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ASSOCIATION OF OLD CROWS

JED

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DISRUPTION

Back in June, the Defense Advanced Research Projects Agency's (DARPA's) Tactical Technologies Office (TTO) issued a Broad Agency Announcement (BAA) titled, "Disruptive Capabilities for Future Warfare." In the program description, DARPA stated, "The U.S. military must expand from their historic emphasis on dominance to one of disruptive performance – enabling enhanced capability where needed, applied by a more agile and resilient force." The BAA is part of DARPA's goal to "… develop new systems and supporting technologies that will fuel new force structures and in turn, challenge DoD warfighting agencies, the defense industrial base, and the resulting military systems to innovate conflict and engagement."

DARPA does not pursue technologies that represent evolutionary or incremental advances. DARPA focuses on revolutionary and leap-ahead solutions, and the Disruptive Capabilities for Future Warfare BAA applies this approach to what it calls "enterprise disruption." That is, it questions some of the most basic assumptions of the DOD's current force structure, which is based around relatively small numbers of relatively high-value assets that are increasingly vulnerable to long-range precision-guided threats. Rather than state a vision of the future, DARPA notes some of the ways our current force structure is falling short in a changing operational environment, and then it asks some fundamental questions.

In the Air Systems section of the BAA, for example, DARPA states, "Our acquisition system is finding it difficult to respond on relevant timescales to adversary progress, which has made the search for next-generation capabilities at once more urgent and more futile. More fundamentally, platform stealth may be approaching physical limits. Are there acceptable alternatives to air dominance? Is it possible to achieve Joint Force objectives without clearing the skies of enemy fighters and bombers, and eliminating all surface-based threats? Can this be achieved without placing a high-value, sophisticated platform and crew at risk – reducing leverage potential adversaries currently hold over the U.S.?"

In the Naval Systems section, DARPA asks a similar set of questions: "Air-launched cruise missiles, advanced ballistic missiles, and hypersonic weapons represent serious threats to the carrier strike group; is there an alternative that could shift onerous or unacceptable costs onto our adversaries? How can we reduce reliance on large, expensive, and increasingly vulnerable carrier strike group platforms? Are there ways to deliver equivalent force projection using less costly and vulnerable assets?"

When you begin asking these kinds of big questions about "enterprise disruption," it is clear that only part of the answer involves technology. Another part of the disruption strategy affects how the DOD develops and buys its technology. Despite its many efforts at acquisition reform over the past few decades, the DOD still operates under the acquisition architecture that Secretary of Defense Robert McNamara helped to establish in the 1960s. While the McNamara acquisition system worked well enough for buying our current force structure, it is not well suited to buying the "disruptive" capabilities the DOD needs for future conflicts that will be won and lost in the EM Environment and in Cyberspace. The US cannot avoid disruption, so it must embrace it in its entirety. – *J. Knowles*

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www.marinemilitaryexpos.com

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Dayton, OH
www.kittyhawkaoc.org

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www.eumwa.org

OCTOBER

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October 8-10
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AUSA Annual Meeting
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Washington, DC
www.ausa.org

Seoul ADEX 2019
October 15-18
Seoul, ROK
www.seouladex.com

Precision Strike Symposium
October 22-24
Laurel, MD
www.precisionstrike.org

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Washington, DC
www.crows.org

NOVEMBER

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November 4-6
Pretoria, South Africa
www.aardvarkaoc.co.za

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www.milcom.org

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November 17-21
Dubai, UAE
www.dubaiairshow.aero

DSEI Japan
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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

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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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OCTOBER

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message

from the president

PASSING THE TEST

After working multiple programs that involved modeling and simulation (M&S), hardware-in-the-loop (HWIL) testing and open-air testing for EW systems, I have observed many testing challenges in my career – some of which we still face today. On the modeling and simulation side, there are many models/simulations out there that run the gamut, from seeker models/simulators to strike simulations incorporating multiple entities (including friendly and enemy platforms) to theater simulations that provide large force-on-force (multi-strike, extended time period) analytics. For modeling and simulation, there are always challenges, such as the fidelity and certification of the model; accurate and vetted CONOPs; a valid threat laydown; and representing a congested and contested EM operating environment.

For testing, I think that we do pretty well in the lab. Then we integrate the EW system onto a weapons platform, which presents additional test challenges. We then take the platform to an operational environment. This brings up the questions of whether or not the environment is representative of the one where the system will operate. Then we integrate into a system-of-systems, not represented well in open-air testing for platforms. Now, throw in the cyber threat and a contested/congested EM operating environment, which is hard to do in an open-air environment. I don't think we are close to solving this one for multiple reasons. A big challenge is this: do we really have representative threats with the density and capabilities that we'll be facing in the real-world EM operating environment?

I just walked through some of the general issues we all face for M&S and testing. Now lets take a look at some observations on how we conduct this business. Test organizations are all working to improve their individual capabilities – each in an organic way. There are labs, ranges, weapons centers, research centers, program offices and industry partners, and they are all competing with each other. There is little effort to establish cross compatibility – even within the syntax, vocabulary or terminology. What is LVC? What is M&S? HWIL is becoming more and more abstract. At the corporate level of the DOD, there is no one minding the store. DOT&E might claim to be orchestrating it all, but they appear to have little to no control over anything within the services. Each of the services, as well as the DOD, have an M&S agency, but there is not enough authority associated with it. Everyone seems to be developing their own requirements, with insufficient "big picture" vision or guidance. I hear of studies about EW T&E capabilities, needs and requirements, but where are the results, and how are the results implemented?

A big part of the EW Community's job is to provide systems that work to the war fighter. With the complexity of systems, system-of-systems and integrated operations, our capabilities in M&S and testing in a cyber and congested/contested EM environment need to evolve and improve at all levels. It's time for us to attack this problem. Our future depends on it. – *Muddy Watters*

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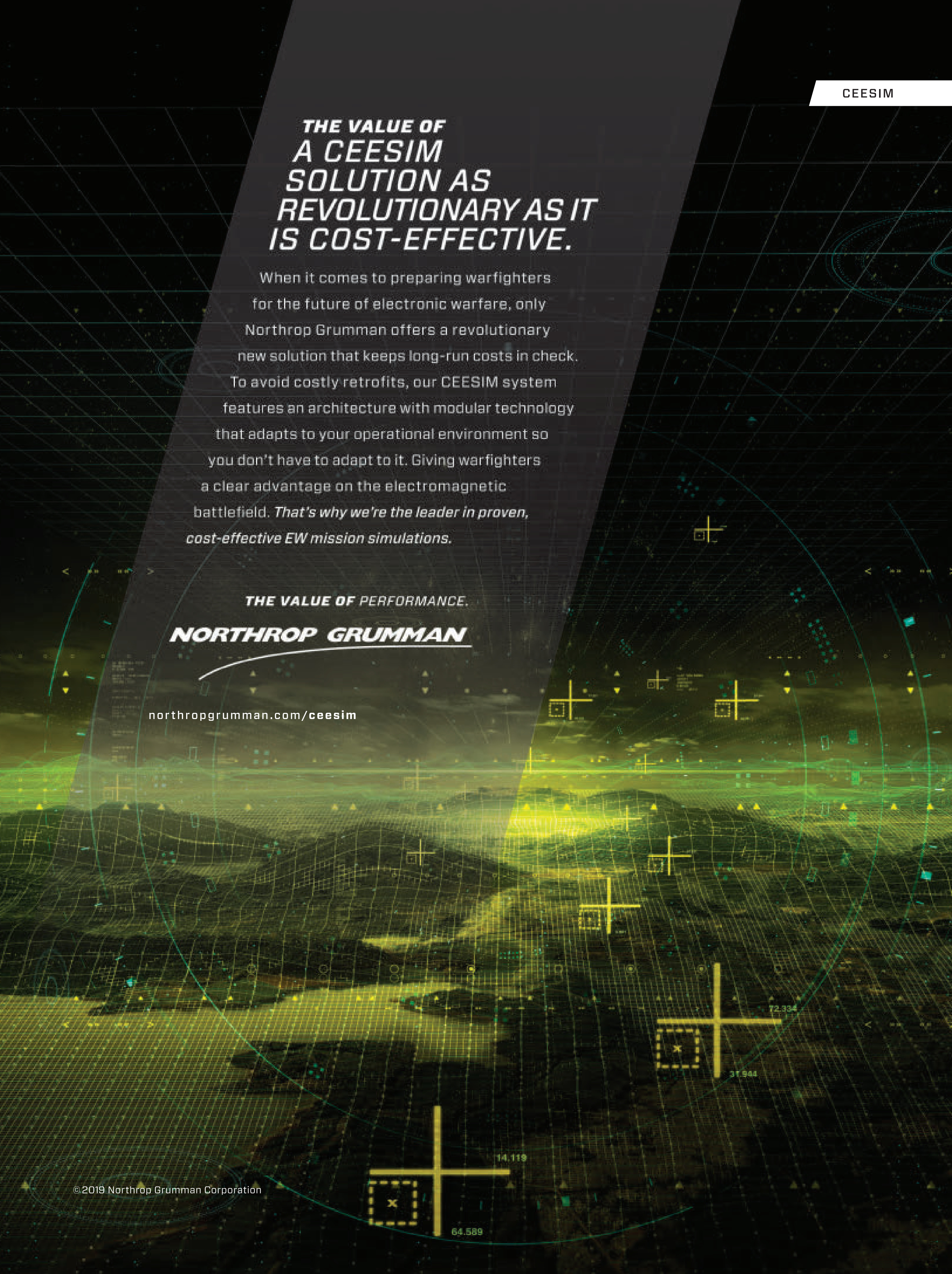
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the monitor

news

HOUSE PASSES NDAA

The House of Representatives has passed its version of the FY2020 National Defense Authorization Act (NDAA). The House NDAA bill and the accompanying committee report, which were drafted by the House Armed Serives Committee (HASC), include several provisions that address electronic warfare (EW) and signals intelligence (SIGINT). Below are some of the highlights:

Electronic Warfare

The HASC, which includes several members of the Congressional Electronic Warfare Working Group (EWWG), has continued to focus on EW policy issues. Three provisions in the committee report direct the DOD to provide a pair of briefings and an assessment related to EW matters.

Briefing on Surface to Air Electronic Warfare Threats: "The committee recognizes that advanced enemy threat systems continue to evolve and modernize and as a result could be immune to current U.S. defensive systems, including Air Force electronic warfare (EW) jamming systems. The committee further recognizes that existing radar guided surface-to-air systems can detect and identify legacy jamming signals, which could significantly increase U.S. military aircraft vulnerabilities for deployed military air crews. Therefore, the committee directs the Secretary of the Air Force to conduct an advisability and feasibility analysis of developing open standards compliant advanced threat system exploitation techniques that could rapidly defeat advanced threat systems within an open system framework. The committee believes this technology could provide increased protection to U.S. military aircraft, resulting in increased mission effectiveness and air crew survivability. The committee further directs the Secretary of the Air Force to provide a briefing to the House Committee on Armed Services by February 1, 2020 on the results of this analysis, as well as update the committee on current actions being taken to improve current EW jamming systems."

