APRIL 2020
Vol. 43, No. 4

ASSOCIATION OF OLD CROWS

JED

The Journal of Electronic Defense

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ASE for FVL

Also in this issue:

New: Directed Energy 101

EW 101: Link Vulnerability in Space EW

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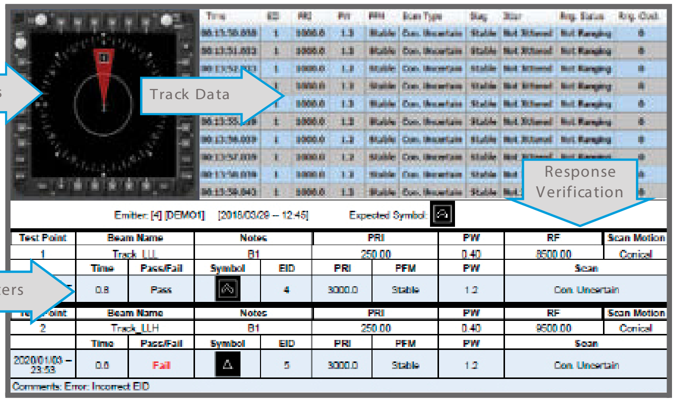

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A U.S. Army Electronic Ground Warfare team with 2nd Brigade Combat Team, 1st cavalry division, packs up their equipment at the end of Combined Resolve XIII at the Joint Multinational Readiness Center in Hohenfels, Germany on Feb. 2, 2020. Combined Resolve XIII enhances professional relationships and improves overall coordination with allies and partners during a crisis. (U.S. ARMY NATIONAL GUARD PHOTO BY SGT. DUSTIN JORDAN)

News

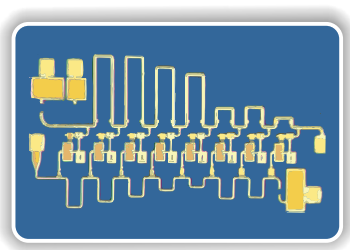
Features

Departments

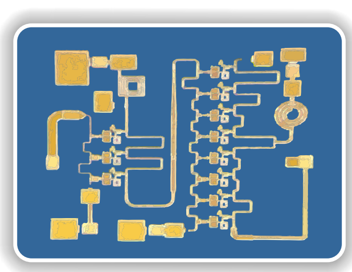
COVER PHOTOS COURTESY OF BELL TEXTRON AND SIKORSKY HELICOPTER

New Broadband GaAs MMIC offerings from AMCOM!

AMCOM's AM06013033WM-XX-R is a broadband GaAs MMIC which operates between 6 and 13 GHz with 28 dB gain and 33 dBm output power. This MMIC is available in both bare die form (AM06013033WM-00-R) and packaged form (AM06013033WM-EM-R).The EM package is a ceramic package with a flange and straight RF and DC leads for drop-in assembly. The MMIC input and output are internally matched to 50 Ohms.



AMCOM's AM00020026WM-00-R is a broadband GaAs MMIC Distributed Power Amplifier die which operates between DC and 20 GHz. This amplifier has 13.5 dB gain, and 26 dBm output power. The chip input and output are internally matched to 50 Ohms.



AMCOM's AM02018026WM-00-R is a broadbandGaAs MMIC Distributed Power Amplifier die which operates between 2 and 18 GHz. This amplifier has 23.5 dB gain, and 26 dBm output power. The chip input and output are internally matched to 50 Ohms.

GaAs MMIC PAs

Model	Freq(GHz)	Gain(dB)	P1dB(dBm)	Psat(dBm)	Eff(%)	Vd(V)
AM003536WM-XX-R	0.01-3.5	23	35	36	20	20
AM002535MM-XX-R	0.03-2.5	24	34	35	25	20
AM012535MM-XX-R	0.03-2.5	20	33	33.5	20	20
AM009023WM-XX-R	0.05-9	21	21	23	20	12
AM008030WM-XX-R	0.05-10	18	30	31	20	12
AM012020WM-XX-R	0.1-2	30	16	17	8	8
AM011037WM-XX-R	0.2-1.0	31	37	37.5	40	8
AM103026MM-XX-R	0.9-3.2	22	25	26	10	14
AM132740MM-XX-R	1.3-2.7	26	38	39	30	14
AM142540MM-XX-R	1.4-1.8	25	39	40	35	14

GaN MMIC PAs

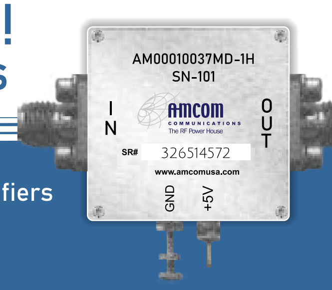
Model	Freq(GHz)	Gain(db)	Psat(dBm)	Eff(%)	Vd(V)
AM00010037WN-00-R	DC-10	13	37	25	28
AM00010037WN-SN-R	DC-10	13	37	23	28
AM003042WN-00-R	0.05-3	24	42	35	40
AM003042WN-XX-R	0.05-3	23	42	33	40
AM206041WN-00-R	1.8-6.5	32	42	27	28
AM206041WN-SN-R	1.8-6.5	30	41	23	28
AM408041WN-00-R	3.75-8.25	33	42	27	28
AM408041WN-SN-R	3.75-8.25	31	41	23	28
AM0751204IWN-00-R	7.75-12.25	28	42	27	28
AM0751204IWN-SN-R	7.75-12.25	27	41	22	28
AM0801204IWN-00-R	7.5-12	22	42	20	28
AM0801204IWN-SN-R	7.5-12	21	41	20	28

visit website to see all MMIC products offerings.

New Release! Compact SSPAs

Compact Power Amplifiers
2.20" x 2.20"

New Release! Compact LNAs



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A TIMELY IDEA

Back in the mid-1990s, the Air Force's EW acquisition office (SAF/AQPE) was led by a gentleman named Col. John "Jack" Booher. He was a savvy operator, even by the standards of the Pentagon. Colonel Booher was responsible for coordinating most of the Air Force's EW program funding. When he began to realize that his acquisition leadership (mostly former fighter pilots) wasn't paying enough attention to his EW programs, Colonel Booher brought a young F-16 pilot onto his staff. He made sure to bring this young Viper driver to most of his meetings with leadership, and it helped to break the ice. The leadership was very receptive to hearing about EW from a fighter pilot, and these senior leaders became more more engaged with the EW acquisition shop as a result.

Colonel Booher knew how to get things done, and this extended to developing his staff. About this time in the mid-1990s, I arrived at *JED* as a new editorial assistant, and I got to know some of the officers in Colonel Booher's shop. I would speak to them for news articles and program updates (media relations were less formal back then), and they would occasionally call our office about writing articles for *JED*. We seemed to get a lot of articles from Colonel Booher's staff. One day, one of his officers phoned to ask about writing an article, and he mentioned (more like groaned, actually) that Colonel Booher required every officer on his staff to publish an article in *JED* or some other magazine.

A few years ago, I ran into one of Colonel Booher's former charges. We talked about Colonel Booher and where his officers had gone after their time in the AQPE shop. Just about all of them went very far in their Air Force careers, and some even got a star or two (including the officer who groaned about writing the article). This was quite a record for such a small office. I would like to think that some of their success owes a little bit to their time under Colonel Booher and the career-building tasks he encouraged them to do, like publishing journal articles.

This brings me to my point. At *JED*, we love to publish articles by active duty military professionals. They provide a unique perspective on EW, SIGINT and related operations in the EM Environment. Yet, we never seem to get enough of them. In an effort to encourage more of these articles, we will be announcing a *JED* writing contest later this month, and we will publish as many of the articles as we can over the subsequent months. The topics and guidelines will be announced in the coming weeks via e-Crow and in the May *JED*. If you would like to receive this information via e-mail, please contact me at JEDEditor@naylor.com. We are always interested in sharing new ideas across our community, and publishing an article is one of the best ways to do this.

In the meantime, I hope you stay safe and remain healthy in these unusual times. – *J. Knowles*

ASSOCIATION OF OLD CROWS
www.crows.org
JED
The Journal of Electronic Defense
APRIL 2020 • VOL. 43, NO. 4

Subscription Information: Please contact Glorianne O'Neilin at (703) 549-1600 or e-mail oneilin@crows.org.

The Journal of Electronic Defense is published for the AOC by
NAYLOR ASSOCIATION SOLUTIONS
5950 NW 1st Place
Gainesville, FL 32607
Phone: (800) 369-6220 • Fax: (352) 331-3525
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APRIL

SPIE Defense + Commercial Sensing
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Online Conference
www.spie.org

MAY

ILA Berlin 2020
May 13-17
Berlin, Germany
www.ila-berlin.de

Defense officials have announced restrictions on domestic travel for service members, Department of Defense (DOD) employees and family members in response to the novel coronavirus, COVID-19. As all travel will be halted through May 11 per the DOD's memorandum, we have removed all in-person conferences through that date. For conferences taking place after May 11, please contact the conference organizer.

JUNE

11th Annual Cyber & Electronic Warfare Convergence Conference
June 2-4
Charleston, SC
www.crows.org

Electronic Warfare Technology Conference
June 8-11
Shrivenham, Oxfordshire, UK
www.cranfield.ac.uk

Eurosatory 2020
June 8-12
Paris, France
www.eurosatory.com

International Microwave Symposium
June 21-26
Los Angeles, CA
www.ims-ieee.org

5th Annual Directed Energy Summit
June 24-26
Washington, DC
www.idga.org

AUGUST

TechNet Augusta
August 17-21
Augusta, GA
www.afcea.org

Defense Services Asia
August 24-27
Kuala Lumpur, Malaysia
www.dsaexhibition.com

SEPTEMBER

Land Forces 2018
September 1-3
Brisbane, Australia
www.landforces.com.au

European Microwave Week 2020
September 13-18
Jaarbeurs Utrecht, the Netherlands
www.eumwa.org

AFA 2020 Air, Space and Cyberspace Conference
September 14-16
National Harbor, MD
www.afa.org

Modern Threats: Surface-to-Air Missile Conference
September 15-17
Redstone Arsenal, AL
www.crows.org

Africa Aerospace and Defense (AAD2020)
September 16-20
Centurion, Gauteng, South Africa
www.aadexpo.co.za

Modern Day Marine
September 22-24
Quantico, VA
www.marinemilitaryexpos.com

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

APRIL

AOC Virtual Series Webinar: Overview of Missile Design, Development, and System Engineering
April 9
1400-1500 EST
www.crows.org

AOC Live Professional Development Web Course: EW against a New Generation of Threats
April 13-29
8 sessions, 1300-1600 EST
www.crows.org

AOC Virtual Series Webinar: Pulse Compression Techniques inside LPI Radars: Basic Principles and Technology Trends
April 23
1400-1500 EST
www.crows.org

MAY

AOC Virtual Series Webinar: The Basic Concepts of ELINT
May 7
1400-1500 EST
www.crows.org

Advanced Radar Signals Collection and Analysis
May 12-14
Atlanta, GA
www.pe.gatech.edu

Adaptive Arrays: Algorithms, Architectures and Applications
May 12-15
Atlanta, GA
www.pe.gatech.edu

Military Electronic Warfare
May 18-22
Swindon, UK
www.cranfield.ac.uk

AOC Virtual Series Webinar: Leveraging Publicly Available Information to Map and Track GNSS Interference
May 21
1400-1500 EST
www.crows.org

JUNE

AOC Live Professional Development Web Course: EW Modeling and Simulation
June 1-17
8 sessions, 1300-1600 EST
www.crows.org

Introduction to ISR Concepts, Systems and Test Evaluation
June 2-5
Atlanta, GA
www.pe.gatech.edu

AOC Virtual Series Webinar: Deep Learning and Waveform Classification
June 4
1400-1500 EST
www.crows.org

Radar Cross Section Reduction
June 8-10
Atlanta, GA
www.pe.gatech.edu

Fundamentals of Radar Signal Processing
June 8-11
Las Vegas, NV
www.pe.gatech.edu

Defense officials have announced restrictions on domestic travel for service members, Department of Defense (DOD) employees and family members in response to the novel coronavirus, COVID-19. As all travel will be halted through May 11 per the DOD's memorandum, we have removed all in-person courses and seminars through that date. For courses taking place after May 11, please contact the course provider.

