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JED

Journal of Electromagnetic Dominance

NATO'S EMS STRATEGY

JED CONTENTS

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NATO must evolve its EMS Strategy across its air, land, sea and space forces. Above, a US Army Bradley fighting vehicle crosses a Polish floating bridge at Zły Łęg Lake during Exercise Allied Spirit. The exercise was part of DEFENDER-Europe 20 Plus, a three-month US-led multinational exercise that brought together more than 6,000 NATO troops (primarily from the US and Poland). It marked the third largest NATO exercise since the end of the Cold War. NATO

US Air Force Airman Joshua Elmore, a crew chief for the 379th Expeditionary Aircraft Maintenance Squadron, and Senior Airman Dale Riches Jr., an electronic warfare systems journeyman for the 379th EAMXS, conduct a preflight inspection on an RC-135 Rivet Joint aircraft in January at Al Udeid Air Base, Qatar.
PHOTO BY TECH SGT BRIGETTE WALTERMIRE

Departments

COVER PHOTO COURTESY OF AIRWOLFHOUND

NEXT STEPS

Whenever I consider an editorial topic for *JED,* such as a mission area or a particular technology – or even a policy area – one of my first instincts is to ask, *what were we doing in this area 10 years ago, five years ago, last year*? When I think back 10 years to 2011, I remember that our community was in the midst of recalibrating how we thought and talked about EW. Back then, we were in the early stages of debating whether the EMS was an operational domain. We were just beginning to use the term EMS Operations (EMSO), which was a new concept that combined EW and spectrum management. Service concepts, such as CEMA, were just being introduced. The Navy's Electromagnetic Maneuver Warfare concept had not been developed. While our community was beginning these discussions internally, the senior levels of the DOD were still several years away from thinking about EW or EMSO in policy terms.

Within the last decade, our professional community has evolved its conceptual understanding of EMSO tremendously. We used to think and talk in terms of EW tactical support to other missions, and now we think about EMSO in terms of strategic effects. That represents a significant shift over a relatively short period, especially when you consider that our community had been pretty comfortable thinking about EW in a tactical paradigm for the previous 70 years.

One of the most important reforms our EMSO community has been pursuing for the past 10 years is governance. In last year's EMS Superiority Strategy (EMSSS), governance was listed as the fifth goal, with three lines of effort: 1) unify Department-wide EMS Enterprise activities; 2) develop a Continuous Process Improvement (CPI) culture; and 3) promote policies that support EMS capabilities and operations. These may seem like "soft" goals. Without this governance discussion, however, the DOD would likely be continuing its historical pattern of managing its EMS requirements in a disjointed way, with minimal resourcing, and setting itself up to continuously react to the latest EMS crisis instead of anticipating it and resourcing solutions ahead of time.

Because of this governance discussion, the DOD is now pursuing an EMS strategy that will transition away from assigning fixed frequencies to a particular system or program. Going forward, it will design its systems for dynamic spectrum access where cognitive performance enables radar, communications, IFF and other EMS functions to dynamically sense the spectrum and optimally choose which frequencies to use within certain broad parameters. This will ease congestion, improve utilization of spectrum and enable the DOD to share larger portions of spectrum with commercial users who are themselves seeking more spectrum availability. This change is long overdue, and it would not have happened without our community's focus on governance issues.

The progress we have made in governance is important because it sets a new foundation for the work we need to accomplish in areas such as technology development and new operational concepts. Governance may seem boring, but it has certainly not been a waste of our time. – *J. Knowles*

JED
Journal of Electromagnetic Dominance

EDITORIAL STAFF
Editor: John Knowles
Publisher: John Bacon
Senior Editor: John Haystead
Managing Editor: Hope Swedeen
Technical Editor: Barry Manz
Threat Systems Editor: Doug Richardson
Contributing Writers:
Dave Adamy, Luca Peruzzi, Richard Scott, Dr. David Stoudt, and Andrew White
Proofreaders: Ken Janssens, Shauna Keedian
Sales Manager: Tabitha Jenkins
Sales Adminstrator: Amanda Glass

PRODUCTION STAFF
Layout & Design: Barry Senyk
Advertising Art: Elaine Connell
Contact the Editor: (978) 509-1450, JEDeditor@naylor.com
Contact the Sales Manager:
(800) 369-6220 or tjenkins@naylor.com
Subscription Information:
Please contact Glorianne O'Neilin at (703) 549-1600 or e-mail oneilin@crows.org.

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Calendar *Conferences & Courses*

MAY

Cyber Warfare/EW Convergence
Atlanta, GA
May 3-5
www.pe.gatech.edu

AOC Professional Development Live Web Course: Advanced Principles of Electronic Warfare
May 3-26
www.crows.org

Radar Warning Receiver System Design and Analysis
Atlanta, GA
May 4-6
www.pe.gatech.edu

AOC Virtual Series Webinar: AI Guided Spectrum Operations
May 6
1400-1500 EDT
www.crows.org

2021 Special Operations Forces Industry Conference (SOFIC) – Virtual Conference: May 17-21
www.sofic.org

Military Electronic Warfare
May 17-21
Swindon, UK
www.cranfield.ac.uk

Signals Intelligence (SIGINT) Fundamentals
May 18-19
Atlanta, GA
www.pe.gatech.edu

Adaptive Arrays: Algorithms, Architectures and Applications
May 18-21
Atlanta, GA
www.pe.gatech.edu

AOC Virtual Series Webinar: 5G for Non-Terrestrial Networks
May 20
1400-1500 EST
www.crows.org

Cyber Electromagnetic Activity (CEMA) 2021
Conference: May 25-26
Belcamp, MD
www.crows.org

Modeling and Simulation of Phased-Array Antennas
Online
May 25-27
www.pe.gatech.edu

AOC Virtual Series Webinar: Technology Advancements Enabling Test & Evaluation Capabilities to Keep Pace with Modern and Future EW and Radar Systems
May 27
1300-1400 EST
www.crows.org

JUNE

Land Forces 2021
Conference: June 1-3
Brisbane, Australia
www.landforces.com.au

AOC Virtual Series Webinar: Introduction to Direct Energy Weapons
June 3
1400-1500 EST
www.crows.org

International Microwave Symposium (IMS 2021) Conference: June 7-10
Virtual Event: June 20-25
Atlanta, GA
www.ims-ieee.org

AOC Professional Development Live Web Course: C4ISR Requirements, Principles, and Systems
June 7-30
www.crows.org

Basic EO-IR Concepts
Las Vegas, NV
June 15-17
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Adaptive Arrays: Algorithms, Architectures and Applications
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continued on page 10

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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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June 17
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www.crows.org

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Las Vegas, NV
June 22-24
www.pe.gatech.edu

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Fundamentals of Radar Signal Processing
Las Vegas, NV
June 22-25
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AOC Virtual Series Webinar: What SOSA Means to the Warfighter
June 24
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JULY

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Las Vegas, NV
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Farnborough Air Show – Virtual Conference: July 13-15
www.farnboroughairshow.com

AOC Virtual Series Webinar: Introduction to Satellite Communications (SATCOM)
July 15
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Basic RF Electronic Warfare Concepts
Atlanta, GA
July 27-29
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AOC Virtual Series Webinar: Electromagnetic Pulse (EMP): Science, Strategy, Politics
July 29
1400-1500 EST
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AUGUST

Navy League Sea-Air-Space Conference: August 1-4
National Harbor, MD
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AOC Professional Development Live Web Course: Direct Energy Weapons
August 2-18
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AOC Virtual Series Webinar: Quick Searches for Emitters in an RWR
August 5
1400-1500 EST
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AOC Virtual Series Webinar: Standards and Applications in Defense Video
August 12
1400-1500 EST
www.crows.org

36th Space Symposium Conference: August 23-26
Colorado Springs, CO
www.spacesymposium.org

AOC Virtual Series Webinar: Introduction to Digital Signal Processing for Electronic Warfare
August 26
1400-1500 EST
www.crows.org

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

CEMA 2021

MAY 25-26

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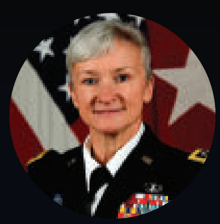
ASSOCIATION OF OLD CROWS

Focus on the Future (MDO 2035 and Beyond)

DISTINGUISHED SPEAKERS

LTG Stephen Fogarty
Commanding General,
U.S. Army Cyber Command



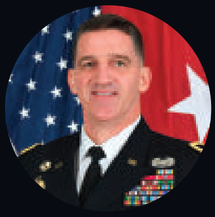
LTG Laura A. Potter
Deputy Chief of Staff, G-2

MG John A. George
Commanding General, Army Combat Capabilities Development Command (DEVCOM) (Invited)

MG Neil S. Hersey
Commanding General, Cyber Center of Excellence and Fort Gordon

MG Mitchell L. Kilgo
Commanding General, U.S. Army Communications-Electronics Command

BG Robert M. Collins
Program Executive Officer for Command, Control, Communications-Tactical (PEO C3T)



BG Paul G. Craft
Commandant and Chief of Cyber, U.S. Army Cyber School

Mr. David Tremper, SES
Director of EW, OSD, OUSD (A&S)A/Platforms & Weapons Portfolio Management (P&WPM)

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LIGHT AT THE END OF THE PANDEMIC TUNNEL

I hope all of you are continuing to stay safe and healthy. The world is continuing to move forward in its campaign against the COVID-19 pandemic and ultimately getting back to some sort of normalcy, hopefully by the end of this year.

In March, I had the honor and privilege of attending and providing opening remarks at the 45th Dixie Crow Symposium at Robins AFB. This event took much planning and coordination with a number of agencies (local, state and federal) to make sure it was held safely and successfully. This event demonstrated that Crows and others can gather in person to network and discuss EMS issues. This was a benchmark event for not only the AOC, but also the US Defense Department and Industry, as we believe it was the first in-person defense-based conference and symposium since the pandemic began over a year ago. This symposium has laid the foundation for moving ahead to other in-person events, to include our annual AOC Symposium and Convention in Washington, DC, later this year.

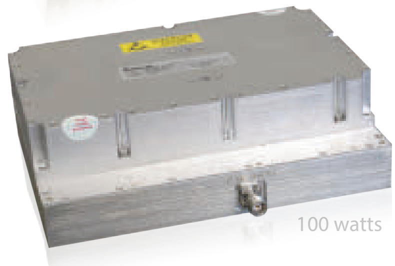
Our community has been networked for decades, but we relied and flourished on primarily in-person and face-to-face events to share ideas regarding the EMS. The AOC grew into a distributed organization with our global growth and presence using in-person events backed-up with electronic and virtual media. That model served us well and gave us a foundation to use to shift to full electronic and virtual models throughout 2020, and we did well; but I always felt there was something missing. I believe that human interaction is essential to get the most out of any event, and it's even more important for technical EMS discussions and interactions. Our return to the in-person model is front and center in our AOC Goals and Strategy to Advocate, Educate and Support. We will continue to respect the pandemic, but not fear it, and we will use the appropriate protocols and procedures to keep our membership safe and healthy, but also move forward with plans to enable us to gather at face-to-face events.