Electronic warfare planning for near-peer adversaries: "The Department of Defense's 2013 Electromagnetic Spectrum Strategy recognizes that Department operations in all domains are fundamentally dependent on our use and control of the electromagnetic spectrum. All joint functions such as movement and maneuver, fires, command and control, intelligence, protection, sustainment, and information are accomplished with systems that use the spectrum. The safety and security of U.S. citizens, the effectiveness of U.S. combat forces, and the lives of U.S. military members, our allies, and non-combatants depend on spectrum access. More recently, in December 2018, the Government Accountability Office issued an Emerging Threats report that similarly echoed that adversaries are developing electronic attack weapons to target U.S. systems with sensitive electronic components, such as military sensors, communication, navigation, and information systems. These weapons are intended to degrade U.S. capabilities and could restrict situational awareness or may affect military operations. The committee is concerned about the extent to which the Department is planning and preparing to defend itself and operate in an environment where peer and near-peer adversaries could use existing and emerging capabilities that degrade use of the electromagnetic spectrum.

"Therefore, the committee directs the Comptroller General of the United States to assess the Department's electronic warfare and electromagnetic spectrum operations strategy and implementation efforts. The assessment should include the current electronic warfare threat from peer or near-peer adversaries and actions the Department has taken in response to include the protection of critical warfighting capabilities; the extent to which the Department has incorporated current and emerging electromagnetic spectrum risks into service and combatant command operational planning efforts and exercises; the status and effectiveness of the Electronic Warfare Executive Committee established by the Secretary of Defense in 2015; the Department's implementation of the 2013 Electromagnetic Spectrum Strategy; and any other matters the Comptroller General determines to be relevant.

"The committee further directs the Comptroller General to provide a briefing to the House Committee on Armed Services not later than March 1, 2020, on preliminary findings, and to present final results in a format and timeframe agreed to at the time of the briefing."

Joint Electromagnetic Spectrum Operations: "Joint Electromagnetic Spectrum Operations (JEMSO) include all activities in military operations to successfully plan and execute joint or multinational operations to control the electromagnetic operational environment. Electronic warfare planning and management tools can be customized for different services and fielded in almost any deployment environment. Joint electronic warfare planning and management tool technology demonstrations are good initial steps towards managing technologies across a broader integrated electronic warfare system, which have the potential to neutralize and exploit enemy signals and equip combat forces with essential electronic warfare mission-planning capabilities. The committee therefore recommends expeditiously establishing joint electromagnetic spectrum operations cells at the combatant commands and ensuring they are equipped with the right resources and technology to successfully meet mission needs."

The Committee Report also addresses several EW items at the program level:

B-2 Spirit Defensive Management System (DMS-M): The Committee noted its continued support of the B-2 DMS-M program. However, it stated its concern about the "… significant DMS–M schedule delays and many substantial challenges highlighted in a recent Defense Digital Service Discovery Sprint report. Unless the B–2 DMS–M program makes significant changes there may continue to be delays that will impact the success of the program. During testimony at a Seapower and Projection Forces subcommittee hearing on March 14, 2019, the Air Force confirmed its commitment to the DMS–M program, and the committee agrees that the program is necessary to ensure the B–2 can operate in all future environments. Therefore, the committee directs the Secretary of the Air Force to provide a briefing to the House Committee on Armed Services by February 28, 2020, on its efforts to address the major areas of concern across the DMS–M program identified by the Defense Digital Service. Such brief shall include the associated schedule and closure plan to address the following items: sufficient government software development expertise; contract definitization schedule; delivery schedule; determination of software baseline; and assessment of related program support of DMS–M."

Joint Threat Warning System: "The committee recognizes that the Joint Threat Warning System (JTWS) provides credible threat warning and intelligence information to special operations forces (SOF). The committee notes that this program has been critical to enhancing the situational awareness of SOF elements by alerting them to threats to the force and illuminating targeting opportunities. The committee is concerned that the program does not include an air-variant precision high frequency band capability. This gap in coverage exposes SOF operators to unknown threats and decreases their situational awareness. Therefore, the committee directs the Commander, U.S. Special Operation Command to provide a briefing to the House Committee on Armed Services not later than December 1, 2019, on efforts to address this critical air-variant high frequency gap in coverage."

Radio frequency countermeasures for rotary wing aircraft: "The committee supports the Department's commitment to modernizing the vertical lift and rotary-wing capabilities across the services. The committee also notes with concern the rapid development and proliferation of advanced radio frequency threat systems that would possess the ability to engage rotary-wing aircraft currently operated by the Army, Navy, Marine Corps and Air Force. Therefore, the committee directs the Secretary of Defense to provide a briefing to the House Armed Services Committee, no later than January 31, 2020, that includes: a near and long-term acquisition and development strategy to provide radio frequency countermeasure (RFCM) protection for current and future rotary wing aircraft for each of the military services. The briefing should also include all current rotary-wing RFCM production programs and address any additional applicable programs with mature technology readiness levels."

SIGINT

Unified Air Force Airborne Signals Intelligence Enterprise: "The committee notes the goal of the Air Force Airborne Signals Intelligence (SIGINT) Enterprise (ASE) program is to produce an integrated, service-wide, capability-focused SIGINT architecture and investment strategy for the U.S. Air Force (USAF). However, the committee observes that while investment in the ASE program has produced significant advances in Air Force SIGINT capability, particularly within the RC–135 Rivet Joint program, the establishment of a true integrated airborne SIGINT enterprise architecture continues to elude the USAF. The committee is aware that significant capability gaps exist in MQ–9 SIGINT sensor relevancy against current threats, and the Air Force has not yet successfully addressed vanishing vendor issues with the high-altitude Airborne Signals Intelligence Payload (ASIP) program. Additionally, the USAF has not yet achieved a unified enterprise for SIGINT processing, exploitation, and dissemination (PED), despite having a distributed technical architecture within both the RC–135 Rivet Joint and Air Force Distributed Common Ground System (AF–DCGS) programs. The committee believes the Under Secretary of Defense for Intelligence should lead synchronization efforts with the intelligence community to integrate like data sources to enable more comprehensive analysis and exploitation on behalf of the military services.

"Therefore, the committee directs the Secretary of the Air Force to provide a report to the House Committee on Armed Services by March 1, 2020, containing the Air Force's vision, strategy, and implementation plan to utilize Air Force airborne SIGINT program resources to establish a unified airborne SIGINT enterprise based on shared joint and intelligence community standards. The committee looks forward to additional clarification on how this enterprise will allow RC–135, U–2, RQ–4, MQ–9, Air Force DCGS SIGINT systems, and future SIGINT capabilities to operate as an integrated enterprise using cloud-based technologies and distributed crew concepts to directly deliver SIGINT data to the joint force from a global Air Force SIGINT system."

A separate section of the Committee Report prohibits any use of FY2020 funds to retire – or prepare to retire – RC-135 aircraft "until 60 days after the date on which the Secretary of Defense certifies to the congressional defense committees that equivalent RC–135 capacity and capability exists to meet combatant commander requirements…"

The Senate has already passed its version of the FY2020 NDAA. The House and Senate will iron out differences in their respective bills via a conference process. – *JED Staff*

IN BRIEF

NAVAIR's **Airborne Electronic Attack Program Office (PMA-234)** announced that it will issue a "…full and open solicitation for a Cost Plus Incentive Fee (CPIF) contract for the Next Generation Jammer (NGJ) Low Band (LB) Capability Block 1 (CB1) phase of the Next Generation Jammer (NGJ) program. The contract will include the design, development, production, integration, and test of 2 Captive Mass Model Aeromechanical Pods, 4 Jettison Mass Model Pods, 2 Mission System Prototype Test Pods, 8 Operational Prototype Pods and 2 Technique Development Stations to deliver a complete solution for low band capability. This effort is estimated for award in the 4th quarter of 2020 for a performance period of approximately five years." The US Navy has also announced plans to solicit a proposal from EA-18G prime contractor **Boeing** to support the integration of the NGJ Low Band system on the Growler.

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The Program Executive Office Special Operations Forces Warrior (PEO-SW) and **Joint Special Operations Command (JSOC)** will conduct a combined 2019 SWORDS/JCTE (previously SOFWIC) event on November 6. This event will provide industry an opportunity to learn about JSOC needs and present solutions. Among the areas of interest are "Electronic Countermeasures (ECM)" (seeking increased battery power density and high-performance multiband antennas that can be used for EW and communications) and "Counter-Unmanned Aerial Systems (C-UAS)" (seeking passive radar, drone autopilot detection, LTE detection and kinetic defeat). White paper proposals can be submitted through the Vulcan SOF website (www.vulcan-sof.com). Proposals are due by August 8.

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Naval Sea Systems Command (Washington, DC) is conducting market research and seeking industry input for its plan to buy anti-ship missile decoy rounds for the four Multi-Mission Surface Combatants (MMSCs) that the Kingdom of Saudi Arabia is buying via the Foreign Military Sales (FMS) program. NAVSEA intends to procure 388 IR seduction 130-mm decoy rounds, 388 RF seduction/distraction 130-mm decoy rounds and 12 "drill" rounds of each type. The decoys will be launched from 130-mm Automated Launcher of Expendables (ALEX) systems, and they will be cued by the WBR-2000 ESM system from Boeing. The point of contact is Steven Noel, (202) 781-0517, e-mail steven.w.noel@navy.mil.

✪ ✪ ✪

The **Air Force Research Lab's Directed Energy Directorate** has awarded four contracts for its Compact High Energy Laser Subsystem Engineering Assessment (CHELSEA) program, which aims to identify, quantitatively analyze and assess candidate technologies for significant increases in power over the current Self-protect High Energy Laser Demonstrator (SHiELD) Advanced Technology Demonstration design. CHELSEA is intended to identify the most promising technology options to scale laser power by calendar year 2024 as a possible drop-in replacement for the SHiELD laser subsystem (Laser Advancements for Next Generation Compact Environments (LANCE)) or as part of a new, prototype laser system for airborne applications. The four contracts were awarded to Boeing (Albuquerque, NM) ($748,942); Lockheed Martin Aculight Corp. (Bothell, WA) ($749,363); Northrop Grumman (Redondo Beach, CA) ($699,953); and Shafer Aerospace, Inc. (Albuquerque, NM) ($704,324).

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The US Air Force's **Program Executive Office for Agile Combat Support, Simulators Program Office,** has issued a Request For Information for Man in the Loop (MITL) Threat Stations. The Air Force's Virtual Test and Training Center (VTTC), which is currently under construction at Nellis AFB, NV, will comprise a number of networked simulators to support testing of new capabilities, performing training and developing new tactics. Part of this effort entails developing manned adversary stations to enhance the realism of the training exercises. The MITL stations will be software reconfigurable and will simulate a number of different types of adversary threat aircraft, including radar, infrared search and track (IRST), datalinks, weapons, Communication Navigation and Identification (CNI), and integration of those capabilities with other aircraft in the adversary formation and ground stations (e.g., Integrated Air Defense System components). The point of contact is Lt DeAndre Schoultz, e-mail deandre.schoultz.2@us.af.mil.

world report

J-MUSIC DIRCM TESTED ON NATO MMF A330 MRTT

NATO, Airbus Defence and Space, and Elbit Systems have successfully executed the integration of the J-MUSIC directed infrared countermeasures (DIRCM) self-protection system onboard the A330 Multi-Role Tanker Transport (MRTT) aircraft of the NATO Multinational Multi Role Tanker Transport Fleet (MMF).

J-MUSIC has been designed to protect large aircraft, including transports, tankers, special mission platforms, VIP jets and others. The system marries a fiber laser with a high-frame-rate thermal camera and a small, dynamic high-speed sealed mirror turret.