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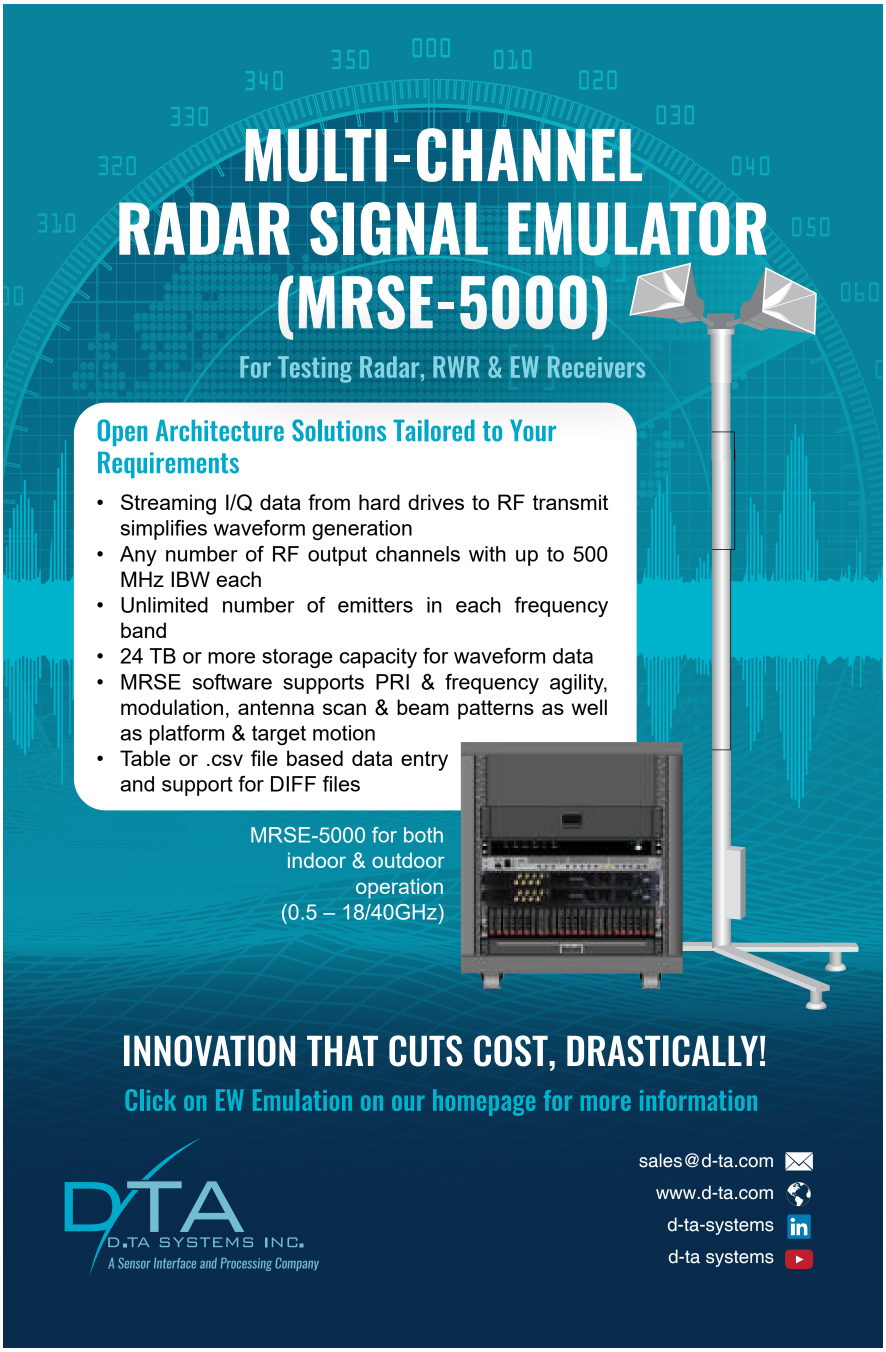

message
from the president

WHAT WE BRING TO THE FIGHT

First of all, for our international body of professionals, I want to express my sincere hope that COVID-19 has not touched you or your loved ones, as it literally changes many aspects of our lives.

This month I would like to touch on what the AOC community brings to the fight. For purists out there, I may blur traditional lanes. We all know it's about the spectrum, or the Electromagnetic Environment (EME) – using it, protecting it, controlling access to it. But, many people outside our community sometimes wonder, what do we bring to the fight? First it's the cadre of professional warfighters – skilled, trained, experienced – who are doing the planning, coordinating activities, synchronizing effects/effectors, conducting operations and making it happen in this all-domain world we fight in. Second it's the program managers, engineers, and scientists in the labs and throughout industry who develop, build and help deploy technologies to the warfighter.

So we have the people and the technology for the EME. What's the impact? We shape the battlefield in the early phases of any conflict by using Signals Intelligence (SIGINT) and cyber operations to build situational awareness, we deploy deception (information warfare) to influence our adversaries, and begin to deny, delay, degrade and deceive opposing forces' operational capability by using electronic attack and cyber operations to conduct information warfare. This further influences their decision makers.

When the shooting starts, our weapons systems are shielded from adversary EW by the electronic protection that has been built into the sensors, communications and Precision, Navigation and Timing (PNT) systems, and we protect the platforms themselves with the self-protection systems that provide jamming, decoys, chaff and flares. Our planners have synchronized the "dance" as events progress using the combination of EW and cyber to confuse and blind enemy forces. We complicate enemy targeting with decoys and deception to delay his responses and degrade his ability to engage our forces. We provide the unseen force multipliers that provide our forces with critical advantages in time and space, and we enable our ability to attack enemy targets and achieve our larger war-fighting objectives. We are the force behind "deny, degrade, delay, destroy." Without our EME community, wars are lost.

Our community had been handcuffed in the past by lack of vision, direction, investment and prioritization. However, each of us can be an advocate for our community. We are beginning to improve EW appreciation among military and government leaders. We need to keep the gas pedal down, stay engaged, show the requirement/benefit that our warfighting capabilities bring and keep moving forward.

Part of "moving forward" is to keep yourself informed. While many of us are affected by COVID-19 protection measures that have restricted our work activities, I hope that you will take advantage of the many Webinars and online courses that AOC offers live and on demand via our Website, www.crows.org. It's an essential resource for an essential community. Have a great month and stay safe.
– Muddy Watters

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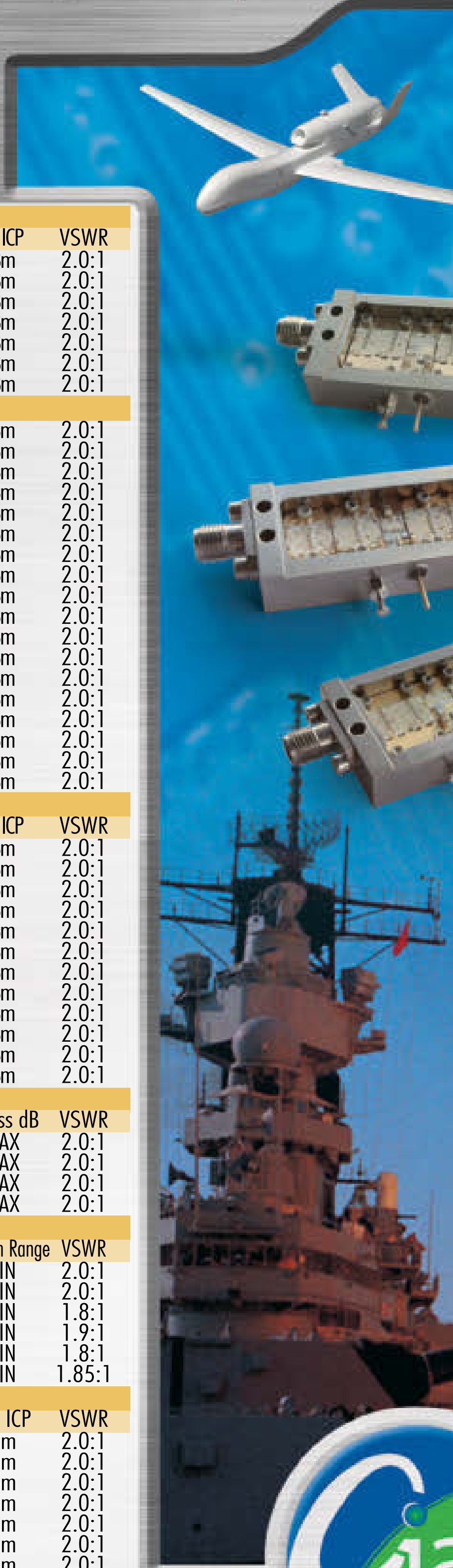

OCTAVE BAND LOW NOISE AMPLIFIERS

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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EW Modeling and Simulation

Dave Adamy

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Kyle Davidson
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Hands-on Introduction to Radar and EW

Dr. Warren Du Plessis
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Dave Adamy
Friday & Saturday
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FIRST ODIN LASER DAZZLE DEVICE INSTALLED ON USS DEWEY

The US Navy has completed the first fit of a new laser dazzler device to a DDG-51 Flight IIA *Arleigh Burke*-Class guided missile destroyer.

Known as ODIN (Optical Dazzling Interdictor, Navy), the new system is a standalone low-power, non-lethal device designed to blind and disrupt unmanned aerial system (UAS) sensors and other platforms to address fleet urgent operational needs in the Pacific theater. ODIN development, testing and production has been led by Navy subject matter experts at the Naval Surface Warfare Center (NSWC) Dahlgren Division in support of the Program Executive Officer Integrated Warfare Systems.

Forming part of the wider Navy Laser Family of Systems (NLFoS) portfolio, the ODIN program is funded to provide eight units for installation on DDG-51 Flight IIA destroyers. The first ODIN ship installation – the beam director being installed just in front of the bridge – was completed onboard *USS Dewey* (DDG 105) in late 2019 during a dry-docking selected restricted availability period.

In a statement, the Navy said that ODIN development has drawn on NSWC Dahlgren's prior experience of developing the AN/SEQ-3 Laser Weapon System (LaWS) 30 kW-class laser weapon prototype. Deployed at sea on board *USS Ponce* in the 5th Fleet area of operations, the experimental LaWS system demonstrated its ability to shoot down small UASs during testing.

ODIN is one of a number of near-term programs being delivered under the NLFoS initiative, which is intended to guide the transition of high-energy laser capabilities onto the frontline, as well as develop and validate requirements for laser weapons. Another strand of NLFoS is the Surface Navy Laser Weapon System, for which Lockheed Martin Aculight was, in February 2018, awarded a $150 million contract to develop the High Energy Laser and Integrated Optical-dazzler with Surveillance (HELIOS) system. An accelerated acquisition intended to field a modular and scalable laser weapon system on a DDG-51 Flight IIA guided missile destroyer, the 100-kW-class HELIOS system is intended to defeat small boats and UASs, and provide a capability for non-destructive dazzling against UAS-mounted sensors. The company announced last month that the HELIOS system will undergo on-shore testing at the Navy's Wallops Island facility in Virginia before being integrated onto an *Arleigh Burke*-Class destroyer for at sea testing.