We will also continue to use technology to plan and hold events, and eventually we will grow to having hybrid events so that we can gather in-person and virtually at events.

I am optimistic that we will execute more in-person events across the globe prior to my tenure completing and that I will be able to visit as many of our AOC Chapters as possible.

I am looking forward to attending the first AOC-sponsored in-person event, May 25-26, for our Cyber Electromagnetic Activities (CEMA) conference, and I hope to see some of you there. I also want to highlight our AOC Awards Program once again; please nominate your best and brightest, by June 30, 2021, so that they have a chance to be recognized by their peers, fellow Crows and the AOC. – *Glenn "Powder" Carlson*


PROVEN POWER



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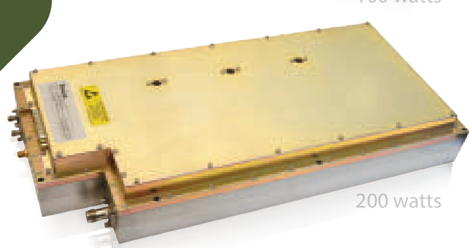

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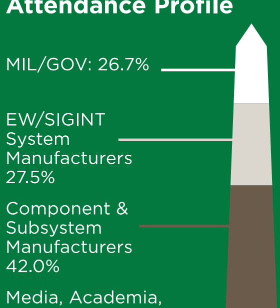
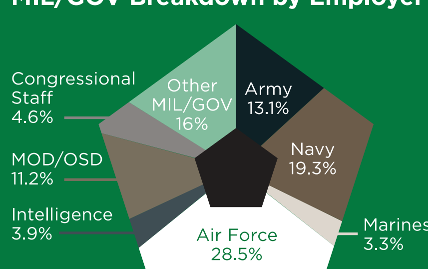
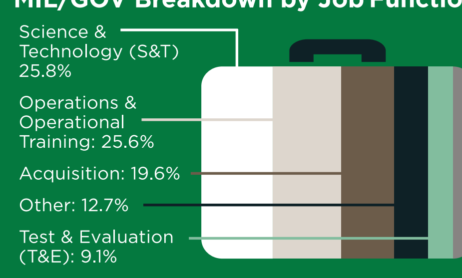


MIL/GOV Breakdown by Employer



MIL/GOV Breakdown by Job Function



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HASC SUBCOMMITTEE HOLDS FIRST EMSO HEARING

The House Armed Services Committee's (HASC's) newly formed Cyber, Innovative Technologies and Information Systems (CITIS) Subcommittee held its first Electromagnetic Spectrum Operations (EMSO) hearing on March 19. Led by Chairman Rep. James Langevin (RI-2) and Ranking Member Rep. Elise Stefanik (NY-21), the virtual hearing focused on "Department of Defense Electromagnetic Spectrum Operations: Challenges and Opportunities in the Invisible Battlespace."

The Subcommittee members heard testimony from Bryan Clark, Senior Fellow at the Hudson Institute; Dr. Bill Conley, CTO at Mercury Systems and former Director of Electronic Warfare at the Office of the Secretary of Defense; and Dr. Joseph Kirschbaum, Director, Defense Capabilities and Management Team, Government Accountability Office.

In his opening statement, Bryan Clark told the CITIS Subcommittee, "Multiple assessments argue the US military is now behind its adversaries in EMS capabilities. With budgets tightening and the window for regaining an advantage now down to less than a decade against the PRC, it is unlikely the US military will be able to restore EMS superiority by attempting to counter each adversary advancement with a new EMS system or countermeasure. DOD will instead need to pursue new operational concepts and technologies that will allow it to 'leap ahead' of its competitors and create enduring advantages in EMS operations."

In March, the Hudson Institute released a new report co-authored by Clark titled, "The Invisible Battlefield: A Technology Strategy for US Electromagnetic Spectrum Superiority". (See article below, "Defining Superiority: An Adaptability-Centric Approach to EMS Dominance.") Some of Clark's testimony drew on this research.

He told the subcommittee members, "At this point, given the timeframe that we're looking at – Admiral Davidson just talked about there being less than a decade to deter China – and our fiscal constraints, we're not going to be able to go and 'system vs. system' try to match the Russian and Chinese and Rest of World's electromagnetic spectrum capabilities. We're going to have to instead mount some different kind of effort, to use different operational concepts and different technologies to get a spectrum advantage." He emphasized that the DOD's legacy approach to EW is no longer capable of delivering what the US needs in the future. "Keeping us back from that," he continued, "unfortunately is that today about 40% of the Pentagon's electromagnetic warfare-related procurement and research and development funding goes to about ten platform-centric programs that largely perpetuate the Cold War operational approaches that we relied on from 30 years ago, such as using manned jamming aircraft to confuse sensors that enemies use for air defenses so we can get a manned bomber to go attack a target. We still use those tactics, even though 30 years ago that was the state of the art. Now it may not be."

"According to GAO," he said, "a series of governance changes that were directed to Congress haven't really yielded the benefits in electromagnetic spectrum superiority that we desired. And so instead of further governance and process changes, Congress should focus now on making sure that DOD pursues the operational concepts and technology changes that are going to help it gain an advantage in the spectrum competition with adversaries like Russia and China. The new Electromagnetic Spectrum Superiority Strategy is a part of that. It highlights technologies such as adaptable systems, agile networked electromagnetic warfare and then virtualized training and testing, as well as open architecture systems. All of those are going to be very important to the new operational concepts and technologies we need to gain an advantage."

In his opening statement, Dr. Conley focused on how the US can adapt to compete in the EMS against its peers and near-peers, such as China and Russia. He told the Subcommittee, "Back in 2015, China formed their Strategic Support Force – an equal mix of electronic warfare, cyberspace operations, and space operations. The Chinese Strategic Support Force reports directly to their Central Military Commission as a peer of their Army, Navy, Air Force, as well as their strategic Rocket Force Headquarters. In comparison, the United States has maintained electromagnetic warfare and spectrum management as capabilities to achieve a tactical outcome. Our organizational charts reflect this tactical prioritization. Our competitive strategy must reflect that we are in the Information Age, and our strategy must also reflect our competitors' strategies."

In terms of moving forward, Dr. Conley seemed to agree with Bryan Clark about the need for new technologies and new operational concepts that utilize them. Dr. Conley told the Subcommittee, "As a Nation, the United States strategy should be based on innovation: in our technology development, in our adoption of these innovations for our national defense, and in the full integration of these innovations into military tactics and operations. Just inventing it is not enough," he emphasized. "This is a dramatic departure from the platform and program-centric legacy investment strategy we have pursued. Instead of viewing capability gaps and shortfalls, EMSO can actually create opportunities for us."

Dr. Kirschbaum's provided a historical perspective on the DOD's challenges to focus on EMS Operations. Much of his opening testimony referenced the GAO's December 2020 report, "Electromagnetic Spectrum Operations – DOD Needs to Take Action to Help Ensure Superiority." He told the Subcommittee members, "As part of our work [on the GAO report], in addition to interviewing a wide range of defense officials and viewing original source documents, we reviewed some

43 [DOD] studies about defense of the electromagnetic spectrum issues. There was remarkable agreement among those studies on the challenges to DOD's EM spectrum capabilities. These challenges included outdated capabilities themselves, lengthy and disjointed acquisition processes, increased spectrum competition and congestion, and gaps in experienced staff and realistic training. Many of these studies also agreed with DOD officials that among the chief causes for the lack of progress in many of these areas was governance." He then described the DOD EMS and EW strategies issued in 2013 and 2017 and explained how they failed to gain traction due to bureaucratic and "organizational hinderances." He said the success of the 2020 DOD EMS Superiority Strategy (EMSSS) would depend on how well the DOD follows through on the strategy's recommendations and, more specifically, the soon-to-be released EMSSS implementation plan.

After these opening statements from the witnesses, the hearing moved on to questions from the members that covered several topics ranging from the DOD's EMS organizational structure to education and developing EMS expertise in the government and industry workforce.

The EMSO hearing was significant in that it was among the first that the newly created CITIS Subcommittee held under the newly seated Congress. It was also the first EMSO-focused hearing Congress has ever held. The House and Senate defense committees have asked EMSO-related questions in other hearings, but neither has ever held a hearing dedicated to EMSO until now.

Congress is waiting for the White House to release its full FY2022 DOD budget request. Last month, the Biden administration provided a top-line figure of $715 billion, but it is not clear exactly when the detailed budget figures will be released to Congress. – *J. Knowles*

Defining Superiority: An Adaptability-Centric Approach to EMS Dominance

The DOD's latest Electromagnetic Spectrum Superiority Strategy (EMSSS), published in September 2020, outlined five critical goals that must be achieved in order to attain and maintain superiority within the EMS. However, as noted in previous articles in *JED,* in order for the latest strategy to be effective, an effective strategy implementation plan is equally imperative.

The five goals under this new EMSSS are: to develop superior EMS capabilities; evolve to an agile, fully integrated EMS infrastructure; pursue total force EMS readiness; secure enduring partnerships for EMS advantage; and establish effective EMS governance.

A recent report by Hudson Institute addresses the United States' progress toward EMS superiority, with the new EMSSS as a launching pad, as well as the rather sizeable challenges yet to be sufficiently addressed by EMS governance, doctrine and capabilities.

The report, "The Invisible Battlefield: A Technology Strategy for US Electromagnetic Spectrum Superiority," written by Bryan Clark and Timothy A. Walton of the Hudson Institute's Center for Defense Concepts and Technology and Melinda Tourangeau and Steve Tourangeau of Warrior Support Solutions, posits the need to view EMS superiority through the lens of in-theater adaptability and agility rather than as an effort to achieve outright EMS *dominance*.

According to the report, the new EMSSS takes a significant step in that direction. "The strategy is notable for its emphasis on creating a force that uses agility, battle management, open architecture, and virtual and constructive training systems to achieve freedom of action in the EMS."

Until quite recently, EMS operations (EMSO) was a long neglected priority in the US, while near-pear competitors, including China and Russia, have been actively pursuing EMS superiority. In the last decade, the US has made progress in EMS acquisition and governance, but these efforts have largely been aimed at modernizing legacy EMS platforms and systems, while a cohesive, all-Service strategy and implementation plan centered on a "decision-centric" force has yet to be manifested, according to the report.

"To regain enduring EMS superiority under today's conditions of technological

and fiscal uncertainty, DOD will need to adopt a decision-centric planning approach in which adaptability is a more important metric than predicted performance against a particular threat in a specific scenario."

"DOD is at a crossroads today in terms of EMS-related technology development. The 2020 EMS Superiority Strategy and operational concepts for EMSO and EMBM advance new approaches to regain EMS advantage by improving the adaptability of US EMS capabilities both during and between operations. The resulting expansion of options for commanders and leaders would allow US forces to break out of today's move-countermove cycle in EMS innovation," the report says.