The three-day long integration flight tests performed at the end of May 2019 at the Madrid-Getafe airfield were led by Airbus team, supported by Elbit Systems engineers and monitored by representatives of NATO Support and Procurement Agency (NSPA) and the Organization for Joint Armament Co-operation (OCCAR). During these flight tests, the J-Music DIRCM system demonstrated the ability to defeat multiple threat types while the A330 MRTT executed a series of flight maneuvers. The integration flight tests also established that the J-Music DIRCM system could handle simultaneous threat scenarios and overcome head-on, tail-on and side-on threats, from several ranges and at different altitudes.

The MMF program is a multinational pooling and sharing initiative in which five nations (Belgium, Germany, Luxembourg, the Netherlands and Norway) are jointly acquiring, managing, operating and supporting a fleet of eight A330 MRTT aircraft from Eindhoven and Cologne. The aircraft, procured by OCCAR from Airbus, are owned by NATO and managed by the NSPA. The delivery of the first A330 MRTT for the MMF fleet is planned to be completed by 2020.

Under a separate activity, Elbit has been awarded a $73 million contract by Diehl Defence to provide J-MUSIC DIRCM systems for Luftwaffe Airbus A400M aircraft. Under the contract, to be performed over a four-year period, Elbit Systems will supply J-MUSIC systems and work with Diehl and Airbus Defence and Space to integrate the DIRCM capability into the A400M Defence Aid Support Systems self-protection suite. – *R. Scott*

ELECTRONIC WARFARE HIGHLIGHTS FROM THE PARIS AIR SHOW

In mid-June, France hosted the 53rd International Paris Air Show in Le Bourget, where several companies discussed their latest EW developments. Hensoldt's new Twlnvis passive radar, launched at the ILA Berlin Air Show in 2018, will be ready for shipment with the first serial production units by the end of the year 2019, company officials disclosed to *JED*. According to Martin Russ, sales director for naval and ground systems at Hensoldt, a single TwInvis passive radar is able to process an air surveillance picture for a range of up to 250 km and an altitude of 45,000 ft. For wider areas, it's possible to cluster more radar sensors. One sensor can simultaneously process 16 FM analogue radio and 5 DAB digital radio transmitters as well as 5 DVB-T digital TV networks. Providing permanent 360-degrees in protection, Twlnvis radars are able to provide 3-dimensional tracking of aircraft with a very high track update rate of 0.5 seconds, allowing for the detection of high dynamic maneuvering fighters, as well.

Leonardo unveiled its latest missile warning system at the air show. The Multi-Aperture Infra-Red (MAIR) has been designed to provide air crews with spherical missile warning coverage together with day and night imaging, hostile fire indication (HFI) and infrared search and track (IRST) capabilities. Rotary-wing aircraft are able to carry between 4-8 MAIR payloads, depending on aircraft size. MAIR, which underwent its first test during Surface-to-Air Launch Trials in 2018, is expected to enter full rate production in 2020. Leonardo is considering the integration of MAIR with its line of fixed and rotary wing EW products, which includes potential contracts with the Italian Air Force. Leonardo is also seeking to integrate MAIR with EW systems for use on VIP aircraft. Flight certification of the MAIR is due to be completed at the end of 2019, with a focus on environmental tests.

Thales discussed its research in Artificial Intelligence (AI) for EW applications. In his briefing about AI and big data for EW, Eric Segura, system architect, described the company's efforts to develop a "neural antenna" – a network of wideband digital receivers – to support the detection of agile, LPD radars. A second neural network development effort is directed at identifying the agile radars and determining which are military radars and which are, perhaps, civilian air traffic control radars. Rather than analyzing a limited set of radar parameters (frequency, pulse width, PRI, etc.), the neural network attempts to identify the radar by looking at the "whole" signal, analyzing a new set of parameters and determining its purpose and intent (military radar vs. civilian air traffic control radar, for example). Segura said both neural systems, because they depend on AI, require large amounts of collected data to train the AI algorithms. – *A. White and J. Knowles*

The RFSoC Upends t

By Barry Manz

Crafting an EW system today is a challenge that appears to have no limit. Designers are faced with increasing functional integration, providing greater signal processing capability, reducing latency, lowering power consumption, dealing with a growing number of channels and transferring massive amounts data at higher speeds – all in the smallest possible space. Without some new technological miracle, there is no easy way to check all these boxes, but the RF System on Chip (RFSoC) is a major step in the right direction.

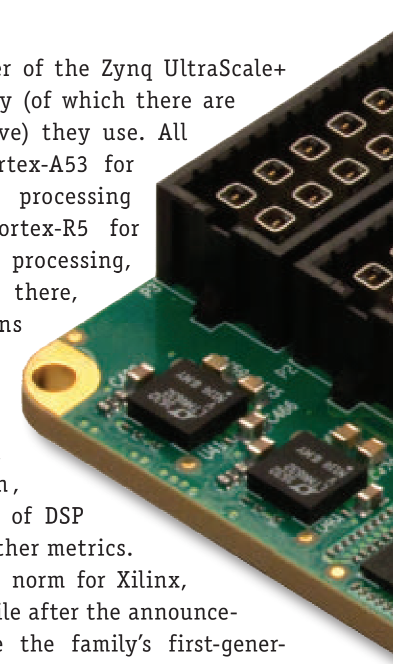
The term SoC has been applied liberally in recent years to cover devices that perform multiple functions previously requiring discrete devices, although they aren't complete systems in the strictest sense. Nevertheless, they save space on circuit boards, consume less power, have fewer interconnects and provide other benefits derived from consolidating functions with a single device. At the actual system level, they make it possible to add more functionality within a rack, LRU or other platforms, and in the commercial and consumer markets, they have even allowed entirely new types of products to be realized.

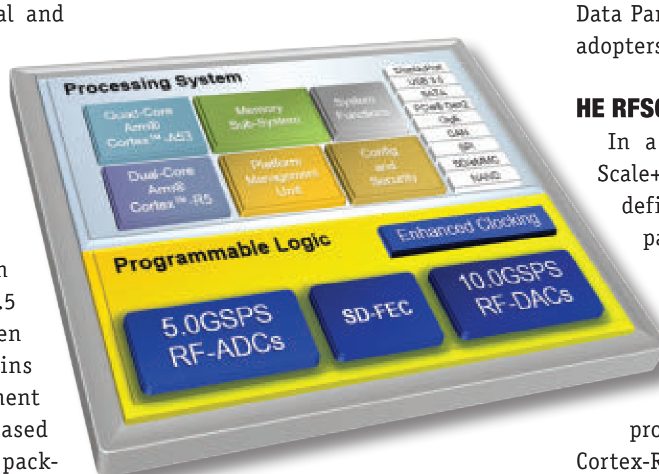
An excellent example in the commercial sector is Qualcomm's QTM052 RFSoC for 5G smartphones and small base stations. It provides 800 MHz of bandwidth at frequencies including 26.5-29.5 GHz, 27.5-28.35 GHz, and between 37 and 40 GHz. The RFSoC contains a 5G transceiver, power management IC and an entire 24-element phased array antenna – in an 18 x 5-mm package. The device can perform beamforming, steering and tracking, and it can route signals to four antennas mounted in each corner of the phone to deal with issues arising from mobility, hand placement and varying positions. That will be essential, as propagating millimeter-wave signal into and out of a smartphone held in someone's hand will be a huge challenge.

THE XILINX APPROACH

The Xilinx Zynq UltraScale+ RFSoC portfolio introduced in 2017 follows the same basic script, but with significant differences, and is arguably the most interesting recent product with benefits for defense systems. "It's an amazing device for many reasons," says Rodger Hosking, co-founder and vice president of Pentek (Upper Saddle River, NJ). "Xilinx spent years developing this type of device, and the converters they created are truly world class, which is very impressive for a company that never offered ADCs or DACs before."

Although various embedded system manufacturers claim to be the first to introduce a product based on the RFSoC, each one takes a different approach, including form factor and which specific member of the Zynq UltraScale+ RFSoC family (of which there are currently five) they use. All use the Cortex-A53 for application processing and the Cortex-R5 for real-time processing, but from there, specifications diverge between 8 or 16 ADCs, 12-or 14-bit resolution, the number of DSP slices and other metrics.





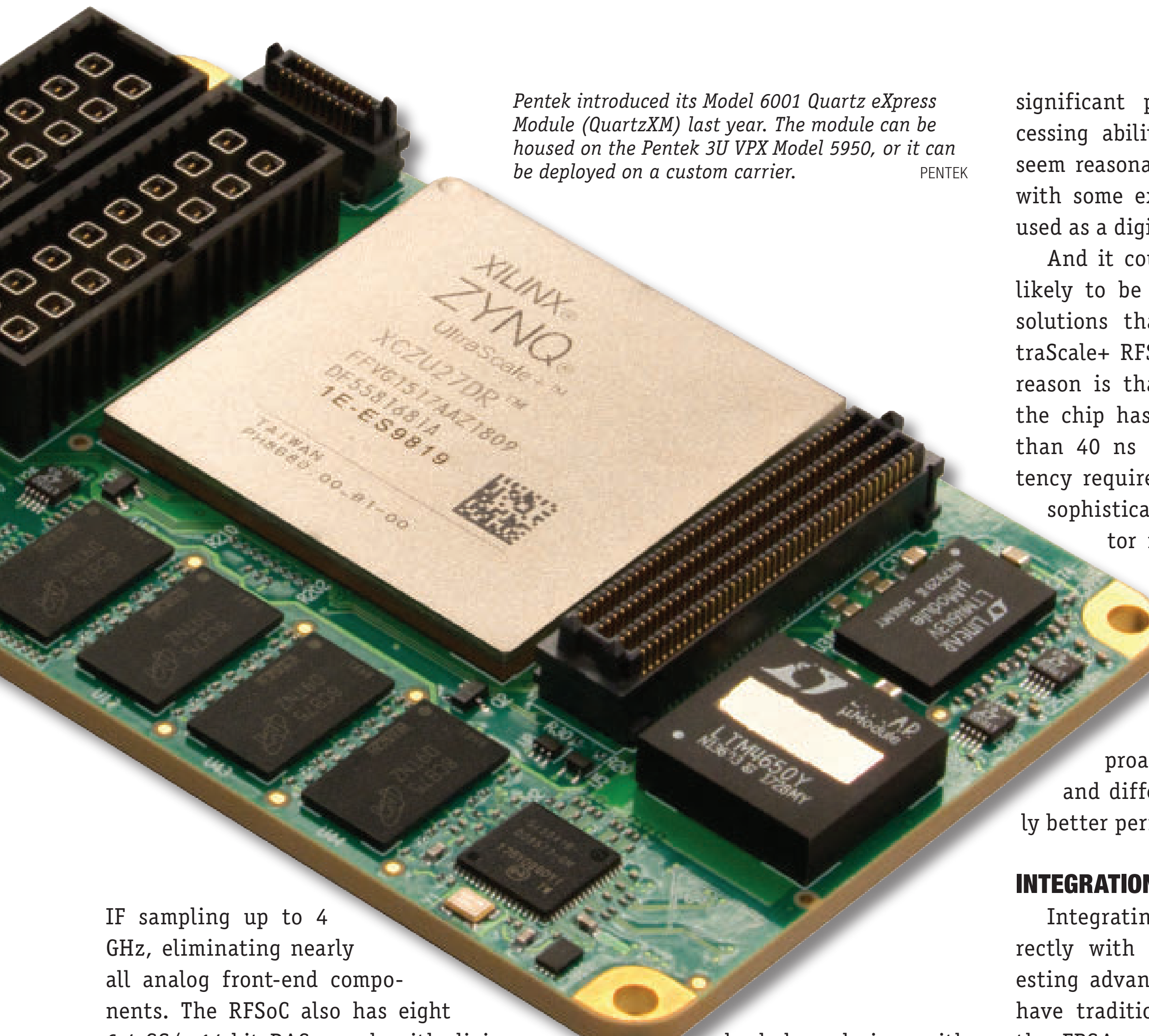
The Zynq UltraScale+ RFSoC Gen 3 from Xilinx, which will begin shipping in the second half of 2019, covers the entire sub-6GHz spectrum.
XILINX

As is the norm for Xilinx, it took a while after the announcement before the family's first-generation devices and development tools got into the hands of embedded systems manufacturers. Beginning late last year, the first board-level products were introduced, and today Pentek, Abaco Systems, Annapolis Micro Systems, Vadatech, HiTech Global, Samtec, Panateq, IRES Technologies and Alpha Data Parallel Systems remain the "early adopters."