Also last month, Lockheed Martin received a $22.4 million contract from the Office of Naval Research (ONR) to integrate, demonstrate, test and operate a prototype Layered Laser Defense (LLD) system onboard a Littoral Combat Ship (LCS). Under the contract, the company will develop a prototype structure and enclosure to protect the LLD from ships' motion. A variant of the HELIOS, the LLD will be integrated onto the USS Little Rock (LCS 9), *Freedom*-Class monohull version of the LCS. The contract marks the first time the Navy has integrated a laser weapon onto an LCS. *– R. Scott and J. Knowles*

DARPA SEEKS PROPOSALS FOR SECURE TACTICAL RADIO RECEIVER

The Defense Advanced Research Projects Agency's (DARPA's) Microsystems Technology Office (MTO) has issued a solicitation for its Wideband Secure and Protected Emitter and Receiver (WiSPER) program, which aims to develop "wideband secure and protected radio interface technologies" for use in future tactical radios.

According to the WiSPER solicitation, "Current DoD tactical radios attempt to achieve security over a wireless channel by spreading transmitted content over time and operating frequency. Temporal and spectral spreading reduces transmitted power density, so as to potentially operate below the adversary's receiver detection limit. However, current spread spectrum techniques lack sufficient complexity to evade detection by modern signal intelligence (SIGINT) receivers or interception by compromised devices." The solicitation goes on to describe specific vulnerabilities of current secure tactical radios to hypersensitive receivers that utilize cryogenically cooled energy detectors and cyclostationary processing, as well as collaborative receiver networks that coherently recombine power to detect the transmitter.

In order to improve radio performance, the WiSPER program "seeks to develop a fundamentally disruptive wireless air interface transceiver technology to enable and sustain secure and robust high-bandwidth RF communication links. The WiSPER wideband adaptive air interface will also mitigate impairment due to dynamic harsh and contested environments to maintain a stable communication link."

WiSPER is structured into three phases organized under a 48-month program schedule. After contract awards in September, companies will pursue Phase 1 over 18-months, developing and proving out a WiSPER architecture and providing benchtop units that will be evaluated in lab tests. The second phase, commencing in FY2022, also runs 18 months. It will focus on enhancing performance, and culminate in field tests of transportable units operating the WiSPER Air Interface in clear weather conditions. The third and final phase, which runs another 12 months beginning in FY2023, will see the Air Interface integrated into portable units and evaluated in another field test with harsher weather conditions.

Responses to the solicitation are due by April 28th. The overall WiSPER program budget is estimated at $50 million. DARPA is expected to award multiple contracts. The solicitation number is BAA HR001120S0030. The program point of contact is Dr. Young-Kai Chen, e-mail HR001120S0030@darpa.mil. – *JED Staff*

USSTRATCOM COMMANDER DISCUSSES JEMSO IN SENATE TESTIMONY

ADM Charles Richard, USN, Commander, US Strategic Command (USSTRATCOM) testified before the Senate Armed Services Committee (SASC) on February 13. In his testimony, he addressed the latest developments in Joint Electromagnetic Spectrum Operations (JEMSO) at USSTRATCOM.

In his written testimony, Admiral Richard stated, "The Electromagnetic Spectrum (EMS) is the one physical maneuver space depended upon by forces across all warfighting domains. If we cannot achieve EMS superiority and assure access to the EMS, the joint force cannot prevail. Our adversaries have observed our use and dependence on the EMS, and have developed and organized their forces to achieve EMS superiority; it is essential we develop capabilities and appropriately organize to counter this threat. Achieving and maintaining EMS superiority is the critical enabler for successful Joint Force operations.

"To address warfighter requirements, USSTRATCOM collaborates with the Secretary of Defense Electromagnetic Spectrum Operations (EMSO) Cross Functional Team, the Electronic Warfare Executive Committee (EW EXCOM), the Services, the DoD Chief Information Officer (CIO), the joint staff, and Under Secretary of Defense offices to advocate for essential warfighter EMSO capabilities. Additionally, we engage with Australia and North Atlantic Treaty Organization partners to ensure compatible JEMSO doctrine, capabilities, and concepts of operation.

"USSTRATCOM led the effort to create the first Joint Publication for JEMSO. Working with DoD CIO and Defense Information Systems Agency (DISA), USSTRATCOM provided the initial warfighter requirements for an Electromagnetic Battle Management (EMBM) system to achieve EMS superiority. In coordination with the DISA Defense Spectrum Organization, USSTRATCOM is establishing the initial Joint Electromagnetic Spectrum Information Analysis and Fusion capability that will provide spectrum specific data for battle management and combatant command operational cells.

"Our Command also led a combatant command JEMSO cell manpower requirement validation study through the joint manpower validation process for the FY2022 Program Objective Memorandum budget. All of these warfighter requirement initiatives will require sustained investments."

As SASC members asked questions during the hearing, Sen. Marsha Blackburn (R-TN) focused on the Electromagnetic Spectrum. Here is the testimony from this portion of the hearing:

Senator Blackburn: Then highlighting another area, let us move over and talk about electromagnetic spectrum. And as you know, this is something where I have spent a good bit of time working on how we proceed in this area, how we utilize expertise when it comes to working in a contested EW environment. Do we have that? Are we moving forward with the right type work, the visualization, the modeling, so that we are growing the expertise in this area?

Admiral Richard: So, ma'am, let me start that. Senator, one, I applaud your interest and your leadership in terms of electromagnetic spectrum. That is yet another domain not unlike space and cyber that was permissive and we had freedom of maneuver for a very long period of time, and that has changed. So it too has to have a certain level of expertise. The Services are working very hard on that. For example, if you would allow me to have a Navy flashback for a second. I am a joint commander now but just left the Navy. The submarine force, which I recently commanded, has been an emergency flank wide open trying to develop that expertise to the point that we have restructured the electronic technicians' rating to elevate greater numbers, better training. And I could go into more detail on that. You see all the Services working like that right now.

Senator Blackburn: Let me ask you this. Are we at a point where we should develop a concept of operations for EW?

Admiral Richard: Yes, ma'am. You hit on a couple of things that we have to continue to work on. There are numerous concepts of operation. To be able to knit them together in a whole is –

Senator Blackburn: Right, but we need one overriding strategy.

Admiral Richard: One overarching piece –

Senator Blackburn: And if you are reworking training and looking at a different utilization of expertise, then it seems to me we would be well served to move to one concept of operations that would enable each of our military divisions.

Admiral Richard: Senator, one, I not only agree, but I would also highlight another point you made earlier that a key piece of that concept is going to be electronic battle management, electronic warfare battle management, the ability to visualize. We cannot be statically assigned anymore in our use of the RF spectrum. We have to be dynamic. We have to maneuver, and we are going to have to be able to visualize and understand it to accomplish that. Now, the concepts will start from there. – *JED Staff*

IN BRIEF

The Defense Information Systems Agency (DISA) has awarded a $121 million contract to **Expression Networks** (Washington, D.C.) for Electromagnetic

Battle Management Situational Awareness (EMBM SA) to automate joint electromagnetic spectrum activities. Backed by Enlightenment Capital (Washington, D.C.), Expression will provide predictive analysis, situational awareness, and command and control functions in support of Combatant Commands, Joint Task Forces and the electronic warfare communities. The contract includes "near-real-time data ingest, data fusion, visualization, analysis, reporting, and user-defined operating pictures for the electromagnetic operating environment, to include friendly-force, adversary, and neutral actor spectrum-dependent systems."

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The Air Force Research Laboratory's Sensors Directorate (Wright-Patterson AFB, OH) is embarking on an upgrade to its Integrated Demonstrations and Applications Lab (IDAL) that will improve its ability to simulate cognitive emitters and to test sensors in advanced threat environments. The program, known as Trusted and Elastic Military Platforms and Electronic Warfare (EW) System Technologies (TEMPEST), has issued its first call for "Integrated Demonstrations and Applications Laboratory (IDAL) Cognitive Enabling Technologies (ICET)" for the "TEMPEST" Advanced Research Announcement. Under Task Order 1, "Technologies for Advanced RF Simulation (TARFS)," program officials are seeking to "develop the digital models required to assess technology and capability performance and to generate synthetic battlespace. Implementation of autonomous mode capability to emulate "cognitive" behaviors must be considered during the model development," according to the Statement of Objectives. Responses were due March 16, but additional task orders are expected in the coming months. The point of contact is Jo Ann Sillaman, 937-713-9965, e-mail jo.sillaman@us.af.mil.

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Elbit Systems of America (Fort Worth, TX) has received a $471 million contract from the US Air Force to equip the Air National Guard and Air Force Reserve's F-16 aircraft with pylon-based infrared missile warning systems. The 10-year, firm-fixed-price contract includes an initial $17 million order for FY2020. Work is expected to be completed by February 2030. The ANG and AFRES have been working with Terma A/S to upgrade their Pylon Integrated Dispenser System-Plus pylons on their F-16s in order to accommodate the new missile warning systems.

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Army Contracting Command – Rock Island (ACC-RI) announced its intent to issue a Request for Information (RFI) for NextGen Software Defined Radio (SDR) modules capable of meeting Joint Counter Radio Controlled Improvised Explosive Device Electronic Warfare (JCREW) requirements. Responses to the RFI must comply with JCREW system design, including backplane design, open system architecture and other JCREW I1B1 interfaces. According to the notice, prototypes must also include "the Digital/RF circuit card assembly, machined housing, Board Support Package, associated drivers, Software/

Firmware Development Kits and Interface Test Adapters," and the final design must reach Technology Readiness Level (TRL) 6 with capabilities to support laboratory and module-level environmental testing. Issued on behalf of the U.S. Army Combat Capabilities Development Command – Chemical Biological Center (CCDC CBC) (Rock Island, IL) and Naval Sea Systems Command (NAVSEA) (Navy Yard, Washington, DC), the RFI notice is restricted to Cornerstone consortium members, with an estimated closing date of 10 business days after its issuance on March 23. Information on the Cornerstone consortium and registration is available at ibasp-public.ria.army.mil/cornerstone.

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BAE Systems (Arlington, VA) recently demonstrated its "Hedgehog" small-form-factor semiconductor, and its ability to sense radio frequency (RF) and communication signals alongside unmanned aerial systems (UASs) in congested and contested battle environments. The demonstration took place in support of the Defense Advanced Research Projects Agency's (DARPA's) Distributed RF Analysis and Geolocation on Networked System (DRAGONS) program, which aims to integrate geolocation and signal identification capabilities in drones. Hedgehog semiconductors are designed using BAE's MATRICS software defined radio (SDR) technology, with applications including EW, SIGINT and COMMS capabilities.

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L3Harris Technologies (Clifton, NJ) has been awarded a $49 million contract option for the Suite of Integrated Radio Frequency Countermeasures program for US Special Operations Command (USSOCOM). This contract modification includes program management, contractor logistics support, field service representatives and travel, and will increase the total contract ceiling to $50 million.