Adaptability, or "optionality," however, is not enough to ensure superiority, according to the report. The benefits of an adaptable Force can only be reaped if supported by technological capabilities that exploit asymmetries that exist between US and competitor forces, namely the People's Liberation Army (PLA) of the People's Republic of China (PRC) and the Russian Armed Forces, as "the US military lacks the time and resources to gain a lead in EMSO against PRC and Russian forces using a symmetric system versus system competition."

According to the report, asymmetries to be addressed and exploited, as they relate to the PLA and Russian Armed Forces, include:

- **Geography:** Any future confrontations outside of allied territories would leave US forces at a disadvantage in EMS access and wired communications use.
- **Technological innovation, including EMS capability development:** The PLA aims to create new, innovative capabilities to specifically combat US systems, with a robust commercial electronics industry to support that ability. Russia's focus lies more on incremental adaptation of existing EMS systems, similar to the US.
- **Command, Control and Communications:** The PLA's C2 operations rely on "redundant and resilient communications networks to support a relatively fixed C2 structure" within its units, while the Russian military relies more on local commanders to execute initial plans and improvise when necessary (i.e., when communications are degraded). The US aims to operate using both approaches when appropriate and necessary.
- **Employment of artificial intelligence (AI):** The DOD has focused its AI efforts on integration in operational systems, whereas the PLA and Russian Armed Forces implement AI primarily in the areas of C2, management support systems, and intelligence, surveillance and reconnaissance (ISR).
- **Deployment of electronic warfare (EW) capabilities:** "The PRC and Russian militaries equip units with offensive and defensive EW systems and personnel down to the ground force company, aviation squadron, and naval or paramilitary ship level." US EW capabilities are not deployed so ubiquitously, implemented at varying echelons across the Services, though generally at higher levels of command.
- **EMS capability governance:** While the PLA and Russian Armed Forces

Australia Signs for New Nulka Decoy Work

The Australian Department of Defence has awarded BAE Systems Australia a five-year contract worth A$150 million for continued development, procurement and in-service support of Nulka active expendable decoys and launcher systems.

The new agreement consolidates development, acquisition and sustainment of the Nulka system into a single contract for both Australia and the United States. The contract provides for the delivery of Nulka systems to the Royal Australian Navy's (RAN's) next generation of surface platforms, including the nine new Hunter-class frigates.

The Mk 234 Nulka is a ship-launched rocket-propelled active offboard decoy system designed to seduce anti-ship cruise missiles away from their intended target. Originated by what is now Australia's Defence Science and Technology Group, the Nulka decoy combines a hovering rocket payload carrier vehicle (produced by BAE Systems Australia) atop which is mounted a US-supplied electronic payload designed to seduce radar-homing anti-ship missiles away from their intended targets.

Nulka was originally configured with a relatively simple broadband repeater payload. The US Navy's Nulka Advanced Decoy Architecture Project (ADAP) upgrade, developed by L3Harris (Clifton, NJ), has led to the deployment of an improved Nulka-X decoy in the US Navy as a Rapid Deployment Capability to address advanced anti-ship missile threats. A number of older RAN Nulka decoys are receiving the ADAP payload capability as a mid-life upgrade under SEA1397 Phase 5. *– R. Scott*

have created a unified governance structure for EMS capability governance, the DOD has divided the responsibility of EMS governance among various offices and commands, thereby limiting EMS policy action and spending capability.

- **Electromagnetic spectrum operations (EMSO):** While the US considers all operations within the electromagnetic spectrum as connected, the PLA and Russian Armed Forces have not released similar concepts, treating EW as separate from communications, sensing and spectrum management.

The report outlines four technology priorities emerging from these identified asymmetries, including: capabilities enabling the DOD to remove or prevent, rather than overcome, fundamental challenges; capabilities that undermine adversary advantages; capabilities that turn challenges into opportunities; and capabilities that exploit existing US strengths.

Each of these priorities, according to the report, are being pursued by the DOD in some capacity, especially in light of the latest EMSSS, but these priorities must be accelerated. "To reverse trends of the last three decades and give the PRC and Russia challenges to address, funding and attention will need to shift to these new priorities and away from legacy programs."

"DOD's choice is whether to accept continued erosion of its edge in the EMS or to make bold bets on the technologies most likely to circumvent or reverse the inherent advantages enjoyed by its great power competitors." *– H. Swedeen*

IN BRIEF

The **Reginald Victor Jones Institute** (www.rvjinstitute.org) officially opened its doors and began operations in February. Led by co-founder and Executive Director Melissa Tourangeau along with Dean and co-founder Doug Tourangeau, the Institute is the first non-profit think tank completely dedicated to Electromagnetic Spectrum Operations (EMSO) studies and research. It is built on three pillars: 1) developing an electronic EMS/EMSO knowledge repository; 2) providing a cadre of EMSO experts; and 3) conducting scholarly EMSO research and publishing articles that are borne out of an academic, conceptual framework for EMSO. The Institute is currently seeking to build its cadre of experts and encourages anyone with deep or specialized EMSO-related experience to reach out about joining them.

Naval Air Systems Command (Patuxent River, MD) announced that Air Test and Evaluation Squadron (VX) 20 successfully completed an airworthiness test of a prototype RF countermeasures pod on a P-8A Poseidon maritime patrol aircraft in March. The pod, adapted from the shell of an AGM-84 Harpoon anti-ship missile, houses a fiber-optic towed decoy (FOTD) dispenser that can deploy the ALE-55 FOTD. The work was funded under an Other Transaction Authority (OTA) contract awarded to ALE-55 contractor **BAE Systems** (Nashua, NH). The company announced in January that it had received a $4 million contract for the integration effort. Following the airworthiness test at the Naval Air Warfare Center Aircraft Division (NAWCAD) Atlantic Test Ranges on March 12, the pod was sent to Naval Air Weapons Station China Lake (China Lake, CA) for effectiveness testing. According to NAVAIR, "It will continue to be tested at a system level leading to platform integration through planned capability fielding phases."

BIRD Aerosystems (Herzliya, Israel) has received a new contract from the Czech Republic to provide additional AMPS-MV missile warning systems with the Missile Approach Confirmation Sensor (MACS) for Czech Air Force Mi-17 transport helicopter fleet. The AMPS-MV is based on Hensoldt's Missile Launch Detection System (MILDS) AAR-60. The MACS is a high PRF Doppler radar that cued by the AMPS and slews to the incoming missile to provide secondary verification, track its angle of arrival, velocity, distance and time to impact. The Czech Air Force has already procured a number of AMPS systems for its Mi-17 helicopters, including those deployed to NATO operations in Afghanistan. According to the company, "This contract comes after BIRD Aerosystems has conducted an overall upgrade to the Czech's existing AMPS systems earlier this year, which provided enhanced functionality to the MILDS UV detection sensors and the MCDU Mission computers."

Alliance Action: NATO C
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By Richard Scott

Electronic warfare (EW) – as both a science and a military art – has been an ever-present consideration for the NATO alliance in the 72 years since its establishment. During the Cold War, there was a realization within NATO that the control and exploitation of the electromagnetic spectrum (EMS) was a vital and potentially decisive enabler, be it supporting strategic intelligence collection, providing tactical situational awareness, penetrating Warsaw Pact defenses or improving platform survivability. Equally, there was an understanding that EW technologies and techniques could be applied to disrupt or deny adversaries the ability to use the EMS for their own advantage.

Accordingly, the Alliance invested substantial sums in doctrine, equipment, and training in the full expectation that any confrontation with Warsaw Pact forces would almost certainly be in a dynamic, dense and hostile electromagnetic environment.

However, the two decades following the end of the Cold War saw NATO's EW capabilities and doctrines steadily atrophy. The Alliance found itself increasingly engaged in crisis response, counter-insurgency efforts and peace support operations in which NATO forces enjoyed a significant technological advantage without facing adversaries that challenged its use of the EM environment. As a result, NATO's EW focus narrowed to concentrate on platform self-protection against specific and localized threats.

Yet all the while, the use of the EMS for sensing, communications, navigation, and targeting has become more important to NATO forces than ever before. Not only does access to the spectrum underpin virtually every kind of command, control, and communications, but it is also a prerequisite for sensing, precise navigation and timing, and enables the delivery of both kinetic and non-kinetic effects. Furthermore, collection and analysis of activity in the spectrum provides opportunities for information exploitation. In short, NATO's offensive battle networks, as well as its defensive battle networks, depend on its ability to access to the EM environment.

The last decade has seen a gradual awakening across the Alliance to the challenge posed by the emergence of increasingly muscular and assertive Russia. NATO has also found itself operating in a new operational realm – the "gray zone" – that sits in the blurred space between peace and war.

As a consequence, NATO is forced to confront a new set of operational realities – including potential challenges within the EMS – that are forcing its strategic thinking to evolve. So while the demand for spectrum access is increasing across the Alliance, so peer and near-peer adversaries have also developed their abilities to operate in, exploit and potentially deny NATO forces' access to the EMS.

According to Air Chief Marshal Sir Stuart Peach, RAF, Chairman of the Military Committee of NATO, the challenge facing the Alliance is to adapt to an increasingly complex and unpredictable security situation in which the EM environment is recognised as an increasingly important operational domain. "We need to understand the requirements better," he told the AOC's EMSO leadership discussion series in early March. "We need to understand the shortfalls, and how to work together to respond both across the boundaries together that sometimes we create ourselves."

Air Chief Marshal Peach continued: "I would argue [that] EW is evolving rapidly, and should be increasing once more in prominence as nations look to sustain and gain an edge through the next generation of technology.

"The fight for electromagnetic spectrum superiority has been going on for

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CLEMENS VASTERS

a long time. But the outcome of future operations will be decided by the protagonist who accomplishes this to decisive advantage."

Another fundamental change is that the commoditization and proliferation of micro-electronics technology means that all manner of adversaries – both state and non-state actors – now have access to capabilities that were once restricted to advanced militaries. "EW is no longer the exclusive province of wealthy nations," explained Air Chief Marshal Peach. "Smaller states [and] non-state actors can gain advantage within the electromagnetic environment with available components [which are] cheap, lower cost, and they're being integrated into military designs."

"Our potential opponents focus on EW," he continued. "It's low cost, it's asymmetric, it is a good way to dominate in an operational domain. And in the 21st century, I think that trend will continue in either offensive or defensive operations. And in many gray areas, such as hybrid strategies, this is probably even more prevalent than it ever has been."

Accordingly, freedom of action on the modern battlefield will require a degree of superiority in the electromagnetic spectrum to enable force commanders to gain advantage across the level of warfare. "In other words," said Air Chief Marshal Peach, "EMS empowers us to communicate with confidence, navigate with certainty, perceive an operational area the best we can, and then engage with accuracy."

In response to this changing landscape, Allied Command Transformation, as the NATO lead in NATO's Warfighting Development, has crafted an EMS Strategy that reflects a new era of operations in a contested and congested EM environment. The accent on the EMS – as opposed to just EW – is reflective of a more holistic approach to operations in the EM environment, and an acknowledgement that the EMS is a maneuver space in its own right.