HE RFSOC

In a basic sense, the Zynq UltraScale+ RFSoC is a complete software-defined radio in a 40 x 40-mm BGA package. It builds on the previous Xilinx UltraScale+ MPSoC (multiprocessor system-on-chip) FPGA-based architecture with four 64-bit quad-core ARM Cortex A53 application processors and two dual-core ARM Cortex-R5 real-time processors. To make this into an RFSoC, Xilinx adds eight 4-GS/s 12-bit or 14-bit ADCs, each with programmable digital downconverters. The ADC sampling rate allows direct RF/

he Design Paradigm



Pentek introduced its Model 6001 Quartz eXpress Module (QuartzXM) last year. The module can be housed on the Pentek 3U VPX Model 5950, or it can be deployed on a custom carrier. PENTEK

IF sampling up to 4 GHz, eliminating nearly all analog front-end components. The RFSoC also has eight 6.4-GS/s 14-bit DACs, each with digital upconverters. The DACs generate an output carrier frequency up to 4 GHz using the second Nyquist zone at a rate of 6.554 GS/s, include programmable interpolation and decimation, and can support dual-band operation.

For interfacing to external memories for data or configuration storage, the processing system includes DMA, NAND, SD/eMMC and SPI controllers PCIe Gen 3, and 100 Gb/s Ethernet. Interlaken chip-to-chip data at 150 Gb/s is transported via a high-speed serial interface. The serial transceivers transfer data up to 28.2 Gb/s, enabling very-high-speed backplane designs with lower power consumption per bit than previous generation transceivers.

The RFSoCs also have clock management circuitry, including clock synthesis, buffering, and routing components that together provide flexible distribution of clocks to minimize the skew, power consumption and delay. Secure-boot capability is supported via 256-bit AES-GCM, and SHA/384 and 4096-bit RSA blocks. The cryptographic engines are also available for user encryption. As the RFSoC provides an analog-to-digital and digital-to-analog signal path with significant programmable signal processing abilities in between, it might seem reasonable that the chip alone or with some external resources could be used as a digital RF memory (DRFM).

And it could, although DRFMs seem likely to be better served by discrete solutions than the current Zynq UltraScale+ RFSoC, for now at least. One reason is that the first generation of the chip has latency of 145 ns rather than 40 ns (or less) of round-trip latency required to confuse increasingly sophisticated radars. Another factor is that DRFMs are custom subsystems whose "secret sauce" consists of proprietary design techniques, software and other technology. Consequently, a discrete approach offers greater flexibility and differentiation, and potentially better performance.

INTEGRATION BENEFITS

Integrating the data converters directly with the FPGA provides interesting advantages. "As ADCs and DACs have traditionally been separate from the FPGA, a high-speed interface was needed to communicate between them, which in many systems is JESD204B," says Phillip Henson, product manager for RF and DSP at Abaco Systems, one of the first companies to develop a product using the RFSoC. "However, it comes at a cost in terms of latency and design complexity."

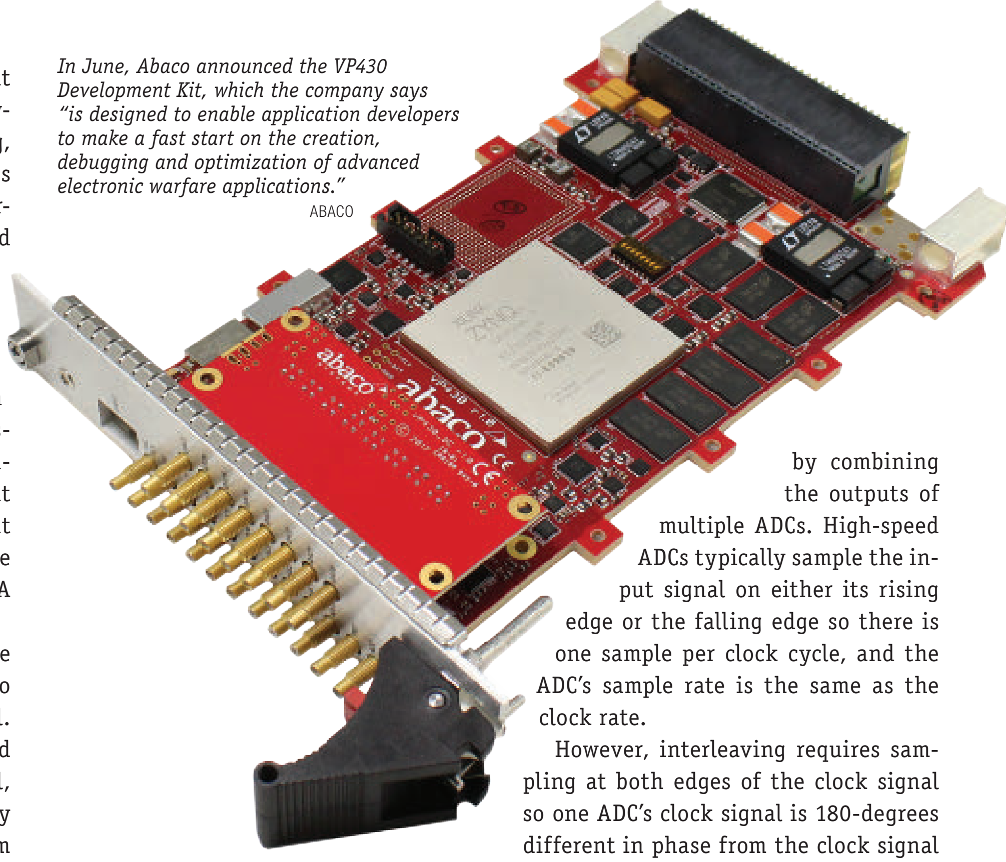
For example, consider a case in which a 12-bit ADC is connected to an FPGA using a parallel interface where each bit is represented by a Low-Voltage Differential Signaling (LVDS) pair with an additional pair used for clock synchronization. If the interface uses double data rate (DDR) technology, the amount of data transferred in a single clock cycle is doubled. "However," says Hosking, "even with DDR, sampling frequencies above about 1.5 GHz generate an enormous amount of data, which is beyond the ability of LVDS to transfer it efficiently to FPGAs."

To remedy this, a 1:2 demultiplexed interface can be used to create two separate parallel interfaces, each running at half the sample rate. So, using the 12-bit ADC example, if the converter samples at 2 GHz in every 12-bit path, the demultiplexer is sampling at 1 GHz, below the maximum clock rate that can be accommodated by the FPGA LVDS interface.

But at even higher frequencies, the ADC would need a 1:4 demultiplexer to keep the data to a manageable level. This presents significant design and fabrication problems at the board level, as more signal pairs must be routed very precisely to ensure that data sent from all 12 bits arrives at the FPGA simultaneously. In this scenario, the 12-bit converter would be using four sets of 12 pairs (96 I/O pins plus clock pins) on the FPGA, and with an FPGA that has 400 to 600 I/O pins (a typical number), half of them would be needed just to connect the two 4-GHz converters.

And as there are so many technologies on the board, all their required pins and signal lanes could (if not addressed adequately) cause interference and reduce the high dynamic range of the ADC and DAC. This could also affect clock synchronization, the two 100 Gb/s Ethernet ports that operate over four 28 Gb/s lanes, and the Gen 3 PCIe Gen 3 interface at 8 GHz per lane, as well as the two banks of DDR4 memory.

The JESD204 standard that was created to help solve this problem uses the FPGA's gigabit serial interfaces instead of LVDS, which significantly reduces the number of signals to be routed and mitigates the need for precise matching of trace length. Unfortunately, four lanes of JESD204 consume about 1 W, and as the JESD204 IP core is proprietary, a license is required to use it. The design complexity results from the interface's clocking solution, which is more complicated than parallel interfaces.



In June, Abaco announced the VP430 Development Kit, which the company says "is designed to enable application developers to make a fast start on the creation, debugging and optimization of advanced electronic warfare applications."
ABACO

JESD204 is also well known for its latency limitations, which for many applications make it a non-starter. For example, "a parallel converter interface can delay the data by a few sample clock cycles," says Hosking. "But JESD204 can add 80 sample clock cycles or more, which increases latency from the ADC to the FPGA (and vice versa for the ADC)."

The RFSoC solves these problems to differing degrees because the converters reside within the chip, dramatically reducing the pin count when compared to solutions in which the signals are transferred externally to the FPGA. This, in turn, allows the FPGA to accommodate more channels as more of the device fabric is available.

THE ADCS

The converters used by the RFSoC generate 128 bits of data in parallel at 500 MHz with successive clock pulses using a technique called interleaving, which has been used for some time but presents significant challenges. "It's pretty remarkable that Xilinx can take eight 500-MHz ADCs and interleave samples at 4 GS/s using this method," says Hosking. The interleaving process is employed to achieve higher sample rates by combining the outputs of multiple ADCs. High-speed ADCs typically sample the input signal on either its rising edge or the falling edge so there is one sample per clock cycle, and the ADC's sample rate is the same as the clock rate.

However, interleaving requires sampling at both edges of the clock signal so one ADC's clock signal is 180-degrees different in phase from the clock signal to the other ADC. The outputs of the ADCs are then multiplexed to provide a higher sample rate than that of a single ADC, and this requires identical devices and two clock signals, and adhering to an exact 180-degree phase relationship. If there is any deviation in clock signals from this phase relationship, spurious responses appear in the output, degrading spurious-free dynamic range and thus signal-to-noise ratio. The interleaving process is difficult enough when combining two ADCs, but the Zynq UltraScale+ RFSoC has eight.

"The hard part is calibrating each ADC with the same DC offset gain and linearity," says Hosking. "If one has a DC offset but the other seven match, [then] one of every eight samples will have a DC offset from the others. The challenge is to calibrate the offsets, gains and linearities, and apply calibration factors when the device is initially turned on and dynamically while it's running because of changes in temperature and other factors.