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The US Air Force Chief of Staff issued general officer assignments in February, including several in the electromagnetic spectrum operations (EMSO) community, including two assignments to the Pentagon. **Brig Gen David M. Gaedecke**, former director, electromagnetic spectrum superiority, Deputy Chief of Staff, Strategy, Integration, and Requirements, US Air Force has been assigned to vice commander, Sixteenth Air Force (Air Forces Cyber), Air Combat Command, of Joint Base San Antonio-Lackland, (San Antonio, TX). In his place, **Brig Gen (select) Michael H. Manion**, former director, joint and National Security Council matters, Deputy Chief of Staff, Operations, US Air Force (Pentagon, Washington, DC) has been assigned to replace General Gaedeke. Manion is the former commander of the US Air Force's 55th Wing (Offutt AFB, NE). During his tenure, he was responsible for training and equipping squadrons to execute intelligence, surveillance and reconnaissance; electronic attack; command and control missions, among others. **Brig Gen (select) Parker H. Wright**, former commander, National Air and Space Intelligence Center, Deputy Chief of Staff for Intelligence, Surveillance, Reconnaissance and Cyber Effects Operations (Wright-Patterson AFB, OH) has been assigned to director, intelligence, surveillance, and reconnaissance operations, Deputy Chief of Staff for Intelligence, Surveillance, Reconnaissance, and Cyber Effects Operations.

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Naval Sea Systems Command (NAVSEA) (Navy Yard, Washington, DC) issued a request for solutions (RFS) for the Electromagnetic Spectrum Predictive Modeling Prototype project. The RFS seeks prototypes that will "develop standards and practices to foster development of electromagnetic solutions and will document and promulgate best practices across government, industry and academia in area such as standard program outreach material; standard training; government and industry standards and best practices." The goal of this project is to assess Department of Defense (DOD) vulnerabilities and create long-term strategic plans for increasing current and future mission effectiveness. According to the RFS, this will be achieved by "measuring impact of the operational landscape and current capabilities, reporting future technological trends, identifying capability gaps, recommending standards, and generating visual management aids and need statements to drive DoD's strategic decisions." All project solutions will be evaluated with the intent of awarding an Other Transaction Agreement (OTA). The contracting point of contacts for this RFS are Michael Allen, (812) 854-8714, Michael.t.allen@navy.mil, and Don Davis, (812) 854-3709, donal.davis@navy.mil.

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The Counter Communications System (CCS) Block 10.2, a terrestrial-based electronic attack system that jams satellite communications receivers, achieved operational capability on March 9. First fielded in 2004, the CCS was developed by **L3Harris** (Melbourne, FL) under a contract from the US Air Force's Space and Missile Systems Center) Los Angeles AFB, CA). CCS Block 10.2 marks the first "new" weapon system for the US Space Force. It was delivered to the 4th Space Control Squadron (Peterson AFB, CO). According to Col Stephen Purdy, SMC Special Programs director, "CCS B10.2 represents the end of the traditional way of development. Future upgrades and enhancements will make use of SMC's Agile DevSecOps [Development, Security and Operations] approach, adapting to the evolving battlefield while delivering capabilities to the warfighter faster and better than our opponents." The Air Force is currently developing the next generation CCS under the CCS Block 10.3 Meadowlands program.

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Leonardo DRS (Arlington, VA) announced that the first AN/AAQ-45(V) Distributed Aperture Infrared Countermeasures (DAIRCM) systems have been deployed on the HH-60G in support of a Joint Urgent Operational Needs Statement (JUONS). The DAIRCM system was developed by three Leonardo DRS business units: Airborne & Intelligence Systems, Daylight Solutions, and Electro-Optical & Infrared Systems.

world report

NEW NATO CONTRACT FOR FLYINGFISH SATPHONE SIGINT

Horizon Technologies (Reading, UK) has secured a new contract to supply its FlyingFish airborne satellite phone (satphone) monitoring system to a NATO user.

The company has also disclosed a first production order for its derivative Xtender product. Xtender is an adaptation of the FlyingFish system designed to enable unmanned aerial vehicles (UAVs) to perform satphone signals intelligence (SIGINT). Now in its third generation, FlyingFish is a satphone SIGINT solution designed for both manned and unmanned intelligence, surveillance and reconnaissance (ISR) platforms. It allows users to simultaneously monitor Iridium, Thuraya and IsatPhone Pro satellite communications.

According to Horizon Technologies, the system will detect and intercept terminal and call activity within radio line-of-sight, including voice, fax, data, and SMS, and it can provide remote L-band capability for those operators of strategic systems. More than 50% of users combine FlyingFish with current European or Israeli strategic SIGINT systems. The latest contract for FlyingFish, valued at over US$1.9 million, is from a NATO nation. The system will be used on a fixed-wing ISR aircraft.

Horizon Technologies has also revealed that its Xtender product is now in production, with the first system destined for a UAV to be operated by a government end-user in the Middle East. Xtender overcomes the weight/space constraints of UAVs by introducing an electronics module and compact antennas sized for unmanned airborne platforms so as to allow intercepted call data (location, metadata and audio) to be downlinked to a modified ground-based FlyingFish system which functions as though it is within line-of-sight of the handset/terminal.

In a further development, Horizon Technologies has launched a FlyingFish mission management system. According to the company, this makes it easy for any operator to add FlyingFish to current aircraft tactical mission management systems as a "plug-and-play" sensor. – *R.Scott*

IN BRIEF

- The Royal Australian Air Force (RAAF) has moved one step closer to buying up to 200 **Lockheed Martin** AGM-158C Long-Range Anti-Ship Missiles (LRASMs) from the US. The US State Department announced in February that it has approved the sale of the LRASMs to Australia under a Foreign Military Sale agreement worth up to $990 million. The potential deal also includes 11 ATM-158C LRASM Telemetry Variant (Inert) units, DATM-158C LRASM, Captive Air Training Missiles (CATM-158C LRASM), containers, support and test equipment, publications and technical documentation, personnel training and training equipment. The RAAF plans to integrate the LRASM on its F/A-18 E/F Super Hornets.
- Indonesian electronics house **Len Industri** (Bandung) and **Thales** (Hengelo, Netherlands) have signed a contract with the Indonesian Government to modernize the sensors and combat systems on the Indonesian Navy's *Bung Tomo*-Class multi-role corvette, *KRI Usman-Harun,* under the class's Mid-Life Modernization (MLM) program. The contract calls for the team to deliver and integrate Thales's TACTICOS combat management System, the SMART-S Mk2 air and surface surveillance radar, the STIR EO Mk2 radar and EO fire control system and the Vigile Mk2 radar electronic support measures (ESM) system. The same configuration has already been installed on the Indonesian Navy's new *Martadinata*-Class frigates. The upgrade to the *KRI Usman-Harun* is scheduled for completion in 2023.
- **Lockheed Martin** will supply an undisclosed number of Sniper Advanced Targeting Pods to the United Arab Emirates for its Mirage 2000 multirole fighters. The deal, conducted as a Direct Commercial Sale, marks the first time the Sniper Pod has been integrated onto Mirage 2000 aircraft. The UAE currently operates 43 Mirage 2000 fighters across three squadrons. The Sniper ATP is also integrated onto the UAE's F-16 Block 60 fleet.
- Australia's **Flinders University** (Adelaide, SA) last month announced a AUS$5 million initiative to establish a National Electronic Warfare Centre over the next five years. The EW Centre is part of a partnership between the University and Australia's Department of Defence to sustain and develop EW skills within the defense sector. The University is establishing a Chair of EW Studies to oversee EW education and research, and it is currently recruiting candidates for the position. In the meantime, the university is also developing new graduate and undergraduate courses for EW. In a related move, Flinders University, the Defence Science and Technology Group (DST), the Joint Capabilities Group and industry EW partner **DEWC** have signed a memorandum of understanding to conduct EW research and deliver EW education and training to help grow Australia's EW workforce.

FVL Program Aims For O
Advancement of Aircraft

By John Haystead

The US Army has identified aircraft survivability as the single most important factor driving the design and development of its next-generation family of Future Vertical Lift (FVL) rotorcraft. In that context, however, the Army views survivability in holistic terms to include platform detectability, maneuverability, standoff range, multi-platform integration, smart weapons, etc. – with on-board electronic protection systems, or aircraft survivability equipment (ASE) providing the final element of protection. BG Walter Rugen, Director of the Army's FVL Cross-Functional Team (CFT), summed up the role of ASE at the Army Aviation Association of America (AAAA) ASE Symposium last November. "If everything else fails, ASE will blunt them at their end game and we will still survive."

The FVL initiative is actually a joint-Service DOD effort led by the Army but including the Navy/Marine Corps and Special Operations Command (SOCOM). The goal is to provide future forces with capabilities that dramatically overmatch enemy air defense systems by, as General Rugen describes – "disintegrating their area access/aerial denial (A2/AD) layers and structures."

Last month (as this issue of JED *went to press), the Army was expected to downselect from among five candidates for the FARA program.*

PHOTOS COURTESY OF AVX, BELL, BOEING, KAREM AND SIKORSKY

verwhelming Survivability Capability

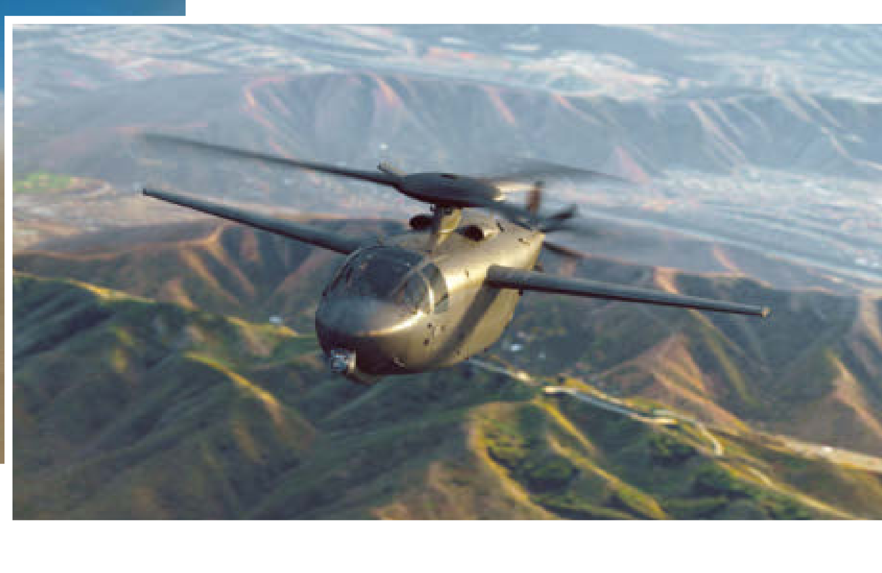
CAPABILITY SETS

The overall FVL aircraft development effort is generally organized around five different "capability sets" (CapSets). As explained by COL Matthew Isaacson, FVL CFT Chief of Operations, the CapSet structure and designations were created to serve as an initial structure for the FVL development plan, but as the program has progressed, their individual focus has somewhat evolved as the Army and the other Services are now moving to meet more of their Service-specific requirements.

As it stands today, CapSet 1 is composed of the development of an optionally-manned, light scout aircraft – Future Attack Reconnaissance Aircraft (FARA), together with the development of future unmanned air systems (FUAS). In April 2019, the Army awarded five industry contracts to develop competitive prototypes for the FARA. The competitors are AVX Aircraft teamed with L3Harris Technologies; Bell Textron; Boeing; Karem Aircraft teamed with Northrop Grumman and Raytheon; and Sikorsky. At the time of this article writing, the Army plan was to down-select to two players in March to be followed by final design and competitive prototypes for flight test and evaluation in 2023. Low-rate production would then begin in 2028 with Operational Test and Evaluation (OT&E) throughout the 2028-2030 timeframe.