NAILING THE CHALLENGE

NATO's Science & Technology Trends 2020-2040 report identifies the continued importance of the EMS to Alliance partners. It identifies the information domain – embracing cyber, EW and electromagnetic spectrum management – as a unique and evolving operational environment that is critical to operational success. At the same time, it is recognized that this is a domain where others are increasingly active.

The report's section on the importance of the EMS to big data and advanced analytics is instructive. Identifying control of the spectrum as "a necessary prerequisite to information dominance." It continues: "The future will bring, among other things, faster, more reliable wireless/radio communications, electronic warfare resilience, secure streaming video and smaller deployed footprint. As a result, the EM spectrum is and will continue to be increasingly congested as military and commercial systems vie for bandwidth.

"The use of AI to support cognitive sensors (e.g., cognitive radars) and communications, which adjust in an agile fashion to maximize collection and through-put, will become essential to avoid conflict in the congested (and perhaps contested) EM spectrum. This will be especially essential for operations in urban environments."

NATO's Science & Technology Trends 2020-2040 report also highlights the challenges to interoperability resulting from an increasing number of users fighting for access in an ever more crowded spectrum. Governments have recognized the growing civil demand and economic value of the EMS, and have come under increasing pressure from the commercial sector to open up portions of the spectrum previously restricted to military use: this is most apparent with the rollout of 5G, where the major networks are targeting bands that have hitherto been overwhelmingly, if not exclusively, used by the military.

Spectrum allocation thus presents a conundrum. While NATO's spectrum needs are growing – driven by the proliferation of battle networks, higher data rates, the increased exploitation of unmanned vehicles and sensor payloads – demand in the civil sector is also increasing, notably in the spectrum below 6 GHz. As a result, the process of assuring spectrum access in the traditional sense is becoming more complex owing to the growth of high-data-rate cellular networks, such as 5G.

Furthermore, 5G presents an additional and significant challenge in that it raises the noise floor within which RF sensors must operate. The adverse impact this has on detection ranges has already become apparent in both operations and exercises.

So, NATO must grasp a thorny problem. Realistic training for operations is essential to operational readiness, and anticipating and adapting to changes within the EM environment is essential for operational advantage and freedom of action. However, any peacetime constraint to spectrum access makes the mantra of "train as you fight" difficult to execute.

"Although EW has been used since the beginning of the 20th century, the congestion and dynamic environment of the EMS demands a new approach," Air Chief Marshal Peach told the AOC. "The more the world connects itself, the more scarce access across the electromagnetic spectrum becomes. The spectrum is bound by the laws of physics, so we can't just procure more. Which means we have to be careful about how we share available spectrum with an increasing number of users. It can continue to constrain our ability to train in these bands, and makes achieving our proficiency a challenge."

At the same time, adversaries and competitors are fielding capabilities that may challenge the Alliance's ability to use the spectrum as and when it requires. The last decade has seen Russia undertake a significant modernization of its EW capability: the impact of this investment has been best demonstrated in both eastern Ukraine and Syria.

NATO nations and partners also have first-hand experience of EW effects in their own "backyards." For example, in

November 2018 the Norwegian government identified Russia as the source of GPS jamming in the Kola Peninsula during NATO Exercise "Trident Juncture." In August 2017, cellular telephone networks in the west of Latvia were taken down. The Latvian government concluded that the disruption appeared to have originated during Russia's Zapad exercise.

While Russia has consistently denied responsibility for such actions, it is increasingly clear that operations in the information space – both EW and offensive cyber – offer the Kremlin a convenient and effective means to disrupt the military and government activities of its NATO neighbors. In an era of growing mistrust and increasing tensions, this ability to deny the spectrum is a key component of hybrid warfare writ large.

It is not just peer and near-peer threats that pose concerns. The proliferation of technology and knowledge means that less advanced adversaries may employ existing dual-use or commercial technologies in innovative and dynamic ways. There is a recognition that, given NATO's growing reliance on networks and sensors for operational advantage and speed of action, the EM environment is a space in which adversaries can seek an asymmetric advantage.

A Falcon 20 equipped with jamming pods provides EW training to NATO forces during Frisian Flag 2019. GERARD VAN DER SCHAAF

Thus it is critical that Alliance forces are equipped and trained such that they can operate, survive and prevail in environments where access to the spectrum may be degraded, or at times denied.

EMS STRATEGY

It is against this backdrop of an increasingly congested and contested spectrum that NATO has been developing its EMS Strategy with the aim of engineering increased coherence and synergy to its activities within and across the spectrum. At NATO Headquarters, the EMS Strategy is coordinated between the main stakeholders of the EMS; the C3 Board, the NATO Advisory Committee on Special Intelligence and the NATO Electronic Warfare Advisory Committee (NEWAC).

The EMS Strategy is aligned to, and builds on, NATO's Framework for Future Alliance Operations. This document, which informs and shapes both warfighting and warfare development, has identified the importance of maintaining freedom of action in the EMS, and the need for resilience in the face of adversary actions.

Throughout the post-Cold War era, there was a feeling by many in the EW community that NATO had lost sight of the importance that EMS has in its operations. Today, however, there is undoubtedly an increased awareness amongst NATO leadership of the criticality of the EMS. This in part reflects the direct operational experience of some military leaders now in the senior echelons of the Alliance, but is also a testament to a more deep-seated understanding of the universal importance of "spectrum-dependent systems."

According to NATO sources who spoke to *JED,* the EMS Strategy distils this intent into a more detailed framework that serves to articulate the criticality of operations in the EM environment, advocate for increased investment in EW and spectrum operations to redress current capability shortfalls, and pursue improvements across all lines of development (doctrine, organization, training, materiel, leadership, personnel, facilities and interoperability).

EW AGENDA

Top of NEWAC's agenda is finalizing Version 12 of NATO's EW policy: this seeks to simplify NATO's approach into a series of succinct policy statements that set out the Alliance's "route map" in four key areas:

- challenges in a contested and congested environment
- interoperability, data sharing, and command and control
- the coherent integration of the EMS Strategy and EW operations
- education and training

As part of work aligned with (and complementary to) the development of the EMS Strategy, NATO revised its Spectrum Management procedures and associated data format in April and May 2019 respectively, while it also revised and promulgated its EW doctrine in March 2020. Also, the strategy leverages and blends doctrines and policies previously developed by NATO members: the overriding aim is that while each partner may apply its own subtly different national strategy, all should follow a common vector.

Accordingly, the NATO allies are learning from one another to create an identifiable NATO route map. The US and the UK are heavily involved, bringing a rich library of lessons learned from their own process of policy and doctrine development in the EM environment and cyberspace.

One key part of this work is defining common terminology to ensure a single frame of reference across NATO. This is important not just to achieve alignment between partner nations, but to also agree a common taxonomy across the various communities of interest (such as EW, spectrum operations and SIGINT). Various corresponding NATO communities are heavily involved in this area, and *JED* understands that the process of defining a common terminology is advancing well.

SPECTRUM STRATEGY

After being endorsed by the NATO Military Committee, the EMS Strategy itself has now been approved by NATO's North Atlantic Council, signaling buy-in from NATO's political leadership, and is informing the NATO Defence Planning Process. Bringing together various strands of work undertaken within the Alliance, it promotes a coherent, harmonized and coordinated framework for activities in the spectrum. And the message is clear that it is an EMS Strategy – not an EW, radio frequency or spectrum management strategy.

One key output is the need for greater coordination in the use of the spectrum. The encroachment of the commercial/civil sector into what were previously reserved parts of the frequency spectrum demands that NATO thinks carefully, and acts appropriately, regarding spectrum sharing. There is an attendant imperative to develop agile, resilient and spectrally efficient planning methodologies and technologies to enable the spectrum to be accessed and exploited while minimizing regulatory spectrum risks and avoiding accidental disruption to civil users. In this vein, NATO's Science & Technology Office continues to explore new areas of EMS related research, such as full-duplex radio to increase spectral efficiency for military applications.

At a broader level, the EMS Strategy serves to underpin the ongoing modernization and reinvigoration of NATO's EW and EMS capabilities. This includes, among other things, introducing a new generation NATO Emitter Database, exploring alternatives to SATCOM and investigating the development of a deployable passive electronic support measures tracker for NATO air command and control. NATO has also canvassed industry to explore new technologies to improve situational awareness of the EM environment, to generate and share the electronic order of battle, and to enhance a commander's ability to plan, direct, monitor and assess EW activities.

NATO also continues to research, develop and test novel technologies and to trial new tactics, techniques and procedures. As an example, 13 nations participated in the NATO Electromagnetic Operations (NEMO) trials held off the south coast of England in late 2019. Sponsored by NATO's Above Water Warfare Capability Group, NEMO is an annual event for NATO partners to perform electronic warfare trials and data gathering. Over a six-day period, the NEMO 19 participants executed a series of trials to evaluate the effectiveness of a range of anti-ship missile defense (ASMD) countermeasures. Infrared and radar signatures were measured to reduce the susceptibility of ships to hostile radars and missiles, and tactical data exchanges between participating ships, as well as reversionary voice procedures, were put to the test.

TRAINING AND READINESS

One key area where NATO has prioritized investment is EW training and readiness. "We must greatly improve our proficiency in the electromagnetic spectrum…to ensure forces understand how to operate in a congested and contested environment," Air Chief Marshal Peach acknowledged in his AOC discussion. "We need to make exercise environments tough and challenging just like we did back in the Cold War, because when NATO deploys on operations we can

The USS Gridley, flagship of NATO's Standing Maritime Group 1, sails near Plymouth, United Kingdom during exercise NEMO 19. The Naval Electromagnetic Operations (NEMO) exercise, which included six ships, eight aircraft and 1,500 personnel from 13 countries, was NATO's largest maritime electronic warfare exercise.Gerard Van der Schaaf NATO

expect any enemy to disrupt our radars, GPS, communications and weapon systems. Therefore we must train realistically – we must experience these effects and practice how to counter them. In the next few years we are really focused on this."

NATO has already committed to a major recapitalization of its Joint Electronic Warfare Core Staff (JEWCS) equipment inventory. Based at RNAS Yeovilton in Somerset, England, NATO JEWCS is a multinational training and subject matter expert organization best known for providing "adversary" EW support to tactical and operational level training and exercises. Its wider portfolio includes support to current and future NATO operations; management, maintenance, and support of the NATO Emitter Database; the provision of the Allied Command Operations' core EW staff function and subject matter expertise; and the provision of support across all of NATO for the delivery of NATO EW policy, doctrine, concepts, and experimentation.

Deploying from its base at RNAS Yeovilton in Somerset, UK, JEWCS supports between 25 and 30 exercise events annually, comprising a mix of NATO, national and NATO EW Force Integration Programme exercises. In this role, the organization is tasked to exercise, train, and evaluate NATO forces in the disciplines of electronic surveillance, electronic countermeasures, and electronic protection measures in both the radar and communications domains across the air, land and maritime environments.