"The problem at initial start-up is that you need the presence of a defined minimum signal, because if it falls below this level, [then] the calibration will not be performed correctly. So, in our QuartzXM module built around the

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RFSoC, we've added some IP in the FPGA within and outside it, which ensures that a signal will be present for the initial calibration by switching in a known good signal. When the signal level during operation falls below this threshold, we freeze calibration at the last known good level and hold it steady until the signal returns to an acceptable level."

THE SWAP-C QUESTION

The most obvious benefit of the Zynq UltraScale+ RFSoC's multifunctional integration is the addition of the ADCs and DACs within the SoC that reduce the bill of materials and cost when compared to the multiple-device approach and reduce the footprint by about 50%, which allows other functions to be added to the board, and reduces weight as well.

An example given by Pentek is illustrative of these benefits. To accomplish the same functions as the RFSoC, a designer would need the following components:

- Multi-core ARM processor
- our 4-GS/s ADCs
- Four 6.4-GS/s DACs
- UltraScale+ FPGA (with the same logic and DSP density as the RFSoC)

In addition to the design challenges and time required to construct and test the resulting circuit, the cost of the discrete components would be about twice that of the RFSoC. In addition, as the ADC is integrated with the FPGA in a single SoC, high-speed parallel processing is possible without the need to precisely route the connections on the board. The RFSoC requires strict attention to DC power as well, as it requires 13 different voltages and currents, all of which must have clean signals and excellent regulation.

The considerable amount of data that the RFSoC can produce requires more than a single way to get the data off the board, beginning with Gen 3 PCIe that can speed along at about 6.4 GB/s. In many subsystems, this is acceptable, but not so with the RFSoC that has eight 4 GS/s ADCs, each generating 8 GS/s, resulting in 64 GB/s incoming data and DACs operating at 6.4 GS/s.

So, PCIe is complemented by two 100-GB/s Ethernet ports in the chip that together deliver 24 GB/s outboard to a switch or other subsystem for archival or analysis. Several companies delivering boards based on the RFSoC convert the Ethernet ports to VITA 66 optical links that have the benefit of zero EMI and RFI and the ability to maintain signal integrity in any environment.

The VERSAL adaptive compute acceleration platform (ACAP) from Xilinx represents a new category of heterogeneous compute devices that the company says features "capabilities that far exceed those of conventional CPUs, GPUs, and FPGAs." XILINX

TODAY AND TOMORROW

While the RFSoC has enormous potential, it's not a panacea for all applications, and like all devices, it has its limitations. "The Zynq UltraScale+ RFSoC lets you shrink your system significantly, especially if have many channels," says Abaco's Hensen. "It's a robust FPGA when you are bringing in two or four channels. But if you're using 16 channels, there is a lot of required filtering that eats up a lot of that resource. The ADCs and DACs also take up some space on the FPGA, but that said, even if you use only four ADC inputs to get 4GS/s at 12 bits, it would be a more difficult to do that in a single slot with a classic FPGA in a carrier."

It's important to remember that these are very early days in what promises to be the long life of Xilinx RFSoCs. In addition to embedded systems companies, defense prime and subcontractors, and various DOD research groups are just now exploring the first-generation device. The third generation will have a higher sample rate and wider analog bandwidth, lower power consumption and enhanced clocking distribution.

Samples of the third-generation device should be available shortly, with production following near the end of 2020. Another version may be dedicated only to the US market (i.e., ITAR restricted) that reduces latency, making it more appealing in applications, such as EW, for which this parameter is critical.

Beyond this, an RFSoC may ultimately be included in the next advance in its FPGAs, called VERSAL, which is what Xilinx calls the industry's first adaptive compute acceleration platform (ACAP). VERSAL combines hardware and software programmability that is designed to be used in any application and simplifies development versus current FPGA solutions.

It features scalar engines, including two Arm Cortex-A72 application processors, two Cortex-R5 real-time processors, more than 2 million logic cells, 3,000 DSP engines for floating-point processing and low latency, and a management controller. It has "intelligent engines" that are very-long instruction word (VLIW) vector processors used for AI and signal processing. The company's goal is to exceed the current capabilities of CPUs, GPUs and FPGAs.

Programmable resources include Xilinx FPGAs that are integrated with a terabit-per-second network on chip (NoC) that connects all the above, communications between them, memory and high-speed I/O. The latter includes 16 lanes of Gen 4 PCIe with a transfer rate of 8 GB/s (twice that of PCIe Gen 3), as well as 32 GB/s via serial transceivers and 100-Gb/s Ethernet.

The first shipments of devices supporting ACAP were made in June. Although ACAP supports the company's larger markets, such as 5G wireless infrastructure, automotive and data center applications, the smaller defense market will also be served, presumably with specific features on interest to radar, EW and SIGINT systems designers, as well as AI for implementing cognitive EW. Although it's too early to make a firm prediction, RFSoC within ACAP seems possible, which would make this device more appealing for defense high-channel-density applications that today's RFSoC technology can't serve.

SPEAKER SPOTLIGHT

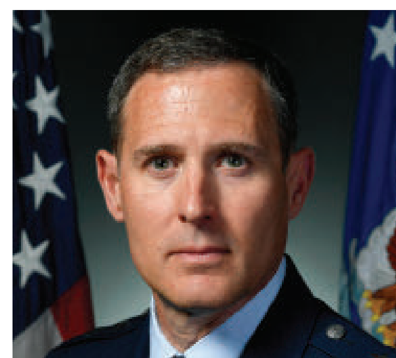
The Honorable Don Bacon
U.S. House of Representatives
NE-02 (Invited)

The Honorable Alan R. Shaffer
Deputy Under Secretary of Defense
for Acquisition and Sustainment

Lt Gen Robert Elder, USAF (Ret'd)
AOC Senior Advisory Board

Dr. Tim Grayson
Director, Strategic Technology
Office (STO), DARPA

James A. Faist, SES
Director, Adv Capability,
OUSD Research & Engineering



Major General David Krumm
Director of Strategic Plans, Office
of the Deputy Chief of Staff for
Strategic Plans and Requirements

Rear Admiral Steve Parode
Director, Information
Warfare Integration (N2N6F)

Brigadier General Giuseppe Sgamba
Assistant Director, Joint Air
Power Competence Centre

Brigadier General Lance Landrum
Deputy Director for Requirements
and Capability Development (J8),
Joint Staff

SYMPOSIUM AGENDA

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Industry (Non-Member)	~~$895~~	$995	$1095
Academia*	~~$445~~	$545	$645
Young Crows (35 and younger)*	~~$445~~	$545	$645
Government Civilian*	~~FREE~~	FREE	FREE
Military in Uniform**	~~FREE~~	FREE	FREE

*Must present proper ID for discounted price:
- Academia - faculty/staff/student ID.
- Young Crows (35 years old and younger) - photo ID with DOB.
- Government Civilian - government ID or civilian CAC card.

**Duty uniform must be worn each day. If not, a fee of $100 will be assessed.

Discounted pricing ends 10/4!

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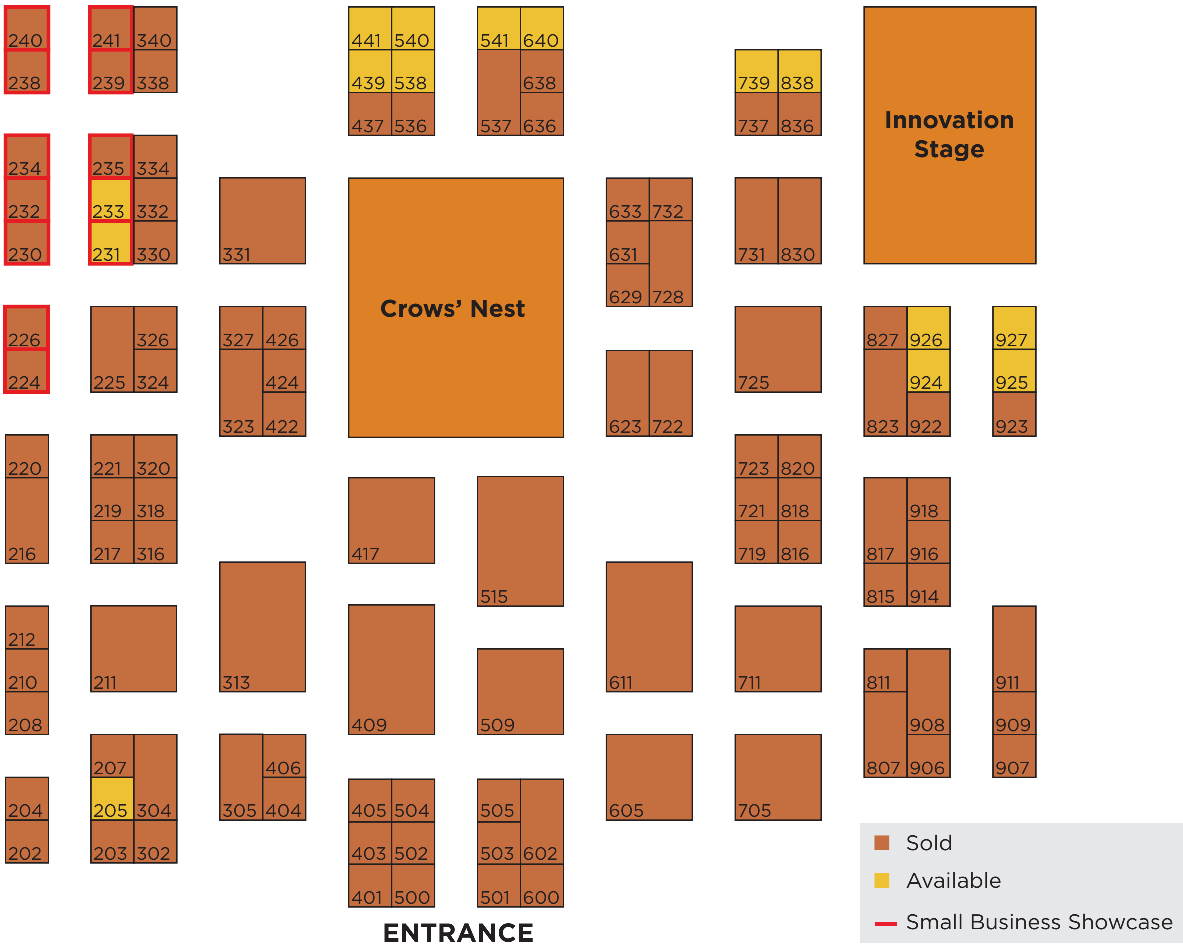
This complimentary registration type provides access to the Welcome Reception and the Exhibit Hall. *It does not allow access into any of the symposium sessions, the Annual AOC Banquet, or any professional development courses.*

	~~By 7/31~~	8/1-10/4	10/5-On-Site
Exhibition Only	~~FREE~~	FREE	FREE

EXHIBIT HALL SPACE IS ALMOST GONE!

Booth space on the convention show floor is almost gone! Don't let the opportunity to exhibit at the biggest Electromagnetic Warfare event of the year pass you by. Check out the available spaces, and see who will be exhibiting at this year's show. Contact **Sean Fitzgerald – fitzgerald@crows.org** or **703-549-1600 x222** for more information. You can learn more at **56.crows.org**.