The use of advanced UAS, or Air-Launched Effects (ALEs), will be a critical element of the FVL mission capabilities. Individual or heterogeneous swarms of ALEs fitted with electronic warfare support and electronic attack payloads will be deployed to assist in the penetration and defeat of enemy A2/AD environments. The CapSet 1 FUAS effort incorporates both armed and unarmed ALE vehicles small enough to launch from the FARA and Future Long Range Assault Aircraft (FLRAA) platforms, as well as a ground-launched Future Tactical Unmanned Aircraft System (FTUAS) intended to replace the RQ-7 Shadow UAS.

Four companies are competing in the program with field testing into 2021 – Arcturus UAV; L3Harris; Textron; and Martin UAV. According to Vincent Baglio, Director of Business Development for EW, L3Harris, Space & Airborne Systems (East Palm Bay, FL), the ALE mix will include both kinetic and EW payloads operating over various ranges. "The idea is to penetrate the area, disintegrate an adversary's integrated air defenses and allow the manned platforms to push ahead." L3Harris has a small form factor EW payload that they have previously flight tested on UAVs and are looking to leverage for the ALE portion of the FVL program.



CapSet 3 covers the Future Long Range Assault Aircraft (FLRAA) or squad carrier. In addition to replacing Army/Navy-Marine Corp Black Hawk/Apache/Seahawk/Venom aircraft, possible plans for the FLRAA had called for it to replace SOCOM MH-60M Black Hawk helicopters. The Marine Corps had also been looking at replacing their UH-1Y utility and AH-1Z attack helicopters with the FLRAA, but may now be looking at a much-lighter platform better suited to small-deck ships that would be a spinoff of FARA. This would be known as the CapSet 2 Attack Utility Replacement Aircraft (AURA). Colonel Isaacson points out that the Army has completed an Analysis of Alternatives (AoA) for the FLRAA that includes all of the multi-Service interests. "It's all a bit pre-decisional at this point, however, since we don't yet have a design selection to one airframe."

Originally, Bell Textron and Sikorsky-Boeing had built Joint Multi-Role Technology Demonstrators (JMR-TDs) to model the FLRAA, however the FARA effort subsequently outpaced and now overlaps development and production of that platform, although the Army says it is looking at expedited decision cycles and contracting processes to align the FLRAA with FARA.

According to an RFI released in April of last year, the schedule for FLRAA had called for a contract award in the fourth quarter of FY2021, first prototype flight in the 3rd quarter of FY2024, a Weapon System Critical Design Review in the 4th quarter of FY2024, and a first-unit-equipped target in the 2nd quarter of FY2030, however, as referenced by Colonel Isaacson, the FLRAA is managed by PEO Aviation, which is currently in a Competitive Development and Risk Reduction (CDRR) and selection phase with the program. As a result, these dates and milestones may be revised.

CapSets 4 and 5 are intended to address future potential heavy air assault missions as well as other heavy-lift requirements such as MEDEVAC, Amphibious Assault, Humanitarian Assistance, etc. But, as pointed out by Colonel Isaacson, these are not currently within the ongoing program's purview, as the Army's interest is limited to CapSets 1-3.

"What we see in the requirements arena of Multi-Domain Operations is the need to have a 'shorter human-decision cycle' – to be able to react, decide, and do everything that military units do, and communicate in a more timely manner."

– COL Matthew Isaacson

"Any Army interest in CapSets 4 and 5 would be something in the future." As described by General Rugen, plans to replace the heavy-lift, Block II enhanced, CH-47F Chinook with CapSet 5 have been placed on indefinite hold. "For the foreseeable future, the modernized Chinook will exploit maneuver windows in enemy defenses opened by FARA, FLRAA and joint forces."

MATCHING ASE TO THE THREAT

Tracking advanced ASE development and integration with the FVL aircraft development schedule, as well as meeting, and in fact out-pacing, the threat is obviously challenging. And, although it is still relatively early in the development process, expectations are that the next-generation ASE suite supporting FVL aircraft will, by demand, offer major advancements over existing capabilities.

James Conroy, Northrop Grumman Vice President, Navigation, Targeting & Survivability (Rolling Meadows, IL) says, "There's no doubt that the threats are getting more complex, and by virtue of this, so too are survivability systems – especially as the threats become multi-spectral. This will require a holistic approach to detecting, avoiding and defeating them. We must also remember that the aircrew is the primary survivability system, and solutions should be focused on enabling the crew to make informed decisions in order to provide the aircrew with a fused pre-declarative understanding of the electronic order of battle. Mission functions, such as targeting, route planning and degraded visual environment operations, can all benefit from a properly integrated aircraft survivability suite."

Dave Harrold, Vice President and General Manager, Countermeasure and Electromagnetic Attack Solutions, BAE Systems Electronic Systems Sector (Nashua, NH), also emphasizes this point. "We recognize that FVL will be required to operate in a contested and congested EM environment for extended periods and under austere conditions. As the threats rapidly evolve, the next generation ASE suite is going to have to provide multi-spectral detection and response across RF, IR, and EO portions of the spectrum. You really need to be moving toward a threat-agnostic type of environment. As a result, these detection and response capabilities can no longer operate independently as standalone systems."

One challenge, observes L3Harris's Baglio, will be balancing the requirements of the concept of operations (CONOPs) and determining how to best design a system-of-systems with both offboard assets such as ALEs and onboard capabilities for self-protection. "This is a tradeoff question that will require a lot of simulation, a lot of force-level type simulation, and a lot of information regarding capabilities."

Colonel Isaacson defines the Army's view of the requirement in the following terms. "What we see in the requirements arena of Multi-Domain Operations is the need to have a 'shorter human-decision cycle' – to be able to react, decide, and do everything that military units do, and communicate in a more timely manner." Referencing the 2018 National Defense Strategy (NDS), which has played a large role in driving today's emerging concepts of MDO and discussion of Joint All-Domain Operations, Colonel Isaacson says that "while each Service has their own interpretation of how this goes, the consistent approach is the need to communicate over, and decide and share in-

> **“We’re looking at going to ‘supervised full autonomy’ as we go forward – combining all the sensor data that you can get and allowing it to help make decisions on routes to and from that will help us be more survivable in the future.”**
>
> ***– COL Kevin Chaney***

formation from system to system over, a resilient, self-healing mesh network across the Joint Services – the Joint All-Domain Command and Control (JADCC) network. With FVL, it’s not ASE alone. It’s the ability to complement and share with other aircraft capabilities including Degraded Visual Environment, artificial intelligence (AI), and Assisted Target Recognition, among others. And, it’s also about sharing across platforms, so if I sense something on my aircraft, sharing that with others across a mesh network.”

COL Kevin Chaney, ASE Project Manager (PM –ASE) within the Army’s Program Executive Office for Intelligence Electronic Warfare and Sensors (PEO IEW&S) fully agrees. Noting that his preference is to discuss the requirement in terms of detect and defeat, Chaney says, “On the detection side, Colonel Isaacson hit it squarely on the head with sensor fusion – the ability to take inputs from different sensors and fuse those together to obtain a holistic picture of the battlefield. This is one of the key elements that we’re pursuing going forward.”

Another emphasis area related to accomplishing shorter human-decision time cycles, says Colonel Chaney, is the development and implementation of AI and automation to provide autonomy and cognitive-offloading within the manned FVL cockpits. “One of the challenges we have right now is the cycle time from detecting a threat to developing a countermeasure solution and pushing that out to the field. We need to get to the point where, when we see something that maybe we haven’t previously seen, but has similar characteristics to something that we have seen, that we will still be able to declare on it.”

Colonel Chaney points to his shop’s Limited Interim Missile Warning System (LIMWS) program as an example of ongoing efforts aimed at maturing and implementing AI. “I think we’re on a path with LIMWS that already has some level of machine-learning capability, getting us away from the look-up tables and able to make determinations based on identifying threat characteristics, particularly if it passes off to a laser-based jammer which is essentially free ammunition to see if we can defeat it. Obviously, it’s not to the higher levels that we ultimately want to reach, but we’re at least progressing on a path to mature this technology as we go forward.”

Also with FVL, Colonel Chaney says they’re looking at shortening decision time cycles for flight systems overall.

"We're looking at going to 'supervised full autonomy' as we go forward – combining all the sensor data that you can get and allowing it to help make decisions on routes to and from that will help us be more survivable in the future."

Specific to the "defeat side" of Chaney's view of the requirement, he says that ultimately the goal is to provide hard-kill, as well as soft-kill, options to defeat threats. "It may be still years away, but we have to be able to defeat everything coming at us – not in the same sense as small-arms fire, but of a major projectile. We need to figure out a way to knock it off course or just completely destroy it."

MOSA

Conformance to the Modular Open Systems Architecture (MOSA) has been clearly identified as a pre-requisite to participating in the FVL ASE solution, and all of the FVL platforms, including Future Unmanned Air Systems (FUAS) will be built upon the architecture.

MOSA is intended to both speed new capabilities to the fleet and eliminate vendor-specific, proprietary software and hardware.

MOSA is being modeled in a three-phase Mission System Architecture Demonstration (MSAD) which runs through December 2020. According to General Rugen, two mission systems architecture capstone demonstrations using government-defined standards and interfaces have already been well-received by industry. Collins Aerospace, Boeing and Raytheon have been named mission system integrators for the third-phase capstone program being managed by the Army Combat Capabilities Development Command (CCDC) Aviation & Missile Center (Huntsville, AL). As explained by Colonel Isaacson, "We're looking to continue to mature the architecture, so that we can incorporate that knowledge in the requirement, and not end up asking too much from an OEM. This is why we have a foundational requirements document just to standardize what MOSA is within the Army, and although this does not yet have final approval, we do have a great deal of consensus."

All of the potential industry participants in the FVL program recognize the critical importance of MOSA in realizing the desired technology and capability goals of the platform. Says BAE's Harrold, "The degree of integration we're looking at of multi-modal sensors, enhancing situational awareness, multi-function capabilities, and the high accuracy of detection and response capability needed, is really a significant change to the existing architectures of ASE capabilities out there. In addition, given how rapidly these threat changes happen, integration really has to be approached in such a way as to retain both the modularity and the openness at those key interfaces in the architecture to really enable rapid upgrades that can keep pace. With MOSA, we can get where we want to go collectively to really enable future increments of new capabilities on the platforms and not have to try to jam as many requirements in before the official acquisition process milestone."

