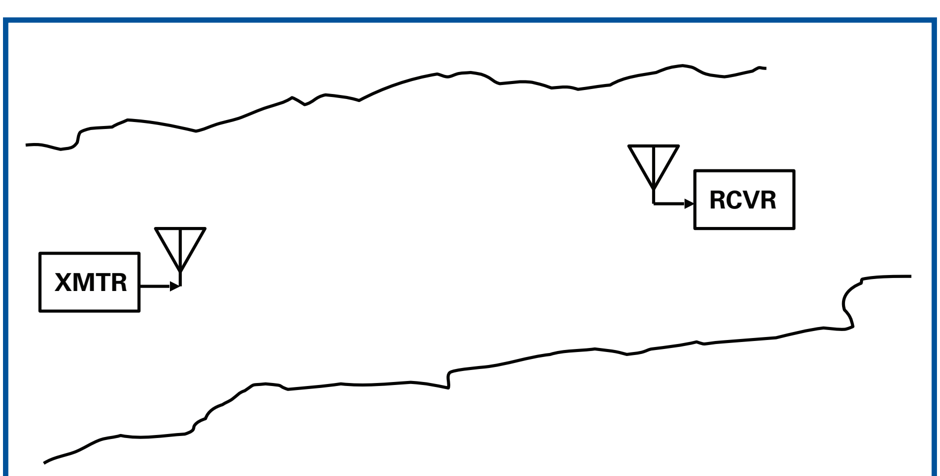

Fig. 4: *If propagation is down a valley or another complex environment, line-of-sight propagation offers the best fit.*

WHAT'S NEXT

Next month, we will complete the presentation of the commonly used radio propagation formulas. For your comments and suggestions, Dave Adamy can be reached at dave@lynxpub.com.

CHESTER ARTHUR CROWELL III

Chester Arthur Crowell III of Macon, Georgia, died Aug. 13, 2021 at age 68.

Crowell was an alumnus of Georgia Institute of Technology, where he earned a degree in electrical engineering. He was the lead radar programmer for the US Air Force for the F-15 program during Desert Storm, and was also an artist and musician. One of his artistic works of art can be found at the visitor's entrance of Building 231, the home of the Electronic Combat Security Assistance Program (ECISAP) Office at Robins Air Force Base.

LT. COL. CRAWFORD ELMER HICKS

Lt. Col. Crawford Elmer Hicks, USAF (Ret.) of Leitchfield, Kentucky passed away on Oct. 2 at the age of 100 at his home in Warner Robins, Georgia.

Hicks was a B-17 pilot, prisoner of war local hero and author.

Hicks' boyhood dream of becoming a pilot was realized when he joined the Air Corp Cadet Program in 1942 and started flying trainer planes in Albany, Georgia. His first mission in World War II occurred in May 1944. His B-17 was shot down in Germany on his 10th mission. He spent nearly a year as a POW before being rescued by Allied Forces in 1945.

After the war, Hicks spent another two decades in the U.S. Air Force and later served his country for many more years as an attorney in the U.S. Housing and Development Authority.

Hicks authored a book entitled, "Prisoner of War: Memoirs of Crawford E. Hicks."

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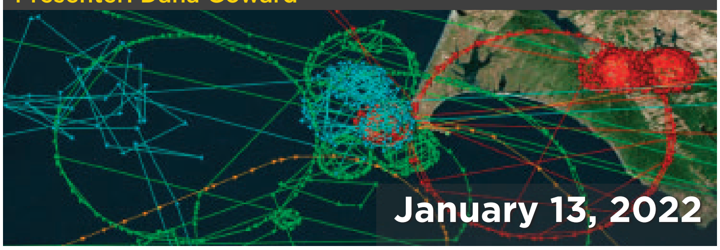

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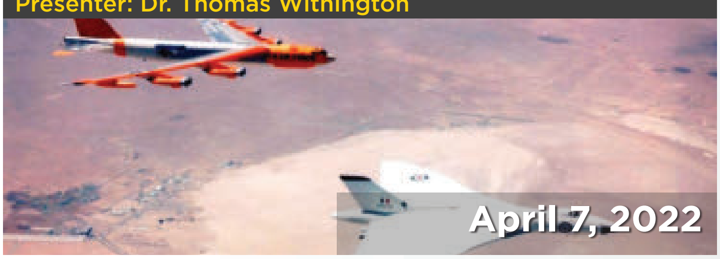

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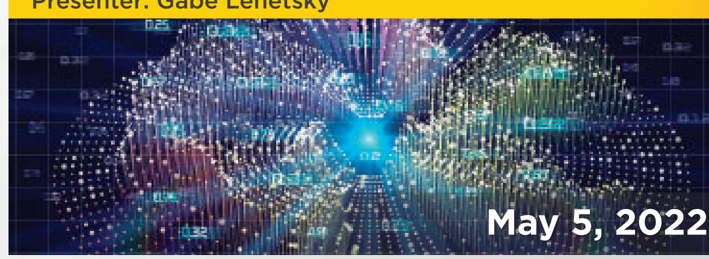

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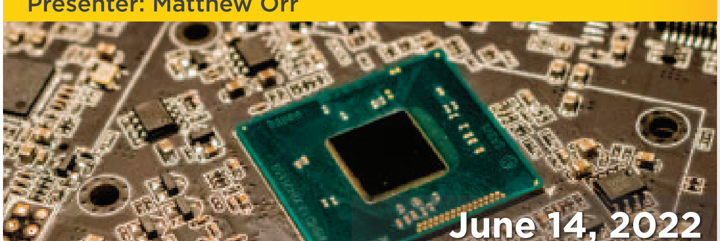

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