COMPANY	BOOTH
3dB Labs	217
412TW Benefield Anechoic Facility (BAF)	916
Advanced Test Equipment Rentals	221
Aethercomm	737
Alaris Antennas (Pty) Ltd	202
American Standard Circuits	240
Ampex Data Systems	316
Analog Devices	731
Annapolis Micro Systems, Inc.	911
Antenna Research Associates, Inc.	338
AOC EW Europe	210
API Technologies Corporation	207
ApisSys	502
Applied Thin-Film Products	212
ASELSAN A.S	334
Atlanta Micro, Inc.	437
Azure Summit Technology	203
BAE Systems	515
Boyd Corporation	503
Cobham	605
Communication Power Corporation	922
Communications & Power Industries LLC	302
Comtech PST	327
Conduant Corporation	239
CRFS	211
dB Control	500
Deepwave Digital	232
Digital Receiver Technology (DRT)	330
Directed Energy Professional Society (DEPS)	340
Dixie Crow Chapter AOC	406
D-TA Systems	633
Elbit Systems	817
Elite RF	241
Empower RF Systems	807
ENGIN-IC, Incorporated	226

COMPANY	BOOTH
Epiq Solutions	318
ESROE Limited	224
FEI-Elcom Tech	816
Ferrite Microwave Technologies	918
General Dynamics Mission Systems	728
Georgia Tech Research Institute	404
Giga-tronics	323
Gowanda Components Group	820
Harris	409
Interface Concept	815
iRF-Intelligent RF Solutions	732
Keysight	602
Kratos General Microwave	505
L3 Technologies	313
Leonardo DRS	908
Lexatys, LLC	238
Lockheed Martin	705
MC Countermeasures Inc.	332
Meggitt	504
Mercury Systems	623
Metamagnetics	914
Microwave Products Group	405
Microwave Specialty Company	719
Motorola Solutions, Inc.	818
National Instruments	304
Northrop Grumman	509
NuWaves Engineering	923
Ophir RF	723
Pasternack	204
Patria	631
Pentek	422
Photonis Defense Incorporated	426
Physical Optics Corporation	424
Planar Monolithics Industries, Inc	907
Plexsa Manufacturing	827

COMPANY	BOOTH
Procitec GmbH	501
PSI Cases	235
Q Microwave, Inc.	401
Qorvo	320
Raytheon Company	417
Research Electronics International	324
Rohde & Schwarz	611
Rotating Precision Mechanisms Inc	219
Saab Defense and Security	537
Schaefer Electronics Inc	216
Select Fabricators	909
Sierra Nevada Corporation	811
Signal Hound	722
Silver Palm Technologies	326
Spectranetix	600
SRC, Inc.	305
Syncopated Engineering Inc	230
Syntonic Microwave	208
TCI	725
TE Connectivity	638
Tektronix, Inc.	830
Teledyne Defense Electronics	711
Terma North America	823
TEVET	636
Texas Instruments	836
Textron	331
TMD Technologies, LLC	721
TrustComm	220
ULTRA ELECTRONICS - EWST	906
Vadum Incorporated	234
VectorNav	629
VIAVI Solutions, formerly Aeroflex	536
Wideband Systems	403

Space subject to change, accurate as of 7/9/2019

TECHNOLOGY SURVEY

A SAMPLING OF EW AND SIGINT ANTENNA SYSTEMS

By John Knowles

This month, our technology survey takes a look at antennas that are designed for electronic warfare (EW) and signals intelligence (SIGINT) applications. EW and SIGINT requirements typically call for wideband performance, and this includes the antenna – or antennas, if the system uses an array.

Many EW design engineers have cut their teeth working on antenna design projects early in their careers because this teaches them how to trade-off between many variables, such as antenna size, type and frequency coverage, radiation patterns and area coverage, while also working with available antenna locations on the host platform. Despite the science, there is still a bit of art involved in antenna selection and location on the platform, and this is especially true in EW and SIGINT.

While there are a lot of "classic" antenna types, as seen in the survey, antenna technology is continually improving, in part because of evolving EW and SIGINT requirements. Stealth requirements have been a significant technology driver. Weapons platforms that feature low-observable designs, such as 5th Gen aircraft, typically require conformal antennas embedded in the skin or structures of the aircraft. On ships, which can feature dozens of antennas for radars, HF/VHF/UHF tactical communications, SATCOM, EW, GPS, IFF, etc., an ongoing trend is to reduce the radar signature by combining these antennas into a smaller number of multifunction arrays. As Active Electronically Scanned Array (AESA) technology becomes more common in EW programs, the Defense Advanced Research Projects Agency (DARPA) has been working on programs, such as Arrays at Commercial Timescales (ACT), to lower the cost and shorten the development time.

Another antenna technology driver is the commercial market, which has needs for compact, low-cost millimeter-wave antennas for anti-collision radars on automobiles, as well as for 5G and other wireless applications. While many commercial applications are inherently narrowband, they are pushing antenna technology into higher frequencies and smaller packages. This provides an expanding technology base for the defense industry leverage and further develop wideband EW antenna technologies.

THE SURVEY

The survey table that follows lists antenna products from 32 companies. The first column indicates the antenna model number. The second column describes the type of antenna or array. Next is the antenna's operating frequency range. As mentioned earlier, EW and SIGINT antennas typically are designed to operate over a very wide range of frequencies.

This US Air Force RC-135W Rivet Joint, seen taking off from RAF Mildenhall in the UK, displays a variety of SIGINT antennas, such as the blade antennas beneath the fuselage, as well as "cheek" arrays behind the cockpit. ALAN WILSON

The fourth column lists the antenna's gain characteristics. Antenna gain is a crucial parameter for EW and SIGINT system engineers. Higher gain translates into less signal amplification further down the receiver signal path. For jamming applications, higher gain also means greater ERP. Jamming antennas can be highly directional, such as log-periodic dipole antennas, or omnidirectional. AESAs, which use hundreds and even thousands of individual transmit/receive elements, can provide variable gain and beamwidth.

The next column describes the antenna's polarization – circular or linear. The following column describes how many antenna elements are used. A single omnidirectional monopole antenna uses one element. A direction-finding array typically uses multiple elements (typically at least four and up to 40 or more).

The remaining columns describe the antenna's size, weight and which types of weapons platforms it is suited for. Although this survey is focused on EW and SIGINT antennas, you'll see that it covers a wide range of antenna types.

NEXT TECHNOLOGY SURVEY

Our next technology survey, which will appear in our December issue, will cover electronic intelligence (ELINT) receivers. Please e-mail JEDEditor@naylor.com for a survey questionnaire.

EW AND SIGINT ANTENNA SYSTEMS

MODEL	ANTENNA TYPE	OP FREQ	ANTENNA GAIN	POLARIZATION	ELEMENTS
Aaronia USA (a division of Kaltman Creations LLC); Seneca, SC, USA; +1 (864) 885-0700; www.AaroniaUSA.com					
BicoLOG 20300	Biconical	20 MHz - 3 GHz	1 dBi	Vertical, horizontal	2
OmniLOG 30800	Omni	300 MHz - 8 GHz	3 dBi	Vertical	1
IsoLOG 3D Array	Omni Array	9 KHz - 40 GHz	Varying	Vertical, horizontal	16-40
Alaris Antennas; Centurion, Gauteng, South Africa; +27 11 034 05300; www.alaris.co.za					
DF-A0095	Wideband Portable DF	1 MHz - 6 GHz	*	Vertical	5
LPDA-A0121	High-power LPDA	400 MHz - 6 GHz	8 dBi typ.	Linear	1
OMNI-A0244	Active Monitoring Antenna	20 MHz - 6 GHz	5-10dBi typical	Vertical	1
Antenna Authority Inc.; Douglasville, GA, USA; +1 (770) 577-7969; www.AntennaAuthorityinc.com					
CBS-12	Spiral	250 MHZ - 3.2 GHz	-6-3.5 dBic	RHCP, LHCP	1
CBS-24	Spiral	100-1900 MHz	-15-3.5 dBic	RHCP, LHCP	1
LPD-600	Log periodic	600 MHz - 18 GHz	0-6 dBi	Vertical, horziontal	1
Applied EM Inc.; Hampton, VA, USA; +1 (757) 224-2035; www.appliedem.com					
AEM-DFA-01	Array	75-2000 MHz	Varying	Circular	*
AR RF/Microwave Instrumentation; Souderton, PA, USA; +1 (215) 723-8181; www.arworld.us					
ATT700M12G	Trapezoidal log periodic	700 MHz - 12 GHz	8 dBi	Vertical, horizontal	*
LP425	Log Periodic	400 MHz - 3 GHz	7 dBi	Vertical, horizontal	*
LP425PCB	PCB	400 MHz - 3 GHz	5.5 dBi	Vertical, horizontal	*
ARA, Inc.; Beltsville, MD, USA; +1 (301) 937-8888; www.ara-inc.com					
SAS-218-22FSL2	Omni	20 MHz - 18 GHz	0 dBi typ.	Vertical	High band and low band
SAS-0518-C3275	Omni/Directional	0.5-18 GHz	0 dBi / 6-20dBi	Slant	Omni / Directional
LPD-1230-108	Directional	120-3000 MHz	6 dBi nom.	Linear	*
ASELSAN; Ankara, Turkey; +90 312 592 60 00; www.aselsan.com.tr					
SPINDF-0540-DP	Spinning DF	0.5-40 GHz	5-16 dBi	Dual Linear	*
SPIRAL-0540-RHCP	Spiral DF Array elements	0.5-40 GHz	-6-4 dBi	LHCP, RHCP	*
OMNI-0540-LP	Omni Array	0.5-40 GHz	0 dBi typ.	V, L, Slant	*
Cobham Antenna Systems; Newmarket, United Kingdom; +44 1638 732177; www.european-antennas.co.uk					
XPO2V-0.3-10.0/1381	Biconical	0.3-10.0GHz	0-3 dBi	Vertical	1
FPA7-0.7-6.0R/2294	Reflector Spiral	0.7-3.0 GHz optimized; 0.4-6.0 GHz extended	4-8 dBiC	Right Hand Circular	1
XPO2V-4.0-18.0/1382	Biconical	4.0-18.0 GHz	0-3 dBi	Vertical	1
Cobham Integrated Electronic Solutions; Lansdale, PA, USA; +1 (215) 996-2000; www.cobham.com					
948-00568	Cross-Notch	2-18GHz	*	Dual-Linear	1
AAIU-2154	Interferometer	2-18 GHz	*	Circular	4
AESA-0020	AESA	2-6 or 6-18GHz	*	Linear	1100