From his point of view, Harrold says he prefers to use the word "approach," rather than "architecture" in the MOSA

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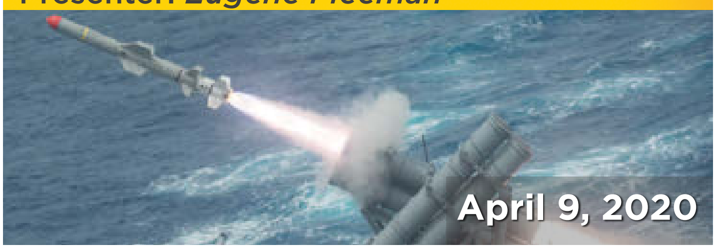

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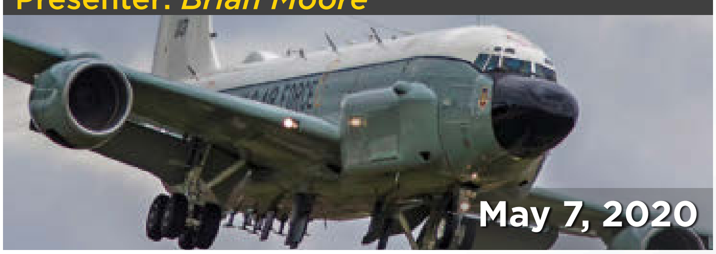

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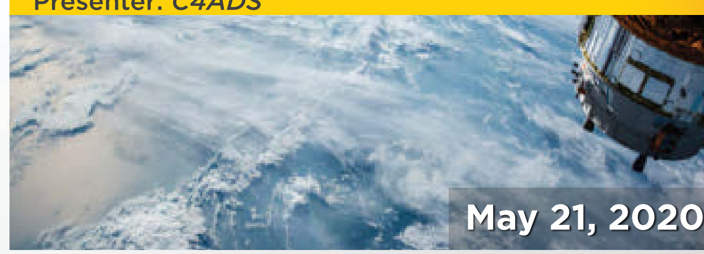

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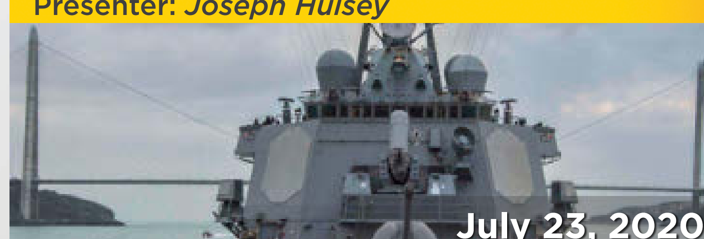

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acronym. "Often when we say MOSA, and use the word architecture, it really constrains the problem for people. So, I prefer the use of the word 'approach,' because it opens the aperture about what's in the art of the possible. Our view is that it's really a business and technology strategy that delivers an open architecture but that the architecture itself has to be defined for the specific application. The Army has established several working groups that define system architectures, and like others we're participating in those groups to help the community come to a consensus on what it needs to look like for FVL."

Northrop Grumman's Conroy observes that the progression of multi-functionality is similar to the innovative use of sensors and software on commercial smart devices, to include an open framework that allows verified third party content to add capabilities as they are required. Architecting for "the progressive integration of the individual survivability realms (IR, RF, EO) is a complex undertaking, and the fusion of real-time data from each part of the survivability suite requires a 'first-do-no-harm' approach that preserves the timelines so critical to a survivability system's effectiveness." Conroy emphasizes that "an important part of that foundation is the warfighter perspective and feedback on how to make the user experience for multifunctional systems as intuitive as possible, ensuring that the operational benefits of integration are optimized for the end user."

Conroy adds, "We've proven that we can do multi-spectral as well as multi-functional, the real question is how to advance the architecture by applying customer-defined MOSA principles while preserving those timelines. Doing so ensures that ASE solutions effectively go beyond their current federated state and become greater than the sum of their parts. This will decrease the time it takes to respond to threats and increase platform capabilities through multi-functional approaches."

SWAP

Closely related to the importance of MOSA is the need for everything intended for FVL platforms to be super compliant to size, weight and power (SWaP) constraints and desires. In that regard, Colonel Chaney says that, "Because SWaP is such a huge concern for us, the more we can combine without degrading performance will help us in the future. As such, multi-spectral sensors that can look across different EMS bands will be extremely beneficial, and we're also looking at ways to get more fiber-optics onto the aircraft and into the systems."

"With MOSA, we can get where we want to go collectively to really enable future increments of new capabilities on the platforms and not have to try to jam as many requirements in before the official acquisition process milestone."

– Dave Harrold, BAE Systems

In fact, as pointed out by NG's Conroy, the greater challenge will be in providing for increased capabilities while also reducing SWaP. "Systems will have to 'buy' their way onto the Mission Equipment package (MEP) by bringing the aforementioned multi-functionality with them. This will require that both requirements and acquisition strategies account for more than one discipline in their processes."

BAE's Harrold agrees, noting that, "There's a trade space across everything that you want to put on the platform, requiring not only getting away from federated, stand-alone systems, but creating greater capability within smaller packaging and form factors.

"L3Harris's Baglio adds that SWaP also relates to the power and location of processing aboard the platforms. The more processing power that can be put into a single processor, even though it may itself be relatively large with multiple drop-in cards for different functionality such as comms, jamming, ESM, etc., will certainly provide SWaP benefits overall."

Chaney says the Army is indeed working to take advantage of advancements in microelectronics technology to reduce the number of black boxes on the aircraft, and potentially host them in something like the Aviation Mission Computer System (AMCS) being developed by PEO Aviation. "It will be essentially like a server in the sky, where I can insert a couple of cards in place of what used to be in multiple black boxes, and potentially provide a huge size and weight saving measure."

REQUIREMENTS DETERMINATION AND LINES-OF-EFFORT

In terms of the Army's overall, all-encompassing approach to the FVL survivability requirement, the Service is organized around a number of critical "lines-of-effort (signature efforts)" and "enabling tenets." The four lines-of-effort are CapSet 1 – FARA and FTUAS; CapSet 3 – FLRAA; MOSA; and ALEs. The four enabling tenets are: lethality, survivability, affordability and reach, and according to Colonel Isaacson, "Survivability is one of the signature tenets across all the other lines of effort and tenets and, we have survivability require-

"Systems will have to 'buy' their way onto the Mission Equipment package (MEP) by bringing the aforementioned multi-functionality with them. This will require that both requirements and acquisition strategies account for more than one discipline in their processes."

– James Conroy, Northrop Grumman

ments defined across all of them." So far, the Army has approved "appropriate-level requirements documents" for FARA, FLRAA, and for ALEs, and a requirements document is in staffing for MOSA.

FARA is the most forward line-of-effort, with the Army gaining approval in the summer of 2018 for an "initial capability refinement document." This turned into a solicitation managed by the Aviation and Missile Center of CCDC, and which is now in a competitive-prototype and source-selection phase. As described by Colonel Isaacson, the approach provided more flexibility in terms of the survivability requirements. "We left the requirements document appropriately vague for where we are in the timeline. Since we're fielding in just less than ten years, it would be premature to set exact requirements, and industry had the opportunity to earn their way onto the OEM's platform."

Colonel Isaacson says that although they've seen a great deal of technology maturation, "there's also a great deal more out there in industry that has not been precluded from being brought to the table. It's not specifically all in the category of ASE, but in terms of affording industry the opportunity to bring a sensor-fusion solution to the table that capitalizes on sharing data, sharing capability, and reducing the SWaP burden and loss of utility on the platform."

Isaacson, says the Army is not yet at the same place with the FLRAA ASE, where they want to make firm requirements decisions. "We've been through one turn of an abbreviated capability development document, and we did mention ASE within that, but we're not at a point where we necessarily need to make those decisions on requirements yet."

Colonel Chaney agrees. "We're basically looking at allowing the OEMs to show us anything that we're not already apprised of, but is embedded within the platform requirements. We're just watching and seeing what the vendors are proposing."

There is also an open question as to the pathway by which the FVL ASE capabilities will ultimately be acquired, with the Army potentially having the airframe manufacturers providing only the platforms themselves and the various aircraft systems provided as government-furnished equipment (GFE). Chaney agrees that these decisions have not yet been made. "We're looking at all available options and are preserving our decision space on this going forward. We want to see if there are any options out there that we haven't seen previously, and we're trying to make sure that we understand everything that all of the OEMs have their hands on, and then try to come up with the best solutions and approaches for each of the platforms."

The real answer to the question of where ASE currently stands in the timeline of the FVL acquisition process requires looking at the entire process, from R&D through fielding. Says Colonel Isaacson, "In the S&T arena, what we're doing now is slightly different than before. We're taking what the engineers have done, discovered and studied, and we're iterating this through prototyping, and not just through prototyping, but taking those prototypes to the next level and putting them in relevant op-

"The more processing power that can be put into a single processor, even though it may itself be relatively large with multiple drop-in cards for different functionality such as comms, jamming, ESM, etc., will certainly provide SWaP benefits overall."

– Vincent Baglio, L3Harris

erational environments with current technology. All along the way, we're incorporating soldier input."

As an illustration of how the process works, Colonel Isaacson points to a technology demonstration exercise called "Project Convergence" and a new phrase the Army is coining known as "MOSA for A3I," standing for modular open system approach for architecture, autonomy, automation, and interface. Says Isaacson, "What we've been lacking in the past is a clear understanding of what MOSA is actually for, but through Project Convergence and MOSA for A3I, we're able to provide an opportunity to cut across not just Army aviation but across the other branches of the Army and the emerging technologies from the other CFTs that represent them, to get after that same architecture." The approach allows us to capitalize on shared lethality and shared survivability concerns, or things that inform, between other commanders and operators on the battlefield. Because of MOSA for A3I, we'll be a whole lot less clunky in the future, a whole lot more enabled, and have an ability to rapidly upgrade at a more affordable cost and therefore increase our chances of success against peer and near-peer adversaries.

As described by Colonel Chaney, "The MOSA for A3I and Project Convergence is a new paradigm of development and acquisition streamlining – bringing in capability faster than previously done. Although he says there are "obviously some challenges with bringing in a new capability this way, and it will still have to go through a lot of the '-ilities' testing," he concludes that "once we've demonstrated it and determined it's filling a capability gap that we need filled, it will be a faster way to bring a new capability to the fleet. It also provides a path that OEMs can use if they have a truly unique capability that they've been working on to bring it to the fight."

"When technology is successfully demonstrated in this manner," says Colonel Isaacson, "it's the easiest way for those technologies to find their way into one of our requirements documents. The benefit is that we're not inventing as much new technology as we used to in a requirements document. We're elevating the standard by which requirements subsets get into that document."

Advertorial

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Directed Energy Weapons: A Technology in Transition

By David C. Stoudt, Ph.D.

"DE 101" is a new column in *JED* that will discuss directed energy (DE) policy, technology and operational issues. The author, Dr. David Stoudt, is president of the Directed Energy Professional Society (DEPS) and Senior Executive Advisor and Engineering Fellow for Directed Energy at Booz Allen Hamilton Inc.

The "DE 101" column will appear in *JED* several times per year. Our hope is to build stronger ties between the directed energy community and the traditional EW community. This is especially important now, as more DE systems are transitioning down the development path from S&T, to acquisition, to operational deployment. We hope you enjoy it and, as always, please send your suggestions for topics in this series to JEDEditor@naylor.com.

It is not often that one sees a new weapon emerge on the battlefield that significantly changes how targets are neutralized or destroyed. The invention of gunpowder in China in the 9th century, followed by harnessing its power to propel projectiles in the 12th century, led to the end of spears, arrows, and catapults as wartime weapons of choice. Since then, nearly all weapon systems impact targets through kinetic effects that are produced either directly by a projectile, such as a bullet or Missile Defense Agency (MDA) hit-to-kill interceptor, or by shrapnel combined with blast overpressure effects, as with a 155 mm artillery shell or a Standard Missile block 2 fired from a Navy surface combatant. Although we have increased the rate of fire, range, accuracy, agility and area coverage, in the end, we are still, except for nuclear weapons, delivering kinetic effects. Nuclear weapons are clearly an outlier in that they primarily produce blast overpressure with a large fireball and heavy radiation close to the detonation point.