Much of NATO JEWCS current equipment inventory is technically obsolete, and increasingly difficult to support (reflecting its early 1980s origins with the erstwhile NATO Multi-Service Electronic Warfare Support Group). To address this, an industry team led by Leonardo was, in December 2018, awarded a contract worth approximately €180 million to deliver a capability package comprising airborne pods, land/maritime EW cabins, and "smart" pods to realize a new NATO Anti-Ship Missile Defence Evaluation Facility (NASMDEF). NASMDEF will provide a capability to assess the effectiveness of soft-kill decoys for ASMD.

The NATO JEWCS Capability Package will roll out over the next three years. In parallel with its introduction, NATO is working to identify where gaps exist in the EW training and education process. The Alliance is also working to incorporate EW in all exercise as a means to strengthen interoperability across all allies and partners.

WAY AHEAD

There is significant activity ongoing within NATO to develop and improve its capability to act in the EM environment. "NATO understands the opportunities, challenges and threats faced by the resurgence of EW and the dynamic element of the electromagnetic environment," Air Chief Marshal Peach told the AOC audience. "We must re-set to make EW in NATO a higher priority. We must improve our edge in the EMS. We must improve… the situational and institutional awareness across the leadership of realistic training, realistic exercises, realistic scenarios to support the strategies we're building."

Above all, the need to enshrine interoperability remains paramount. "That's the way forward from our perspective for EW," he explained. "Putting our resources and all of our efforts into interoperability pays dividends for us all. An interoperable NATO is greater than the sum of its parts."

FEATURED LIVE COURSES

Advanced Principles of Electronic Warfare

Dave Adamy

Mondays & Wednesdays
1:00 – 4:00 PM ET | May 3 – 26, 2021
This Advanced Electronic Warfare course has eight three hour sessions. It is designed for individuals who have completed a fundamental EW course or have significant experience in the field.

Aircraft Radar Cross Section Engineering

Renan Richter

Mondays, Wednesdays & Fridays
1:00 – 4:00 PM ET | July 12 – 30, 2021
This course introduces students to Radar Cross Section (RCS) engineering and its basics fundamentals inside the modern EW context. Stealth technology will be addressed by presenting current challenges and future perspectives.

Introduction to Satellite Communications (Satcom)

Dr. Patrick Ford

Mondays, Wednesdays & Fridays
1:00 – 5:00 PM ET | December 6 – 10, 2021
This course will cover the core material required for participants to understand and discuss basic Satcom theory and operations.

C4ISR Requirements, Principles, and Systems

Dr. Clayton Stewart

Mondays & Wednesdays
1:00 – 4:00 PM ET | June 7 – 30, 2021
This 24 hour web based course delivers a thorough overview promoting an understanding and building a successful Command, Control, Communications, Computers, Intelligence, Surveillance, Reconnaissance (C4ISR) architecture.

Direct Energy Weapons

Kyle Davidson

Mondays & Wednesdays
1:00 – 4:00 PM ET | August 2 – 18, 2021
This course introduces students to the fundamentals of Direct Energy Weapons (DEW) across the electromagnetic spectrum. The goal is to provide an understanding of the operation of laser and high-power microwave DEWs in military applications, including their design trade-offs, and target effects.

= Web Course, no travel required!

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TECHNOLOGY SURVEY
A SAMPLING OF COUNTER-UAS SYSTEMS

By John Knowles and Hope Swedeen

The counter-UAS system market continues to grow and evolve – its staying power ensured by the growth and evolution of small unmanned aerial systems (UASs) themselves. If anyone ever held the notion that the small UAS threat is merely a fleeting novelty, that idea has by now fully given way to the recognition that drones are a pervasive, long-term reality. The small UAS threat reaches across civilian applications, such as protecting industrial facilities; public safety applications, such as sporting events, festivals and concerts; and military applications ranging from special forces missions to base security to air and missile defense. Evolving in parallel with the drone threat is the counter-UAS market, which is offering increasingly specialized solutions to meet this growing set of needs and requirements.

This month's survey reflects the dynamic nature of the counter-UAS market. In our previous survey, from May 2019, all of the counter-UAS systems were designed for terrestrial fixed-site operation or ground vehicles. This month's survey includes soldier-worn threat warning systems, as well as an airborne HPM-based solution to counter UAS swarms. And these systems are offered with varying functionality. Some solutions only provide drone detection using a single sensor mode, such as an RF receiver. Others provide a full suite of multispectral sensors (ESM, radar, acoustic, EO/IR, etc.), a command and control system and a multispectral countermeasures suite (RF jamming, taking over the drone C2 link, GPS jamming, HPM or high energy laser, etc.). As users develop a better understanding of their counter-UAS requirements, industry is broadening its solutions accordingly.

THE SURVEY

In the survey table, the first column lists the Counter-UAS model name. The next columns list the system's detection sensors and tracking sensors. (Sensor range, if provided, is listed in the "Features" column.) The "DF" column indicates if the system provides a direction finding capability. In many applications, direction finding is useful for locating and tracking the drone via its datalink and for geolocating the drone operator via the command and control signal.

The "C2" column indicates if the counter-UAS system features a command and control capability with a workstation or other type of user interface. Many counter-UAS systems offer a software suite that can be hosted on a tablet or laptop computer, and some provide C2 functionality. The next few columns cover the systems' countermeasures performance characteristics, such as techniques, range and operating frequencies. The remaining columns list the systems' configuration, size and weight.

Next month, *JED*'s technology survey will focus on airborne EW self-protection suites.

COUNTER-UAS SYSTEMS

MODEL	DETECTION SENSORS	TARGET TRACKING SENSORS	DF SYSTEM	C2 SYSTEM	COUNTERMEASURES	ECM RANGE
Allen-Vanguard; Ottawa, Ontario, Canada; +1 613-739-9646; www.allenvanguard.com						
ANCILE	*	*	Yes	Yes	Command link and GPS/ GNSS jamming	*
SCOPRION CUAS	*	*	*	N/A	Command link and GPS/ GNSS jamming	*
ApolloShield; New York City, NY, USA / Tel Aviv, Israel; +1 888-474-5646; www.apolloshield.com						
RF Gun and Backpack Series - Man-portable drone protection	RF detection	Optional DF	Optional (manual)	Man-portable operation using LEDs and buttons	Command link control jamming, GPS/GNSS jamming	Up to 1 km
ASELSAN; Ankara, Turkey; 90 (312) 592 10 00; aselsan.com.tr						
iHASAVAR	*	*	*	*	Spot, sweep, barrage, multi-frequency TDM	*
MiRKET	ESM	*	*	*	*	*
CACI International, Inc.; Alexandira, VA, USA; +1 703-707-2509; www.caci.com						
SkyTracker® CORIAN™ Family	ESM	ESM	Yes	Yes	RF barrage jamming; C2 link; GPS/GNSS jamming	10 km
X-MADIS	Radar	Radar, EO/IR (opt.)	*	Yes	RF barrage jamming; C2 link; GPS/GNSS jamming (opt.)	*
CerbAir; Boulogne-Billancourt, France; +33 9 72 62 58 58; www.cerbair.com						
CerbAir Stationary Unit	DW-RF-01 RF detector; DW-OP-01 EO sensor	*	*	Yes	RF jamming, control link disruption, GNSS jamming	Up to 1 km
D-Fend Solutions, Ltd; Ra'anana, Israel; sales@d-fendsolutions.com; www.d-fendsolutions.com						
EnforceAir ™	Passive comm	Comm	*	Part of the product, optional API	Cyber /Communication	Up to 2 mi
Dedrone; San Francisco, CA, USA; +1 (415) 813-6116; www.dedrone.com						
Drone Defender	*	*	*	*	RF jamming, control link disruption, GNSS jamming	2 km
RF 360	RF detector	*	*	*	*	*
Department 13; Columbia, MD, USA; +1 (410) 497-6616; www.department13.com						
MESMER	RF detector	*	*	*	RF control link protocol manipulation	*
Diehl Defence GmbH; Überlingen, Germany; +49 7551 89-01; http://drohnenabwehr.de						
Guardion	ESM	ESM	Yes	TARANIS	RF jcontrol link jammer, Wi-Fi disruptor; GNSS jamming, HPEM	*

JAMMING FREQ./BANDS	PLATFORM	SIZE (in.)	WEIGHT (in lb/kg)	FEATURES
*	Grd-fix; grd-mob. man transportable	2 cases: 48 x 48 x 40 cm and 64 x 48 x 44 cm	Quick deploy config (2 cases): 12 kg, 38 kg	Operationally proven at major global events. Delivers a robust hemispherical (360/180) dome of protection against a multi-directional drone attack. Government formal competitive test results available.
*	manpack	40 x 35 x 15 cm	7 kg	Condensed capability that delivers a manportable, robust hemispherical (360/180) dome of protection against a multi-directional drone attacks.
*	Man-portable	Config dep. 85 x 26 x 12 cm to 45 x 56 x 27 cm	Config dep. 5-18 kg	Various man-portable models available: With or without detection; With or without a backpack for longer-lasting higher power defeat; Variable frequency bands covered; Various antenna form factors: Rifle shape or panel (stop sign) shape.
400 MHz-6 GHz	Fixed; vehicle mounted; manpack/ man-portable	*	*	Software-defined jammer; programmable 100 preset jamming modes; dynamic notch filters for friendly comms; 60W RF output power; highgain directional antenna and 1.5 hours of operation from Li-Ion batteries for manpack configuration
20 MHz - 6 GHz	Fixed; manpack/ man-portable	130 x 70 x 30 mm (without battery and phone)	500 g (without battery and phone)	MiRKET comes with a ruggedized phone or a tablet for controlling and monitoring the frequency spectrum. It can be integrated with anti-drone jammer systems.
20 MHz - 6.1 GHz	Fixed; mobile; dismounted	*	*	Available in fixed (CORIAN-FS), mobie (CORIAN-M) and dismounted (CORIAN-D) versions. Size and weight vary accordingly.
20 MHz - 6 GHz	Grd-fix; grd-mobile	*	*	Manufactured by Ascent Vision Technologies (AVT), a CACI subsidiary; Counter UAS Operator Assist (CUAS-OA) software.
432-436 MHz; 900-1170 MHz; 1171-1380 MHz; 1570-1620 MHz; 2400-2500 MHz; 5-5.4 GHz; 5.4-5.9 GHz	Grd-fix	*	*	Uses Hydra RF detection technology; also available in convoy protection, individual ground vehicle, and man-pack (Chimera) configurations.
*	Grd-fix, grd-mob	SDR Sensor: 17 x 17 x 5 in. / 44 x 43 x 12 cm Antenna Radom: Height: 9 in. / 23 cm, Ø: 18 in. / 46 cm	Total: 104 lb / 47.2 kg	Passive detection, IFF, non-jamming, non-kinetic, full take-over and safe landing.
C2 and GPS	man-portable	*	6.8 kg	Battery power runs up to 2 hrs. continuously;
*	grd-fix	12 x 12 x 15.96 in.	15.5 lb	
Wi-Fi	Grd-portable	19-in. 6 RU	*	
*	*	*	grd-fix	Partnership between ESG (TARANIS C2 system), Rohde and Schwarz (ARDRONIS ESM and jamming and WiFi disconnect); and Diehl (HPEM); radar and EO sensors, such as Hensoldt's Spexer 2000 rdar and OWL M EO/IR cameras, optional