SIZE (HxWxL in inches or mm)	WEIGHT	PLATFORM	FEATURES
350 x 160 x 140 mm	350 g	Handheld, grd-fix	Passive or active versions.
173 x 62 x 9 mm	54 g	Grd-mob	90 degree knuckle.
800 x 800 x 300 mm	10 kg	Grd-fix, grd-mob	360 Degree DF, drone detection.
731 x 1100 mm	33 kg	Fixed & mobile mast mount	2-3 degree RMS Accuracy , lightweight, correlative interferometer with HF and omni capability.
770 x 450 mm	3.7 kg	Mounting bracket	High power (100W), wideband, rugged LPDA.
475 x 102 mm	< 2.5 kg	Vehicle mount	Wideband, compact vehicle-mount monitoring antenna.
12 x 12 x 5 in.	5 lb	Grd-mob	Handheld
24 x 24 x 5 in.	15 lb	Grd-mob	Handheld
12 x 9 in.	7 oz	Grd-mob	Handheld
16 x 6 in.	8 lb	*	High-accuracy DF for low- and high-frequency bands.
28 x 28 x 55 cm	1.7 kg	Grd-fix	High power handling; flat gain; wide beamwidth; lightweight.
18 x 41 x 48 cm	1 kg	Grd-fix	Rugged construction, low PIM, optional powdercoat finish with UV inhibitors.
1.3 x 29.2 x 39.4 cm	1 kg	Grd-fix	Rugged construction; weather resistant; compact design; easy mounting to any flat surface.
18 x 18 (d) in.	20 lb	Grd-mob, grd-fix	Active or passive configurations and fiber-optic output option.
50 (h) x 40 (d) in.	210 lb including ACU controller	Grd-fix, shp	DF with optional 0.5-18 GHz slant omni; 200 RPM.
60 x 50 x 6 in.	17.5 lb	Grd-mob, grd-fix	No tools for setup. <2 minute deploy and stow in supplied storage tube.
1.2 (h) x 1 (d) m	120 kg	Grd-fix	200 RPM max, compact versions for air platforms are also available.
25 (d) x 8.5 (h) cm	1.5 kg	Grd-fix, air, shp, sub	Frequency limitations may occur due to the size constraints of the platform.
50 (d) x 50 (h) cm	9 kg	Grd-fix, air, shp, sub	Frequency limitations may occur due to the size constraints of the platform.
6.5 (d) x 14 (h) in.	3.6 lb	Static mast or grd-mob	Ground-plane independent; can handle 100 W.
12.7 (d) x 1.9 (h) in.	2.7 lb	Pod	Can be used for transmit (20W) or receive.
1 (d) x 3 (h) in.	1.8 oz	Various	Ground-plane independent; can handle 40W.
Approx. 2.5 x 2.5 x 5 in.	1.3 lb	Grd-fix, grd-mob, shp, space	9.1 bandwidth high-power dual polarized.
3.75 x 14 x7 in.	9 lb	Air, grd-mob, grd-fix, shp	High-precision emitter location.
14 x 16 x14 in.	85 lb	Air, Ground, Maritime	High-EIRP; multiple beams.

EW AND SIGINT ANTENNA SYSTEMS

MODEL	ANTENNA TYPE	OP FREQ	ANTENNA GAIN	POLARIZATION	ELEMENTS
COJOT; Espoo, Uusimaa, Finland; +358 9 452 2334; www.cojot.com					
WB30512XM	Monopole	20-520 MHz	*	Vertical	1
WD1350XQ	Dipole	118-512 MHz	0 dBi	Vertical	1
HD827XM	Dipole	790-2700 MHz	3 dBi	Vertical	2
Collins Aerospace; Richardson, TX, USA; +1 (972) 705-1438; www.rockwellcollins.com/ewsigint					
CS-3120	Phase Interferometer Array	2-18 GHz	2-10 dBi	Circular	*
ANT-1040A	Spinning DF	0.5-40 GHz	5-21 dBi	Slant linear, 45°	*
ANT-1040G	Spinning/Omni Stack	0.5-40 GHz	5-21 dBi	Slant linear, 45°	*
Dayton-Granger, Inc.; Fort Lauderdale, FL, USA; +1 (954) 463-3451; www.daytongranger.com					
RX010-858	Interferometer	20-500 MHz	*	Vertical	*
Elbit Systems EW and SIGINT - Elisra; Bene Beraq, Israel; + 972-3-6175 111; www.elbitsystems.com					
TDA-1200	Array	20-3000 MHz	*	Vertical	*
1570F00801	Spiral	1-6 GHz	-12 to -1 dBLi	LHCP	*
1570F03801	Spiral	6-18 GHz	-1 dBLi	LHCP	*
ET Industries; Boonton, NJ, USA; +1 (973) 394-1719; www.etiworld.com					
BAA052-5	DF Blade Array Antenna	700-2000MHz	15 dBiL for omni, -2 dBiL nominal for DF elements	Vertical	Various
FIRST RF Corporation; Boulder, CO, USA; +1 (303) 449-5211; www.firstrf.com					
FRF-105LY	Omni	20 MHz-6 GHz	2 dBi	Vertical	*
FRF-230	Airborne Pod Antenna	100-1000 MHz	2 dBi	Vertical	*
FRF-220	Conformal	20-600 MHZ, 600 MHz - 6 GHz	5 dBi	Vertical	*
GEW Technologies; Pretoria, South Africa; +26 12 421 6212; www.gew.co.za					
MRA7000	DF Array	20 MHz - 9 GHz	*	Vertical	*
MRA55	Active Monopole	9 kHz - 2 MHz	*	Vertical	*
GFX9	Spiral	3-9 GHz	*	Circular	*
JEM Engineering; Laurel, MD, USA; +1 (301) 317-1070; www.jemengineering.com					
MBA-0162	Array	400-2700 MHz	4-16 dBic	RHCP	64
HSA-218	Spiral	2-18 GHz	5 dBic	RHCP or LHCP	1
JEM-2438MFC	Magnetic Flux Channel Antenna	30-512 MHz	-25-2 dBiL (-30-512 MHz)3 dBic (240-380 MHz)	Linear, Vertical (30-512 MHz) Right-Hand Circular (240-380 MHz)	2
L3Harris; North Amityville, NY, USA; +1 (631) 630-4000; www.harris.com/what-we-do/antenna-products					
DF360	Circular Array	2-18 GHz, MMW	-1 dBi	Slant linear	8 per band
SE131-1	Linear Interferometer	2-18 GHz	-6.6 dBic	RHCP/LHCP switchable	4 per polarization
SE135	Linear Interferometer	2-6 GHz, 6-18 GHz	Low band 0 dBi, high band 5-10 dbi	Low band RHCP, high band slant 45	Low band spirals, high band horns

SIZE (HxWxL in inches or mm)	WEIGHT	PLATFORM	FEATURES
Length: 2040 mm	4.9 kg	Grd-mob	High power
Length: 995 mm	0.72 kg	Grd-mob, manpack	High power
Length: 600 mm	2.0 kg	Grd-mob	High power
27 x 12 x 5 in.	<30 lb	Air, grd-fix, grd-mob, shp	Monopulse precision DF antenna array; option for 0.5-18 GHz.
20.5 x 19.5 in.	46 lb	Air, shp	0.5-18 GHz version also available; includes RF electronics.
40 x 19.5 in.	80 lb	Grd-mob, grd-fix, shp	Integrated high-gain spinning DF antenna and omni antenna; 0.5-18 GHz version also available.
13.3 x 10.6 x 3.5 in.	3.3 lb	Air	Blade; phase matched; high power; speed rating 600 kts.
3.2 x 4.2 in.	50 kg	Grd-fix	Suitable for TDF-2020 and TDF-1200 DF systems.
100 (d) mm	260 g	Air, shp, grd-mob	Phase matched
33 (d) mm	70 g	Air, shp,sub, grd-mob	Phase matched
5.95 x 5 x 6 in.	<3 lb	Air	Five simultaneous outputs; amplified omni-directional output; four quadrant DF outputs.
83 x 1.5 in.	13 lb	Grd	Broadband ground tactical.
50 x 3 in.	6 lb	Air	Broadband
33 x 1.5 in.	3 lb	Grd	Conformal ground tactical.
1100 x 550 mm	25 kg	Grd-fix, grd-mob	For vehicle and mast applications.
1800 x 130 mm	4 kg	Grd-fix, grd-mob	*
360 x 110 mm	6 kg	Grd-fix, grd-mob	Built-in downconverter.
16 x 16 x 2.5 in.	7.5 lb	Air	Efficiency of over 50% for the aperture across the entire band.
2.7 (d) x 1.35 (h) in.	0.25 lb	Air	Low-profile compact spiral designed for DF arrays.
21 x 21 x 2.5 in.	30 lb	Grd-mob, shp	Ultra low-profile, MFC technology, exceptional UHF LOS gain, UHF/MUOS SATCOM capability.
19 (h) x 13 (d) in.	40 lb	Shp, sub	BIT/Cal
16 x 7 x 5.25 in.	9.5 lb	Air (UAS)	Dual polarization, LNA's and filter limiters.
27 x 12 x 7.7 in.	22 lb	Air (transports)	Polarizers and radomes.

EW AND SIGINT ANTENNA SYSTEMS

MODEL	ANTENNA TYPE	OP FREQ	ANTENNA GAIN	POLARIZATION	ELEMENTS
L3Harris Technologies Randtron Antenna Systems; Menlo Park, CA, USA; +1 (866) 900-7270; www.randtron.com					
Broadband DCP/DLP Arrays	Interferometer Array	0.4-18 GHz	-8-3 dBiL	V and H; Slant +45 and -45; L and RHCP	3, 4
Low Observable RX/TX Array	Spiral	0.5-18 GHz	*	LHCP or RHCP	*
Wideband mmW RX/TX	Spiral/Horn	18-100 GHz	*	LHCP, RHCP, or Linear	1
Microwave Specialty Company, A division of Rantec Microwave Systems, Inc; San Marcos, CA, USA; +1 (760) 744 1544; www.microwa					
00-60306	Reflector/Feed	1-6 GHz	19 dBi min.	Linear, dual linear, circular, dual circular	*
40-00356	Horn	30-36 GHz	10 dBi	RHCP or LHCP	*
40-00984	Reflector Array	0.5-40 GHz	18-40 dBi	Linear, dual linear, CP	4
mWAVE Industries, LLC; Windham, ME, USA; +1 (207) 892-0011; www.mwavellc.com					
RPDCx-33W-SM0	Parabolic Reflector	1.4-5.15 GHz	Variable	Linear, dual linear, circular, dual circular	*
RPDCx-102-90FM0	Parabolic Reflector	8.0-12.4 GHz	Variable	Linear, dual linear, circular, dual circular	*
HRPDCx-800	Parabolic Reflector	71-86 GHz	Variable	Linear, dual linear, circular, dual circular	*
Octane Wireless; Hanover, MD, USA; +1 (410) 590-3333; www.octanewireless.com					
BW-700-3000	Wearable Antenna	700-3000 MHz	3 dBi	Linear	1
MP-400-6000	Gooseneck Antenna	400-6000 MHz	0 dBi	Linear	1
Covert Antennas for Non-tactical Vehicles	Covert Vehicle Antenna	30-6000 MHz	0 dBi	Linear	1-8
Plath GmbH; Hamburg, Germany; +49 40 23734-0; www.plath.de					
DFA 2440	DF Array	20 MHz - 3 GHz	*	Vertical	7
DFA 2450	DF Array	20 MHz - 6 GHz	*	Vertical	7
DFA 2451	DF Array	1 MHz - 6 GHz	*	Vertical	7
Radixon Group (WiNRADiO); Melbourne, Australia; +61 3 9417 3417; www.winradio.com					
AX-12B	Omni	0.15 MHz - 1.5 GHz (3 ranges)	0 typ.	Vertical	3
AX-37AH	Log-Periodic	300 MHz - 3 GHz	6.0 dBi @ 950 MHz	Horizontal or vertical (depending on mounting)	Planar
AX-81-SM	Omni monopole	20 kHz - 30 MHz @ 3 dB	0 typ.	Vertical	1
Rohde & Schwarz; Munich, Germany; +49-89-4129-0; www.rohde-schwarz.com/campaigns/antenna/en					
R&S HE600	Active, Omni	20 MHz - 8 GHz	-9-18 dB	Linear, vertical	*
R&S HE010E	Active, Omni	8.3 kHz - 100 MHz	Varying	Linear, vertical	*
R&S AC005	Omni	500 MHz - 40 GHz	0-4 dBi	Linear, slant	*