New threats have emerged, such as weaponized large and small unmanned air systems (UAS), the latter sometimes referred to as drones, increasingly robust advanced missile systems, and hypervelocity weapons. These threats have been infused with complex high-speed electronics for capabilities like command and control, higher accuracy, and stable flight, and they have been developed with requirements to operate in the electromagnetic environment (EME) that they were expected to encounter during their use, whether it's a drone inspecting a pipeline, or a missile used in combat. Here, we will include optical (i.e., laser) frequencies in our definition of the EME. In most cases, the EME that was factored into those system designs was comprised of non-hostile unintentional electromagnetic (EM) sources, such as communication and radar emissions, or for some weapons, a hostile EME created by conventional Electronic Warfare (EW), as discussed later. Since the 1960s, the US government has made significant investments in developing capabilities that are specifically designed to create an intense EME to disrupt, damage or destroy targets in combat. These capabilities are referred to as directed energy weapons (DEWs), and while they have been popularized in science fiction for over a century, they are now finally becoming an operational reality.

DEW technologies typically take the form of: 1) high-energy lasers (HEL); 2) high-power microwave (HPM) or high-power radio frequency (HPRF) systems; and 3) charged or neutral particle beam weapons, which are technically immature relative to the first two categories and will not be addressed in this series. Both HEL and HPM/HPRF systems are now emerging, and initial prototypes are being developed and integrated into various platforms to allow warfighters to assess their military utility. The first installments of this DE101 series introduce the activities and topics that need to be addressed to support the development, integration and operational employment of DEW capabilities. The author intends it to be a primer on the topic of operationalizing DEWs, with subsequent articles to follow that explore those activities in further detail.

ELECTRONIC WARFARE, ELECTRONIC ATTACK, AND DIRECTED ENERGY WEAPONS

Electronic warfare (EW) is typically defined as the art and science of preserving the use of the EM spectrum for friendly use while denying its use to the enemy. Since its inception, the EW community has been very successful in using electromagnetic energy to deceive, deny or degrade enemy sensors and weapon systems, so much so that there are a number of formal EW Programs of Record (PORs) and entire platforms dedicated to the EW mission. The Boeing EA-18G Growler and the Lockheed EC-130H Compass Call aircraft are two

examples. The primary subdivisions of EW are electronic support (ES), electronic attack (EA), and electronic protection (EP).

Conventional EA takes advantage of a target's intended RF or optical sensors. Using detailed knowledge of how inputs from those sensors are processed by the target's electronics, EW practitioners develop techniques to generate operationally useful impacts on the targeted system for various scenarios. Joint Publication 3-13.1, "Electronic Warfare," states that DEW is a part of the EA subdivision of EW, although the technical communities and funding streams for EW and DEW tend to be somewhat distinct. Recent activities by the Directed Energy Professional Society (DEPS) and the Association of Old Crows (AOC) aim to enhance the collaboration between the two communities.

The US Army sees HELs playing a role in short-range air defense applications, especially against drones. Above, a prototype Multi-Mission High Energy Laser is installed on a Stryker. US ARMY PHOTO

HIGH-ENERGY LASERS

The impact of HEL and HPM/HPRF weapons on a target appreciably expands the range of effects typically generated by conventional EW systems. Most HEL weapon systems currently being developed or deployed can be categorized as solid-state, high average power, continuous wave (CW) lasers that impact a target by delivering a sufficient power density (in Watts/cm^2), at a predetermined aimpoint for a sufficient engagement time, to accumulate the energy density (in Joules/cm^2) required to create the intended structural damage to the target or its electronics. This kinetic-like effect that HEL weapons have on targets, much like a blowtorch at a distance, is well understood by senior military leadership, which has resulted in considerable funding in this technology area.

Other short-pulse and ultra-short-pulse (USP) lasers are also being evaluated to determine their viability as HEL DEWs. Unlike CW lasers that rely on energy deposition to damage a target, USP lasers create highly intense pulses of light, in the terawatt range (10^{12} Watts) or higher, for extremely short periods of time, typically less than a picosecond (or 10^{-12} seconds). The resulting power density on target can damage optical sensors or create surface ablation effects. USP laser atmospheric propagation effects are also being studied to determine its DEW viability. Laser propagation in general is a critical issue for consideration for all HEL weapons.[1]

The US Navy has been evaluating high-energy lasers on its ships beginning with the AN/SEQ-3 Laser Weapons System deployed on the USS Ponce in 2014. US NAVY PHOTO

RF WEAPONS

For this discussion, we will refer to an HPM/HPRF weapon as an RF weapon (RFW). Most RFWs in development for counter-materiel applications rely on the creation of extremely high peak powers, in the range of megawatts to terawatts effective radiated power (ERP), with pulses typically less than one microsecond that disrupt, degrade, or damage a target's electronics. RFWs can affect targeted systems by either coupling energy into intended RF apertures, known as "front door" coupling, or through unintended RF apertures such as seams, non-conductive surfaces, or unshielded wires, which is "back door" coupling. One example of front-door coupling is RF energy from

1 Stoudt, D., (2018) "Cloudy and a chance of rain need not sideline high-energy lasers," C4ISRNET, https://www.c4isrnet.com/opinion/2018/02/26/cloudy-and-a-chance-of-rain-need-not-sideline-high-energy-lasers/, (downloaded 10 February 2020).

HPM weapons, such as the Phaser, are being evaluated for counter-UAS missions. US ARMY PHOTO

an RFW entering through the antenna of the targeted receiver to disrupt, degrade, or damage the low-noise amplifier (LNA) on the front end. In backdoor coupling, RF energy couples into circuits within the targeted system, resulting in the creation of transient voltages that can disrupt their operation or even exceed their physical limits (which in some cases is only several volts) causing breakdown or arcing within the microchips themselves. Unlike conventional EW, these RFW effects in most cases will continue in the electronics after the RF illumination has ended.

The NIRF system during its development phase. DOD PHOTO

HPM technology has seen dramatic reductions in size-weight and power over the past several years. Above, the Active Denial System (left) requires a truck, and the more recent Solid-State Active Denial Technology demonstrator (right) fits on a table top. SMC PHOTOS

Two counter-materiel RFWs with very high average powers are the counter-IED systems called the Neutralizing Improvised Explosive Devices with Radio Frequency (NIRF) system that the Navy/Marine Corps deployed to Iraq in 2005, and the MaxPower system that the Air Force deployed to Afghanistan in 2012.

RFWs can also be used for counter-personnel applications. The most well-known example is the Active Denial System (ADS) developed by the Joint Non-Lethal Weapons Directorate in Quantico, VA. The ADS basically works as a CW RFW at a millimeter wavelength, corresponding to a frequency of 95 GHz. When directed at human skin, this frequency is absorbed in the first 1/64 inch, causing a quick and reversible heating sensation that does not penetrate the target.

Rather than go into technical depth about the DE-related efforts underway in the Department of Defense (DOD), the initial series in this column will address the need to change the discussion from DEW technology capabilities to DEW support for warfighting functions, as well as the actions by the technical community, policymakers, and leadership required to support that transition. This series will also focus on what it will take to gain warfighter acceptance of HEL and RFW capabilities, since these systems have reached the point of being ready for operational testing and evaluation and, in some cases, operational use on the battlefield. Acceptance will mean that warfighters have confidence that the DEW will function as intended when the "trigger" is pulled, *and* that it will have the desired impact on the target.

NEXT

In our next installment, we will look at how the DOD has evolved its DEW technology approach from one in which it concentrated mainly on increasing power levels to a more holistic technological approach.

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PMI designs and manufactures a variety of Coaxial Monopulse Compartors for beamforming antenna applications up to 21.2 GHz. Form, fit and functional designs can also be replicated to specific requirements. Standard models with various options are available at PMI's website:

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MPC-20R2G21R2G-CD-LNF


PMC-24-7D5-SFF


PMC-3G3D5G-6D8-SFF


PMC-33D7-6D8-SFF

PMI Model No.	Frequency Range (GHz)	Gain (dB)	Noise Temperature	Phase Balance	Amplitude Balance (dB)	Size (Inches) Connectors
MPC-20R2G21R2G-CD-LNF https://www.pmi-rf.com/product-details/mpc-20r2g21r2g-cd-lnf	20.2 - 21.2	0 to +10	100 K	±3°	±0.3	6.25" x Ø4.8" x 2.0" SMA (F)

PMI Model No.	Frequency Range (GHz)	Insertion Loss (dB)	Isolation (dB)	Phase Balance	Amplitude Balance (dB)	Size (Inches) Connectors
PMC-24-7D5-SFF https://www.pmi-rf.com/product-details/pmc-24-7d5-sff	2 - 4	0.8 - 7.5	18	±10°	±1.0	3.23" x 3.23" x 0.43" SMA (F)
PMC-3G3D5G-6D8-SFF https://www.pmi-rf.com/product-details/pmc-3g3d5g-6d8-sff	3 - 3.5	0.8 - 6.8	23	±5°	±0.4	3.23" x 3.23" x 0.43" SMA (F)
PMC-33D7-6D8-SFF https://www.pmi-rf.com/product-details/pmc-33d7-6d8-sff	3 - 3.7	0.8 - 6.8	24	±7°	±0.5	3.23" x 3.23" x 0.43" SMA (F)
PMC-9G10G-7D9-SFF https://www.pmi-rf.com/product-details/pmc-9g10g-7d9-sff	9 - 10	1.9 - 7.9	18	±6°	±0.6	3.48" x 3.48" x 0.43" SMA (F)
PD-CD-001-1 https://www.pmi-rf.com/product-details/pd-cd-001-1	9.3 - 9.9	8.0	30	±7°	±0.5	2.35" x 1.7" x 0.5" SMA (F)
PMC-9D5G10D1G-7D6-SFF https://www.pmi-rf.com/product-details/pmc-9d5g10d1g-7d6-sff	9.5 - 10.1	7.6	20	±5°	±0.5°	3.48" x 3.48" x 0.43" SMA (F)


PMC-9G10G-7D9-SFF


PD-CD-001-1


PMC-9D5G10D1G-7D6-SFF

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Space EW (Part 18)

Link Vulnerability

By Dave Adamy

This column returns to the series which ran in the JED from June 2016 to October 2017. If you would like to reference the previous articles in this Space EW series, you can download the earlier columns from the JED archives at www.jedonline.com.

In the earlier parts of the series, we covered orbit mechanics; spherical trigonometry; geometric relationships between satellites and points on the Earth; and several important calculations, such as distance to the horizon, Doppler shifts, and the time a satellite can see a point on the Earth. We also covered intercept and jamming of Earth-surface targets from space. However, we did not cover the important subject of the vulnerability of satellites to threats from hostile electromagnetic attacks. In this continuation of the series, we will fill this gap and talk about a few more related subjects to round out the coverage.

SATELLITE VULNERABILITY

Satellites are far from the Earth, but they present excellent line-of-sight from a large part of the Earth's surface. Therefore, they are highly susceptible to strong hostile transmissions. These can be jamming signals, interfering with uplink or downlink signals to prevent the signals from being properly received. They can also be "spoofing signals" that cause the satellite to interpret them as functional commands, or inaccurate status or data signals. Uplink jamming is illustrated in **Figure 1,** and downlink jamming is illustrated in **Figure 2.** In both cases, the jammer transmits to the link receiver.

Successful uplink jamming could prevent the proper function of the satellite or the payload – for example preventing changes in satellite orientation or selection of a payload function. Command spoofing could cause a satellite to perform a maneuver that ends its mission or could put the payload in an unusable state.

Successful downlink jamming could prevent the ground station from knowing about a condition on the satellite that must be corrected. It could also prevent the transmission of payload data to the ground station.