COUNTER-UAS SYSTEMS

MODEL	DETECTION SENSORS	TARGET TRACKING SENSORS	DF SYSTEM	C2 SYSTEM	COUNTERMEASURES	ECM RANGE
DroneShield; Warrenton, VA, USA/Sydney, Australia; +1 540-215-8383; www.droneshield.com						
DroneSentry	RF, radar, EO/IR, acoustic	RF, radar, EO/IR	Yes	Yes	RF barrage jamming, C2, video links, GNSS	2 km
DroneGun MKIII	*	*	*	*	RF barrage jamming, C2, video links, GNSS	1 km
DroneSentry-X	RF	RF	*	Yes	RF barrage jamming, C2, video links, GNSS	*
Elbit Systems EW and SIGINT - Elisra; Holon, Israel; +972-77-293-9798; www.elbitsystems.com						
ReDrone	DF, geolocation, radar, EO/IR, acoustic	DF; geolocation; radar; EO/IR; acoustic	DF of drone and operator	Map-based display	Command link jamming GPS/GNSS jamming	3000 m (min)
ELETTRONICA Group - ELT GmbH; Meckenheim, Germany; +49 2225 88060; https://www.elettronica.de						
MUROS-S (c-UAS configuration)	Radar 2D FMCW, RF Interceptor	Radar 3D FMCW, EO/IR Tracking Unit, Low-end RF Direction Finder	Yes	Yes	*	*
ELETTRONICA Group - ELT Roma; Rome, Italy; +39 06 41541; www.elt-roma.com						
ADRIAN	Radar (2D and 3D) EO/IR, acoustic, ESM, DF	Radar (2D and 3D) EO/IR, acoustic, ESM, DF	Yes	Yes	RF jamming, cyber attack to take control of a drone's command link, GPS/GNSS jamming, GPS spoofing	300 m - 2.5 km
H.P. Marketing & Consulting Wuest GmbH; Reinfeld, Germany;+49 4533 7011-0; www.hp-jammer.de						
HP 47	*	*	*	*	Jammer Dronegun	*
HP 3055T	*	*	*	*	Modular Rack Jammer	*
HP 3962 H	*	*	*	*	Trolley Case Jammer	*
HENSOLDT Holding Germany GmbH; Taufkirchen, Germany; +49.89.51518-0; www.hensoldt.net						
XPELLER Family	Radar; EO/IR; ESM	Radar; EO/IR; ESM	Sector, LOB or Positon	Yes	RF/GNSS jamming, Hunter drone	up to 9 km
IAI ELTA Systems Ltd.; Ashdod, Israel; +972-8-857-2312; www.elta-iai.com						
Drone Guard	Radar, COMINT (DF, geolocation), EO/IR, Acoustic, IFF, ADS-B	Radar, COMINT (DF, geolocation), EO/IR, Acoustic, IFF, ADS-B	Yes, for drones and operators	Yes	RF jamming, GNSS jamming, TakeOver, Drone-kill-Drone, Smart Sight on rifle, RCWS, Laser	Up to 10km
Drone Guard COMJAM	RF/COMINT (DF, Geolocation)	RF/COMINT (DF, Geolocation)	Yes, for drones and operators	Yes	RF jamming, GNSS jamming	Up to 10km
Kirintec Ltd; Ross-on-Wye, Herefordshire, UK; +44 (0) 1989 568350; www.kirintec.com						
Sky Net Longbow+	*	*	*	K- Net Mesh Network	RF Jamming of control, video and GPS links	*
Sky Net Recurve Max+	*	*	*	K- Net Mesh Network	RF Jamming of control, video and GPS links	*
L3Harris; Fleet, Hampshire, UK; +44 (0) 1252 775700; www.l-3asa.com / www.l3-droneguardian.com						
L3 Drone Guardian™	Radars, EO/IR, acoustic, ESM (RF TDOA), and DF	Radars, EO/IR, acoustic, ESM (RF TDOA), and DF	Yes	Yes	RF barrage jamming of drone contol links, GPS and GLONASS	*

JAMMING FREQ./BANDS	PLATFORM	SIZE (in.)	WEIGHT (in lb/kg)	FEATURES
*	Grd-fix, grd-mob	*	*	Modular, multi-sensor solution to detect, track, classify and defeat; sensor agnostic DroneSentry-C2 incorporates AI/ML and multi-sensor fusion.
C2, video and GNSS frequencies	Man-portable, grd-mob	24 x 15 x 8 in.	4.5 lb	Tactical, low SWaP handheld (pistol form factor) countermeasure.
C2, video and GNSS frequencies	Air, grd-fix, grd-mob, ship	24.9 x 24.9 x 9.1 in.	56 lb	Mounted detect, identify, classify and defeat solution; AI/ML detection; can operate standalone or interoperable with third-party C2 systems.
Frequency bands: 400/900 MHz, 2.4 GHz, 5.8 GHz, GPS & GLONASS L1	Grd-fix, grd-mob, man-portable	*	37 kg	Acoustic sensors for perimeter sensing and alert.; open architecture for additional sensors or attacking systems; swarm handling; high efficiency in urban areas.
*	Grd-fix, grd-mob	Config. dep.	Config. dep.	Detect, track and characterize multiple drones from different directions; automatic or manual operation; open and scalable configuration; algorithms for target characterization.
400 MHz, 900 MHz, 2.4 GHz, 5.8 GHz, GFSK/OFDM/FH/DSSS	Grd-fix, grd-mob, ship	Config. dep.	Config. dep.	Detect, track and defeat multiple drones from different directions; take control of most commercial drones; automatic or manual operation; open and scalable configuration.
Customizable	Man portable	*	7,5 kg	All in one piece, no backpack needed.
Customizable	Fixed or vehicular	19-in. rack	*	Open interface, directinal and omnidirectional jamming possible.
Customizable	Man portable (Trolley)	Customized	*	Mobile Version.
500 MHz - 6 GHz, GNSS	manpack (Gear); grd-mob (Rapid); grd-fix (Guard);	*	manpack starting from 22 kg; grd-mob & grd-fix starting from 60 kg	Modular counter-UAV solution to address individual user groups (civil and military) requirements in regards to mobility, range, counter-measures.; available as stand-alone system and/or as part of a larger security system; ITAR free.
100 MHz - 6 GHz	Grd-fix, grd-mob, man-portable	Config. dep.	Config. dep.	Artificial intelligence, data correlation, threats evaluation, aoutomatic procedures.
100 MHz to 6 GHz	Grd-fix, grd-mob, man-portable	Config. dep.	Config. dep.	Affordable anti-drone system based on advanced RF-detection sensors and jamming capabilities.
20 MHz - 6GHz	Grd-fix, grd-mob	10 (H) x 20 (W) x 17 (D) in.	41 kg	Fully and rapidly programmable 500-W system covering all known and likely future threats; completely sensor agnostic.
20 MHz - 6GHz	Man portable	18 (H) x 12 (W) x 11 (D) in.	22.6 kg	Fully and rapidly programmable 90-W system covering all known and likely future threats; optional Handheld Antenna System (HAS).
20 MHz - 6 GHz	Grd-fix, grd-mob	Config. dep.	Config. dep.	Multiple sensor types resulting in a high probability of detection, accurate tracking and false alarm filtering; simplified C2 GUI and alerting system with integration to PSIM and jammers.

COUNTER-UAS SYSTEMS

MODEL	DETECTION SENSORS	TARGET TRACKING SENSORS	DF SYSTEM	C2 SYSTEM	COUNTERMEASURES	ECM RANGE
Leonardo; Rome (Via Tiburtina), Italy; +39 06 41501; www.leonardocompany.com/en/home						
CON-DR	RADAR 3D multi mission, RF detector & DF, EO/IR	RADAR 3D multi mission, RF detector & DF, EO/IR	Yes	Yes	RF barrage jamming, RF selective jamming, GPS/ GNSS jamming, GPS spoofing	Up to 2km
Leonardo; Southampton, UK; +44 23 8051 4100; www.leonardocompany.com/en/home						
Falcon Shield	Radar, ESM	EO/IR	*	Yes	Video, command and GNSS links	4km
Lockheed Martin; Bethesda, MD, USA; 607-751-3199; www.lockheedmartin.com						
ICARUS	ESM	EO, acoustic	*	*	RF barrage jamming, control link	*
Mobile Radio Frequency-Integrated UAS Suppressor (MoRFIUS)	RF detection	*	*	*	HPEM	*
METIS Aerospace Ltd; Lincoln, Lincolnshire, United Kingdom; +44 1522 963125; www.metisaerospace.com						
SKYPERION Rugged/Lightweight	ESM (400 MHz - 6 GHz)	ESM	Yes	Yes	*	*
SKYPERION Marine	ESM (400 MHz - 6 GHz)	ESM	Yes	Yes	*	*
SKYPERION Vehicle	ESM (400 MHz - 6 GHz)	ESM	Yes	Yes	*	*
Netline Communications Technologies; Tel Aviv, Israel; +972-3-6068100; www.netlinetech.com						
C-Guard DroneNet Family	ESM (400MHz, 900MHz, 2.4GHz and 5.8GHz)	ESM	Yes	*	RF jamming of ISM bands (C2 link) and GPS	*
Patria; Tampere, Finland; +358 20 4691; www.patria.fi						
Multistatic Coherent Location (MUSCL)	ESM (passive radar)	ESM	Yes	*	*	*
PLATH AG; Bern, Switzerland; +41 31 311 64 46; www.plath-ag.ch						
Eagle Eye 540	RF, radar, EO/IR	Radar, EO/IR	Yes	Yes	Jamming C2 link; GPS/GNSS	Up to 8 km (field-tested)
Eagle Eye 360	RF, EO/IR	EO/IR	Yes	Yes	Jamming C2 link; GPS/GNSS	Up to 8 km (field-tested)
Rafael Advanced Defense Systems Ltd; Haifa, Israel; +972-50-403-9954, www.rafael.co.il						
Drone Dome	Radar, EO/IR, ESM, DF	Radar, EO/IR, ESM, DF	Yes	Yes	RF jamming, control link disruption, GNSS jamming	3-5 km
Rohde & Schwarz; Munich, Germany; +49 89 4129-0; www.rohde-schwarz.com						
ARDRONIS Direction	ESM receiver 20 MHz to 6 GHz	DF	Yes	*	*	*
ARDRONIS Disruption	ESM receiver 20 MHz to 6 GHz	*	*	*	RF smart follower/sweep jammer	*

JAMMING FREQ./BANDS	PLATFORM	SIZE (in.)	WEIGHT (in lb/kg)	FEATURES
*	Grd-fix, grd-mob	Config. dep	Config. dep	Open and modular C-UAS system supporting multi-domain applications; GBAD full interoperabilit; already supporting future effectors (L-DEW, HPEMP, etc.).
*	Grd-fix, grd-mob	*	Config. dep	Low collateral "RF sniper rifle" Electronic Attack capability provides focused and long-range electronic defeat of video, command and GNSS links, either individually or combined.
*	Grd-fix, grd-mob	*	*	
*	Area-I Altius-600 UAS	1.02 (L) x 2.54 (wingpspan) meters (air vehicle)	*	UAS-based high-power electromagnetic (HPEM) countermeasure designed to defeat single or multiple UAVs.
*	Grd-fix	Config. dep.	74Kg (Rugged) 49Kg (Lightweight)	Sensor outputs through a generic workstation and GUI, or can be distributed via a mesh network, copper or fibre link, and integrated into third party C2; sensor agnostic.
*	Ship	Radome: 1000 mm (Dia) x 1200 mm	50 kg	
*	Grd-mob	Sensor Processor: 500 x 330 x 360 mm	70 kg	
20 MHz - 6 GHz	Grd-fix, grd-mob; manpack	Config. dep.	Config. dep.	DroneNet family available in four variants: Manpack, Rapid Deplylorment; Vehicle; fixed installation.
*	Grd-mob	*	*	Passive radar that exploits external broadcasting signals as illuminators of opportunity to detect and locate UAVs and other aircraft.
30–500 MHz; 500–2500 MHz; 2500–6000 MHz	Grd-fix, transportable	*	345 kg	Capable of simultaneous jamming in the different bands with up to 6 channels of up to 80 MHz bandwidth.
30–500 MHz; 500–2500 MHz; 2500–6000 MHz	Grd-fix, transportable	*	230 kg	Capable of simultaneous jamming in the different bands with up to 6 channels of up to 80 MHz bandwidth.
433-470 MHz; 800 MHz – 2.5 GHz; 5.1-5.8 GHz; GNSS (L1, L2, L5)	Grd-fix, grd-mob	Cong. dep	Config. dep	Sensors: Radar – RPS-42/RPS-82 (Active Electronically Scanned Array (AESA) S-Band Doppler Radar); EO/IR – SPEED-ER/SIGHT-HD (EO, IR-MWIR, SWIR - Option); ESM based on DTOA method.
*	Grd-fix, grd-mob	176 × 426 × 450 mm	18 kg	Control center software included; open interface for integration available; passive detection and localization of pilot and drones; support of variety of drones from different manufacturers with hopping/fix links.
20 MHz - 6 GHz; config. dep.	Grd-fix, grd-mob	229 × 426 × 450 mm	20 kg	Highly effective jamming mode allows omni jamming; disrupts selected drones with no/minimal effects on other signals; GNSS jamming and WiFi disruption available as option.

COUNTER-UAS SYSTEMS

MODEL	DETECTION SENSORS	TARGET TRACKING SENSORS	DF SYSTEM	C2 SYSTEM	COUNTERMEASURES	ECM RANGE
Samel-90; Samokov, Bulgaria; +359 68201, www.samel90.com						
SADS-V / SADS-P	ESM/DF	Yes	Yes	Yes	C2 link, GNSS	6 km
SESP; Paris, France; +33 (1) 73 04 91 17; www.sesp.com						
Drone Defeater	*	*	*	*	RF control link jamming; GNSS jamming	*
SRC, Inc.; North Syracuse, New York, USA; 315-452-8000; www.srcinc.com						
Silent Archer® Counter-UAS Technology	Radar, ESM and DF	Radar, ESM and DF	Yes	Yes	C2 link, GNSS	*
Systems & Processes Engineering Corporation; Austin, Texas, USA; +1 512-479-7732; www.spec.com						
ADEP Blade	Radar	Radar	*	Yes	RF barrage jamming, C2 link manipulation, GPS/GNSS jamming	*
TCI International; Fremont, CA, USA; +1 510-687-6100; www.tcibr.com						
TCI Drone Detection Systems	ESM, DF	ESM, DF	Yes	Yes	*	*
Thales Air Systems; Paris, France: +33 (0) 1 79 61 40 00; www.thalesgroup.com						
EagleSHIELD	Radar, ESM	Radar, ESM, EO/IR	*	Yes	RF jamming	*

JAMMING FREQ./BANDS	PLATFORM	SIZE (in.)	WEIGHT (in lb/kg)	FEATURES
433 MHz, 800 MHz, 900 MHz, all GNSS bands, 2400-2500 MHz, 5100-5900 MHz (all bands are tunable)	Grd-mob; man-portable	Two Peli 1560 briefcases (56 x 46 x 27 cm)	< 35 kg	Detection in 360° at distances up to 8 km; SADS-V: vehicle installation in any vehicle platform; SADS-P: portable system for field.
*	*	*	grd-mob	
*	Grd-fix; grd-mob; grd-unattended; UAS; air launched effects	Config. dep.	Config. dep.	Sensor options include: AN/TPQ-50 with LSTAR® air surveillance software; Precision Fire Control Radar (PFCR); SkyChaser® on-the-move radar; Gryphon R1410 multi-mission radar; and Whisper Hunter™ DF unit.
20 MHz to 2.5 GHz, optional to 3.6 GHz	Grd-fix, grd-mob, man-portable	5 x 7.9 x .89 in.	< 2 lb	Full remote control and very low power requirements; backpackable comms jammer and low frequency radar DRFM.
*	Grd-fix, grd-mob, man-portable	grd-fix: 126 x 95 x 23 in.; grd-fix: 47 x 26 x 30 in.; grd-portable: 14 x 18 x 14 in.	grd-fix: 210 lb; grd-portable: 46 lb; antenna: 29 lb	Key Features: 20MHz to 8GHz coverage; multiple stations can be networked together to expand coverage; automatically detects drones and their radio controllers; geolocates and tracks the drone and/or controller.
*	*	*	grd-fix	Gamekeeper holographic radar, detection out to 7km; options for kinetic and directed energy countermeasures

SURVEY KEY: IED JAMMERS AND COMMUNICATIONS JAMMERS

MODEL
Product name or model number

DETECTION SENSORS
Indicates sensors types and models used to detect and acquire the target UAS
- ESM = electronic support measures

TARGET TRACKING SENSORS
Indicates sensor types and models used to track the target UAS

DF SYSTEM
Indicates if a direction finding (DF) system is used to determine the direction of the drone and/or the drone operator.

C2 SYSTEM
Indicates if the system provides a command and control system to manage tracking sensors and countermeasures.

COUNTERMEASURES
Indicates the type of countermeasures and/or the countermeasures techniques the system employs to defeat the target drone.
- HPEM = high power electromagnetic payload

COUNTERMEASURES RANGE
Indicates the typical effective range of the Counter UAS system's countermeasures

JAMMING FREQUENCIES
Indicates the system's jamming frequencies in MHz or GHz

PLATFORM
air = airborne
grd-fix = fixed ground installation
grd-mob = ground mobile vehicle
shp = ship based

SIZE
H x W x L/D in inches, millimeters or centimeters

WEIGHT
Indicates system weight in pounds (lb) or kilograms (kg)

FEATURES
Additional features

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

JUNE 2021 PRODUCT SURVEY: AIRBORNE EW SELF-PROTECTION SUITES

JED's next survey will cover integrated EW self-protection suites for aircraft. Please e-mail JEDEditor@naylor.com to request survey materials.

5G communication – Part 2

Millimeter-Wave Propagation

By Dave Adamy

Since an important feature of 5G is the expansion into the millimeter wave (mmW) portion of the Electromagnetic Spectrum (EMS), we will look at the nature of mmW propagation, focusing on the advantages and challenges associated with this frequency range.

The mmW frequency range is defined as 30 to 300 GHz, which includes signals with a wavelength from 10 millimeters to 1 millimeter, however it is often characterized in literature as extending down to about 20 GHz.

The propagation losses described here are from line-of-sight propagation attenuation, atmospheric loss, rain or fog attenuation, and loss from passage through foliage. In each, several cases are run to include a UHF signal, a microwave signal and two of the signal frequencies used for 5G propagation. You will note that the losses from the various causes are significantly higher in the mmW region than at lower frequencies.

RANGE LOSS

Because of the high frequencies of mmW signals, the propagation loss is line of sight. This loss is also called the spreading loss, because it is the ratio between the signal energy captured by the effective area of an isotropic receiving antenna and the total energy transmitted (in all directions) from an isotropic transmit antenna.

The formula for this loss between these two antennas with clear line of sight is:

$$\text{Loss} = 32.44 + 20 \log(d) + 20 \log(F)$$

Where: the distance between the two transmitting and receiving antennas in km is *d,* and the frequency of propagation in MHz is *F*.

Figure 1 is a nomograph from which the loss in dB is given by the crossing point of a line between the frequency in MHz and the distance in km.

Table 1 shows the loss at representative frequencies.

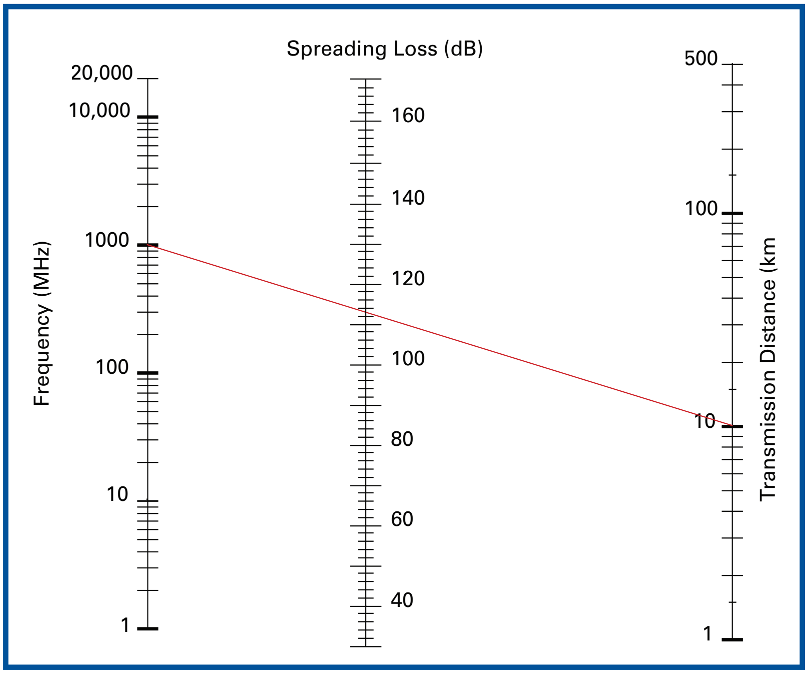

Fig. 1: This nomograph shows the spreading loss between two isotropic antennas vs. frequency and transmission distance.

Table 1: *Spreading Loss*

Frequency	Specific Loss	Loss at 25 km range
700 MHz	89.34 dB/km	117.30 dB
3.5 GHz	103.32 dB/km	131.28 dB
28 GHz	121.38 dB/km	149.34 dB
60 GHz	128.00dB/km	155.96 dB

ATMOSPHERIC LOSS

Figure 2 shows the atmospheric attenuation for standard air, for water vapor and for completely dry air. Note the spike in attenuation at 22 GHz for water vapor, and spikes for oxygen at 60 GHz and 180 GHz. **Table 2** lists the atmospheric loss per kilometer for representative frequencies and the losses at 25 km range.