COMMUNICATIONS JAMMING

Jamming of any satellite link is communications jamming. Jamming effectiveness is normally defined in terms of the jamming-to-signal ratio (J/S) it causes. The J/S for communication jamming is calculated from the following formula:

$$J/S = ERP_J - ERP_S - LOSS_J + LOSS_S + G_{RJ} - G_R$$

Where: J/S is the jamming to signal ratio (in dB),

ERP_J is the effective radiated power of the jamming transmitter toward the target receiver in dBm,

ERP_S is the effective radiated power of the desired signal toward the transmitter in dBm,

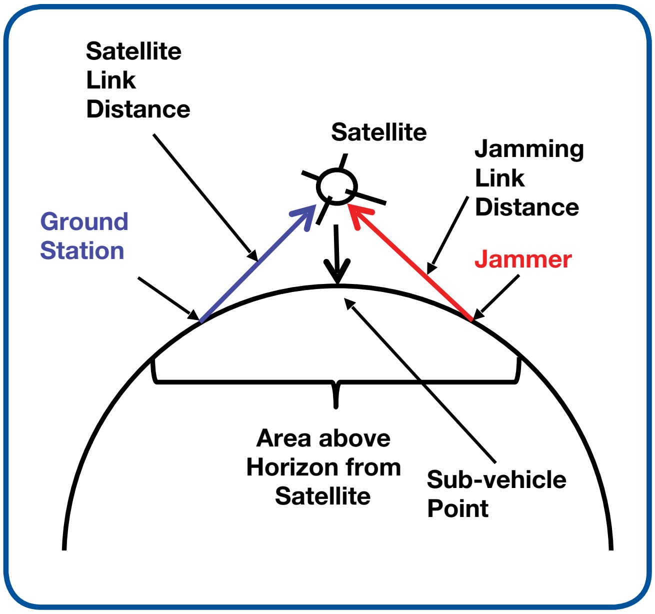

Figure 1: *A ground based jammer operating against a satellite up-link transmits to the link receiver in the satellite. Both the ground station and the jammer must be above the horizon from the satellite.*

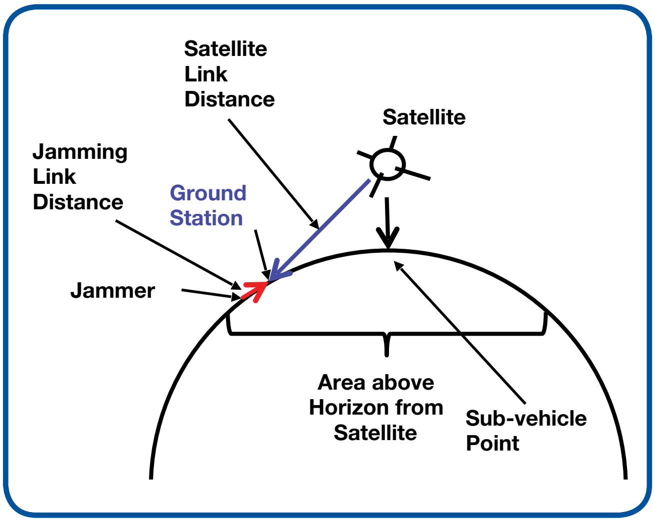

Figure 2: *A jammer operating against a satellite down-link transmits to the link receiver in the satellite's ground station. The jammer can be on the Earth's surface or anywhere else that is above the horizon from the ground station.*


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$LOSS_J$ is the transmission loss from the jammer to the target receiver in dB,
$LOSS_S$ is the transmission loss from the transmitter to the target receiver in dB,
G_{RJ} is the gain of the receiving antenna in the direction of the jammer in dB, and
G_R is the gain of the receiving antenna toward the transmitter in dB.

This formula has been used in many other "EW 101" columns dealing with communications jamming, but in this case, there are considerations associated with satellites. In the September and October 2016 EW 101 columns, we talked about the path loss from a ground transmitter to the satellite, or from a satellite to a receiver on the ground. These columns dealt with line-of-sight loss, atmospheric loss, antenna misalignment loss, polarization mismatch loss and rain loss. Both of the transmission losses in the *above* equation must include all of these space-related loss contributions. As the two columns on this subject were published over two years ago, the relevant space-related formulas and figures are repeated here for your convenience.

SPACE-RELATED LINK LOSSES

Line-of-Sight Loss

Since the satellite is orbiting far from the Earth, the transmission loss is best modeled as line-of-sight loss for both desired signals and jamming signals, defined by the formula:

$$L_{LOS} = 32.44 + 20 \log d + 20 \log F$$

Where: L_{LOS} is the propagation loss in dB,
32.44 is a conversion factor in dB to simplify the formula,
d is the distance from the satellite to the ground station or the jammer in kilometers, and
F is the signal transmission frequency in MHz.

This is a large number because of the great distances involved. For example, for a low Earth satellite with a two-hour (*i.e.,* 120 minute) period, the link distance to a ground station at the horizon would be 4,935 km. If the link transmission frequency is 2 GHz, the link line-of-sight loss would be:

32.44 dB + 20 log (4935) + 20 log (2000) = 32.44 + 73.87 + 66.02 = 172.33 dB.

Note that there is a large table of the horizon distances vs. satellite periods in the June 2017 "EW101" column, along with the underlying calculations. That table is repeated here as **Table 1** for your convenience. In this table: *"p(min)"* is the period of the satellite in minutes *"rng(km)"* is the link propagation distance between the satellite and the Earth surface transmitter or receiver, and *"dist(km)"* is the Earth surface distance between the sub-vehicle point and the Earth surface transmitter or receiver.

WHAT'S NEXT

Next month we will continue the space EW series with the space-related link loss discussion. For your comments and suggestions, Dave Adamy can be reached at dave@lynxpub.com.

Table 1*. Height, semi-major axis and range to horizon and Earth surface distance to horizon for circular satellites with the orbital period specified*

p(min)	h (km)	a (km)	rng(km)	dist(km)		p(min)	h (km)	a (km)	rng(km)	dist(km)
90	281	6652	1914	1859		330	9447	15818	14478	7365
105	1001	7372	3710	3359		345	9923	16294	14997	7447
120	1688	8059	4935	4198		360	10392	16763	15505	7523
135	2346	8717	5950	4785		375	10854	17225	16004	7593
150	2980	9351	6845	5232		390	11311	17682	16494	7658
165	3594	9965	7662	5587		405	11761	18132	16976	7719
180	4189	10560	8422	5880		420	12206	18577	17451	7776
195	4768	11139	9137	6127		435	12646	19017	17918	7830
210	5332	11703	9817	6339		450	13081	19452	18379	7880
225	5883	12254	10467	6523		465	13510	19881	18833	7928
240	6422	12793	11093	6685		480	13936	20307	19281	7973
255	6949	13320	11698	6829		495	14357	20728	19724	8016
270	7466	13837	12284	6958		510	14773	21144	20162	8056
285	7974	14345	12853	7075		525	15186	21557	20594	8095
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315	8964	15335	13949	7277						


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SIXTH INTERNATIONAL CONFERENCE ON ELECTRONIC WARFARE IN INDIA (EWCI 2020)

By AOC India Chapter

The sixth edition of the popular International Conference on EW in India, EWCI 2020, organized by the India Chapter of Association of Old Crows, and held during 17-20 February, 2020 in Bangalore, concluded in a grand and memorable fashion. The three-day conference, one-day pre-conference tutorials and accompanying indoor exhibition of state-of-the-art EW products, which were actively supported by Defence Research and Development Organisation (DRDO), Government of India and Defence Public Sector Unit – Bharat Electronics Limited (BEL), were a big success both technically and commercially. The event, designed with the idea of providing a platform for international collaboration and sharing the latest developments in the field of Electronic Warfare and Information Operations (EW/IO), with a theme "EW: Collaborate for Success," has lived up to expectations and has been of immense use to participants.

EWCI 2020 started off with a traditional Inaugural Function in the presence of several dignitaries and about 350 delegates. The Conference Chair, Dr. U K Revankar; the Chief Guest for the occasion, Mr. M V Gowtama; the Chairman and Managing Director of Bharat Electronics Limited; the President Elect of AOC International, Mr. Glenn Carlson; and Technical Chair, Dr. Anupam Sharma, delivered opening and keynote addresses and inaugurated the event. EWCI 2020 provided a platform for interactions of all stakeholders in the field of EW/IO, including techno-managers, research and development professionals from DRDO, manufacturers – Bharat Electronics, Indian Armed Services personnel, and industry partners.

Following the Inaugural Session, two sessions of Plenary Talks highlighted the current and near future developments and innovations in the areas of EW/IO, including phased array antenna, UV/IR based systems, simulation and testing by replication of real life operations, use of artificial intelligence and cyber techniques, and space-based EW payloads.

During the Conference, six Invited Talks were delivered by eminent personalities in the field of EW/IO on selected topics: "Establishing EW Relationships" by Ms. Lisa K Fruge Cirilli, former AOC President, USA; "New Developments in Test and Evaluation of EW Systems" by Mr. Greg Patshke, Keysight Technologies, USA; "Improving Situational Awareness by Gathering Critical Meta Data" by Mr. Volker Brands, Narda STS, Germany; "Portable Modern Communication and Radar-EW Test and Training Systems" by Mr. Robby Miles, OAK Defense Ltd., Canada, and Mr. H V Harish, CEO, Aidin Technologies, India; "Specific Emitter Identification of COMMS Signals" by Mr. Fabrizio Vergari, Elettronica, Italy; and "Advances in Submarine ESM Systems" by Mr. Patrick Clarke, SAAB Grintek Defence, South Africa.

The Conference attracted a large number of technical papers, of which about 70 were selected that were contributed by authors from India and abroad. The papers were presented in 21 sessions conducted in three parallel halls. The papers were segregated into eight thrust areas: EW Systems and DF Techniques, EW Receiver and RF Subsystems, Electronic Attack and High Power Transmitters, EW Antennas and Active Phased Array Systems, EW Signal Processing and Digital Receivers, EW/IO Threat Simulators and EW Testing/Evaluation, EW Systems Installation and Testing/Evaluation, and EW Software Engineering/Modelling and Certification. The sessions were chaired by eminent personalities in the field of EW/IO.

The pre-conference tutorials day was also well attended by about 230 delegates. The in-depth tutorials addressed contemporary subjects: "Naval EWS: The Modern Naval EW Defence System" by Dr. Andrea De Martino, Elettronica S.p.A., Italy; "Border Surveillance and Traffic Analysis: The boost of Artificial Intelligence in Homeland Security" by Dr. Andrea De Martino and Mr. Fabrizio Vergari, Elettronica, Italy; and "Advancements and Design Concepts for Modern EW Test and Training Ranges" by Mr. Robby Miles, Vice President, OAK Defense Ltd., Canada.

The Technical Exposition accompanying the EWCI 2020 Conference had participation from about 50 major EW organizations, including firms from eight countries. The exhibitors had quality interactions with both developers and end users of the systems in India. The details of the vendors are compiled into "EW Sources" in the EWCI 2020 souvenir book released during the inauguration. The proceedings of the conference, which has high referential value, was provided to all delegates in electronic form.

The EWCI 2020 event not only showcased technical advances concerning the field of EW/IO in India, but also presented a glimpse of a conducive environment for international collaborations and interactions in the form of a cultural event and conference dinner during the event.

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JED, The Journal of Electronic Defense (ISSN 0192-429X), is published monthly by Naylor, LLC, for the Association of Old Crows, 1555 King St., Suite 500, Alexandria, VA 22314.

Periodicals postage paid at Alexandria, VA, and additional mailing offices. Subscriptions: *JED, The Journal of Electronic Defense*, is sent to AOC members and subscribers only. Subscription rates for paid subscribers are $160 per year in the US, $240 per year elsewhere; single copies and back issues (if available) $12 each in the US; $25 elsewhere.

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