Table 2: *Atmospheric Attenuation*

Frequency	Specific Loss	Loss at 25 km range
700 MHz	.005 dB/km	0.1 dB
3.5 GHz	.008 dB/km	0.2 dB
28 GHz	.1 dB/km	2.5 dB
60 GHz	3 dB/km	75 dB

RAIN AND FOG LOSS

Figure 3 shows the loss per kilometer vs. frequency for various levels of rain fall and for various fog densities. **Tables 3** and **4** show the loss per kilometer and the loss at 25 km for representative frequencies.

***Table 3**: Heavy Rain Attenuation (16 mm/hr)*

Frequency	Specific Loss	Loss at 25 km range
700 MHz	negligible	negligible
3.5 GHz	negligible	negligible
28 GHz	2.7 dB/km	67.5 dB
60 GHz	7.2 dB/km	180 dB

***Table 4:** Heavy Fog (visibility 30 meters)*

Frequency	Specific Loss	Loss at 25 km range
700 MHz	negligible	negligible
3.5 GHz	0.015 dB/km	0.375 dB
28 GHz	2.7 dB/km	20 dB
60 GHz	7.2 dB/km	100 dB

FOLIAGE LOSS

The loss as a mmW signal passes through foliage is:

$$L = 0.2\, F^{0.3}\, R^{0.6}\, \text{dB}$$

Where: *F* is frequency in MHz, and
R is depth of foliage in meters.

This formula is valid for 200 MHz to 95 GHz. Examples for passage through 10 meters of foliage are:

***Table 5:** Loss for transmission through 10 meters of foliage*

Frequency	Attenuation
700 MHz	5.7 dB
3.5 GHz	9.2 dB
28 GHz	17.2 dB
60 GHz	21.6 dB

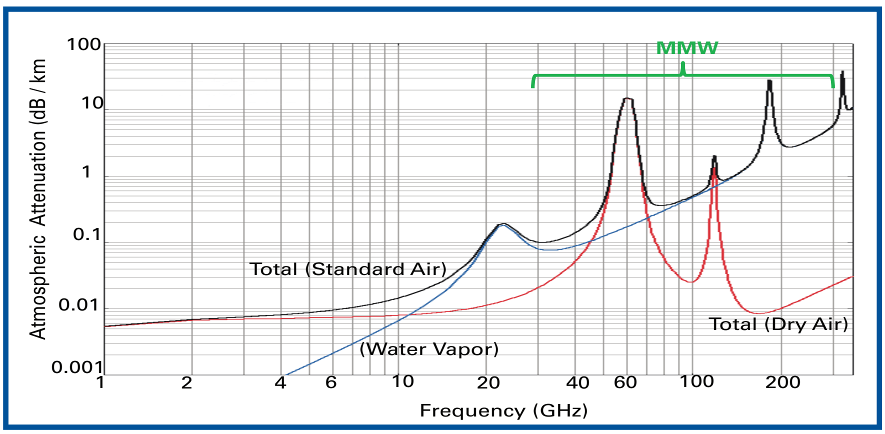

***Fig. 2:** The attenuation per kilometer caused by passage of a signal through the atmosphere is very low at low frequencies, but it can be significant at millimeter wave frequencies.*

WHAT'S NEXT

Next month, we will continue our 5G discussion with consideration of the performance of narrow-beam phased array antennas at 5G frequencies. For your comments and suggestions, Dave Adamy can be reached at dave@lynxpub.com.

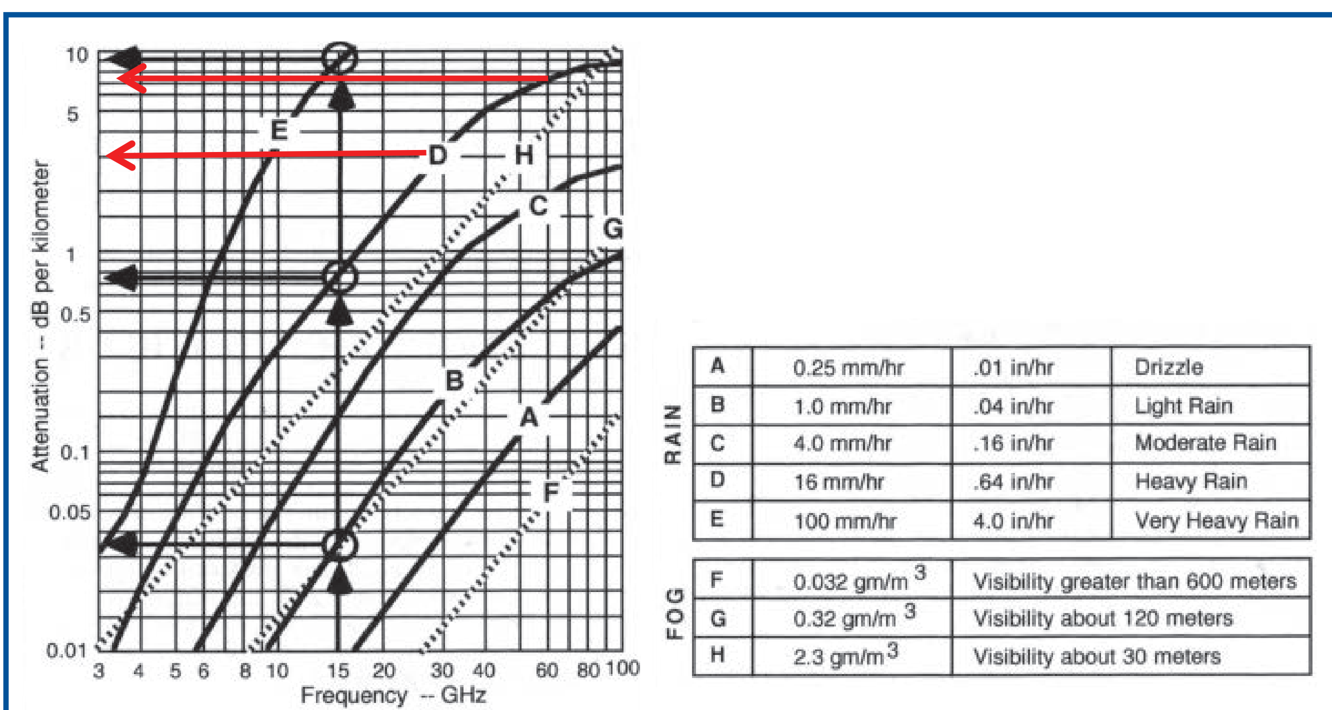

***Fig. 3:** The loss per km for signal transmission through rain and fog vs. frequency is shown in this chart. For example, at 15 GHz, the loss for light rain is .033 dB/km and for heavy rain is .73 dB/ km. The red lines show the loss per km for heavy rain at 28 and 60 GHz.*


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LISTEN UP! AOC LAUNCHES TWO NEW PODCASTS

AOC has launched two podcasts to bring our community together: “The History of Crows” launches in May, illuminating the evolution of Electromagnetic Spectrum Operations (EMSO); and “From the Crows’ Nest” launched in April, featuring interviews and analysis of the leading issues of the day. Stakeholders and professionals across government, industry and academia, not to mention the self-described technologist, can learn our history and engage in the issues impacting our community today. Advertisements and episode sponsorships are available. Please visit crows.org/podcast for more information, or find the podcasts on Apple, Spotify or wherever great podcasts are found!

2021 AOC AWARDS NOMINATIONS OPEN!

A central tenant of AOC’s mission is recognizing individuals, groups, and military units for their outstanding performance in furthering the aims of the AOC and the Electromagnetic Warfare enterprise. AOC has a number of awards that are available each year, with two categories – Competitive and Non-Competitive. Nominations are due by June 30, 2021. Please visit crows.org/awards for more information.

DIXIE CROW CHAPTER HONORS AWARD RECIPIENTS AT DIXIE CROW 45 SYMPOSIUM

AOC President, Glenn “Powder” Carlson posthumously presented Mr. Tim Clark with the AOC Distinguished Service Award at the 45th Dixie Crow Symposium at Robins AFB, GA. Tim’s widow, Dianne Clark, was present to accept the award, which was presented by Col Gregg Jerome, AFLCMC/WNY SML, and Adam Delestowicz, Dixie Crow Chapter President.

Tim Clark was a dedicated Aerospace Consultant for more than forty years. He represented several companies and contracts over the decades, particularly those supporting the electronic warfare (EW) and avionics organizations at Robins AFB. Tim was a true professional, always keeping his clients and customers informed and satisfied. Tim’s vast experience was a source of continuity during constant government employee turnover.

Some of Tim’s recent work supported critical EW systems such as the AN/ALR-56C radar warning receiver (RWR) and AN/ALQ-172 electronic countermeasures (ECM) systems. Tim was instrumental in resolving supply constraints and was a trusted liaison. A particularly notable project was the repair capability standup for the top MICAP and Awaiting Parts driver in the EW System Program Office (AFLCMC/WNY), resulting in the resolution of all MICAPs and substantially improved support to the organic depot.

Tim was a man of his word and unfailingly responsive to customer requests. He always had a smile on his face and brought humor and joy to the office. Tim’s presence and expertise is sorely missed.

During the Symposium, Colonel Jerome and Chapter President Delestowicz also presented the Dixie Crow 2021 Young Crow Award to Mr. Lucas Kinser.

As the technical lead for the MERC Laboratory Intelligence Validated Emulator Test and Evaluation team supporting the EW and avionics integrated support, Kinser led the closed-loop T&E efforts. He is also involved in several developments designed to augment the integration and application of these closed-loop systems. His efforts enable 24/7 T&E operations, thereby increasing survivability and lethality of our warfighters in contested environments.

Kinser operated the live system for approximately 100 T&E events and capability demonstrations, directly supporting OFP and ACC 16 EWS technique updates for the ALQ-161, adaptive digital technology testing for the angry kitten pod, and F-16 next-gen EW system development.

LUNCH IS SERVED: DIXIE CROW CHAPTER SUPPORTS HABITAT FOR HUMANITY

The Dixie Crow Chapter Chuck Wagon crew, led by Dixie Crow’s own “Chef Roadkill,” aka Mark Leslein, assembled on March 6 to feed the Habitat for Humanity crew that was working on homes #63 and #64 off of Hickory Street in Warner Robins, GA. The crew prepared and served over 32 volunteers.

Dixie Crow Members in attendance were: Mark Leslein, Adam Delestowicz, Scott Wolf, Bob and Mary Thrower, Rodney Brooks, Ron Herpst and Debbie Koenig.

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Glorianne O'Neilin
(703) 549-1600
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JED Sales Offices

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1430 Spring Hill Road, 6th Floor
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Tel (800) 369-6220
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Project Manager:
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Direct: +1 (352) 333-3468
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Project Coordinator:
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NAYLOR (Canada) Inc.
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