SIZE (HxWxL in inches or mm)	WEIGHT	PLATFORM	FEATURES
Various	1-10 lb	Air, grd-mob, shp, sub	EW, SIGINT, RWR interferometers, conformal and designed to spec. Can provide LO performance.
Various	*	Air, grd-mob, shp	EW, EA, EP; Jamming antenna arrays with low observable treatments.
0.5 x 2 in.	4 oz	Air, grd-mob, shp, sub	EW, SIGINT, wideband receive antennas, can be conformal and low observable applications; 18-100 GHz RX; 18-40 GHz TX.
vespecialty.com			
3 (d) ft	12 lb	Grd	Two-minute setup, no hand tools, segmented option.
2 x 2 x 4 in.	2 lb	Air	200 W CW
Various	Various	Grd-fix	300 W CW; reflector antenna array; threat emitter.
2-10 ft	*	Grd-fix, grd-mob, shp	Application: SIGINT; Features: High radiation efficiency; Options: Perforated reflectors up to 4 ft. dia.
2-8 ft	*	Grd-fix, grd-mob, shp	Application: EW, SIGINT, threat sim.; Features: high-power handling; Options: remote polarization control.
1-4 ft	*	Grd-fix, grd-mob, shp	Application: SIGINT; Features: High radiation efficiency & polarization purity, integral radome.
3.5 x 5.8 x 0.4 in.	2 oz	Grd-mob	Wearable DF/SIGINT capability for locating LTE, GSM cellular devices.
19.5 x 1.3 x 1.3 in.	9 oz	Grd-mob	Flexible gooseneck provides EW/SIGINIT performance from UHF through C-band.
Various	0.1-20 lb	Grd-mob	Covertly integrated into OEM features of vehicles for EW/SIGINT applications.
350 x 1106 Æ mm	30 kg	Grd-mob	Active DF-antenna, vehicle roof installation with homing capabilities, rms < 2°.
1190 x 640 Æ mm	45 kg	Shp	Passive DF-antenna for OPV, height without lightning rod.
1548 x 1200 Æ mm	60 kg	Shp	Passive DF-antenna for ships, height without lightning rod.
9.2 (h) m	35 kg	Grd-fix, grd-mob	Three antennas in one (elevated monopole /discone): Band 1: 0.15-30 MHz, Band 2: 30-100 MHz, Band 3: 100-1500 MHz.
300 x 248 mm (excluding handle or mounting bracket)	720 g	Portable or mast mount	Versions available with and without preamplifier (12V DC operation for preamp version).
1350 x 38 mm	555 g	Grd-fix	Active HF, 12V DC operation.
550 (h) x 140 (d) mm	2 kg	Grd-fix, grd-mob, shp	COMINT/CESM, high sensitivity.
1000 (h) x 120 (d) mm	1 kg	Grd-fix, grd-mob, shp	COMINT/CESM, low inherent noise.
410 (h) x 400 (d) mm	9 kg	Grd-fix, grd-mob, shp	SIGINT/CESM/RESM, compact design.

MODEL	ANTENNA TYPE	OP FREQ	ANTENNA GAIN	POLARIZATION	ELEMENTS
Signal Antenna Systems Inc.; Watsonville,CA, USA; +1 (831) 722-9842;www.signalantenna.com					
SA UWB300	Omni	0.3-12.4 GHz	2-4 dBi	Vertical	1
SA UWB 800	Omni	0.8-20 GHz	2-4 dBi	Vertical	1
SA MP80-8	Omni	0.08-6 GHz	0-3 dBi	Vertical	1
Southwest Antennas; San Diego, CA, USA; +1 (858) 277-3300; www.southwestantennas.com					
1001-228	Gooseneck Omni Antenna	1.35-2.5 GHz	2.4 dBi	Vertical	2
1001-231	Gooseneck Omni Antenna	1.7-1.85 GHz, 2.2-2.5 GHz, 4.4-5.0 GHz	1.3-2.7 dBi	Vertical	3
1001-154	Omni Antenna	1.25-1.85 GHz	2.05 dBi	Vertical	2
Southwest Research Institute; San Antonio, TX, USA; +1 (210) 522-2517; www.swri.org					
AF-369	Multiple; DF Array	20 MHz - 3 GHz (extension to 9 GHz)	-2 to >+5 dBi	Vertical (below 500 MHz); circular	5 per band
AS-420G	Multiple; DF Array	30 MHz - 6 GHz	-15 to >+5 dBi	Vertical (below 800 MHz); circular	8 per band
AU-506B	Multiple; DF Array	0.5 MHz - 3 GHz	-18 to >+5 dBi (above 8 MHz)	Vertical	3 per band (below 50 MHz); 8 per band
Steatite Antennas Ltd; Leominster, Herefordshire, UK; +44 (0)1568 617 920; www.steatite-antennas.co.uk					
QMS-00488	Sinuous	2-24 GHz	-6.4-2.2 dBi	Dual	1
QMS-00972	Spinner	0.5/1-40 GHz	1-20 dBi	Slant	2-3
QMS-01007	Array	2-40 GHz	-7.7-4.7 dBi	RHCP	6
TCI, An SPX Company; Fremont, CA, USA; +1 (510) 687-6100; www.spx.com/en/tci					
Model 625	Loop	2-30 MHz	5 dBi	Vertical	*
Model 632	Monopole	0.3-30 MHz	5 dBi	Vertical	*
Tech Comm, Inc.; Ft. Lauderdale, FL, USA; +1 (954) 712-7777; www.techcommdf.com					
TC-8220	DF Array	30-2700 MHz	3uv/M	Vertical, 3-deg. RMS	2-bay annular slot
TC-8111-3	DF Array	30-2000 MHz	3uv/M	Vertical, 4-deg. RMS	2-bay annular slot
TC-8120	DF Array	30-2000 MHz	3 uv/M	Vertical, 4-deg. RMS	2-bay annular slot
Thales Communications & Security; Gennevilliers, France; +33-1-46-13-2000; www.thalesgroup.com					
ANT184X	DF interferometry	20 MHz-3 GHz	*	Vertical	2 x 5
ANT206X	DF interferometry	20 MHz-3 GHz	*	Vertical	2 x 5
ANT205	DF interferometry	30 MHz-3 GHz	*	Vertical	2 x 5

SIZE (HxWxL in inches or mm)	WEIGHT	PLATFORM	FEATURES
12 (d) x 12 (h) in.	3 lb	*	Handles power
8 (d) x 6 (h) in.	1.5 lb	*	Handles power
6 (d) x 24 (h) in.	1 lb	*	Man-pack contermeasures antenna.
8.95 x 0.812 x 0.812 In.	0.22 lb	Air, grd-mob, grd-fix, shp	Rugged design, waterproof sealed RF gooseneck base, high performance across entire operational frequency range.
11.74 x 0.812 x 0.812 in.	0.33 lb	Air, grd-mob, grd-fix, shp	Rugged design, waterproof sealed RF gooseneck base, tri-band L, S, and C-band design.
8.05 x 0.562 x 0.562 In.	0.14 lb	Air, grd-mob, grd-fix, shp	Rugged design, sealed spring base that can bend ±90 degrees.
120 x 58 x 58 in.	105 lb	Grd-fix	Full-spectrum DF antenna.
130 x 55 x 55 in.	450 lb	Shp	Integrated COMINT/ELINT functionalities; provisions for mounting ELINT or other antenna above.
35 x 20 x 20 in.	258 lb	Sub	Includes pressure-bearing radome.
81 (d) mm mount flange, 49 (L) mm	180 g	Air, grd-mob, grd-fix, shp	Dual Llinear polarized sinuous antena with SMA-type connectors.
600 (d) x 775 (h) mm	≤ 30 kg	Grd-mob, grd-fix, shp	1-40 GHz ELINTreflector antenna and positioner fitted with a K type and SMA connector and radome.
200 (d) x 100 (h) mm	≤ 10 kg	Air, grd-mob, grd-fix, shp	2-40 GHz spiral array for ELINT/DF system fitted with an K type connector.
14.4 ft	*	Grd-fix	*
192 in.	34 lb	Grd-fix, grd-mob	54 x 6 in. stored position.
20 (d) x 8 (h) in.	15 lb	Grd-fix, grd-mob, shp	Used with TC-5000 Series, TC-9300 and TC-9320 Signal Intercept & DF Systems.
0.5 (h) x 14 (d) in.	15 lb	Airborne, low profile	Used with TC-9300 and TC-9320 DF Systems.
20 (d) x 8 (h) in.	11 lb	Grd-mob	Used with TC-5000 Series, TC-9300 and TC-9320 Signal Intercept & DF Systems.
110 (d) x 45 (h) cm	<17 kg	Air, grd-fix, grd-mob	DF accuracy < 2 deg RMS.
160 (d) x 165 (h) cm	<25 kg	Grd-fix	DF accuracy < 1.5 deg RMS.
135 (d) x 220 (h) cm	<13 kg	Grd-fix, grd-mob	DF accuracy < 2deg RMS; foldable.

SURVEY KEY – COMINT AND COMMS ESM RECEIVERS

MODEL

Product name or model number

ANTENNA TYPE

- DF = direction-finding
- LPDA = log periodic dipole array
- omni = omnidirectional
- *TSA = tapered slot antenna*

OPERATING FREQUENCY

Operating frequency in kilohertz (kHz), megahertz (MHz) or gigahertz (GHz)

ANTENNA GAIN

Typical installed gain in decibels expressed as dB, dBi, dBiC, dBil and dBLi,

ANTENNA POLARIZATION

LHCP = left-hand circular polarized
RHCP = right-hand circular polarized

ELEMENTS

Number of antenna elements (if an array)

SIZE

Antenna size (length, diameter, height) in inches (in.), feet (ft), millimeters (mm) or centimeters (cm)

WEIGHT

Weight in pounds (lb), ounces (oz), grams (g) or kilograms (kg)

PLATFORM

Host platform

- air = airborne
- grd-fix = ground-fixed
- grd-mob = ground-mobile
- shp = shipboard
- sub = submarine

OTHER ABBREVIATIONS USED

- > = greater than
- < = less than
- config = configuration
- deg = degree
- d = diameter
- freq = frequency
- max = maximum
- RMS = root mean sqaured
- typ = typical
- UHF = ultra high frequency
- VHF = very high frequency

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

In the December *JED*, our technology survey will cover ELINT receivers. If you would like to participate, please e-mail JEDEditor@naylor.com for a survey questionnaire.

New EA Techniques Part 7

Escort and Modified Escort Jamming

By Dave Adamy

For several decades, we have been achieving excellent results with stand-off jamming, in which (blue force) low-density/high-demand (LD/HD) support jamming aircraft (usually operating in formations of two or more) use high-power electronic attack systems to protect multiple formations of (blue force) attacking aircraft from beyond the lethal range of (red force) radar-controlled weapons.

However, next-generation threats feature significantly greater lethal ranges than legacy threat systems, which challenges the ability of support jammers to operate effectively while remaining outside the lethal range of the radar-controlled weapons systems. Because support jamming aircraft typically broadcast their jamming signals into the side lobes of multiple threat radars, these longer jamming distances reduce the support jammers' effectiveness by a significant factor. This means that the jammers must operate closer to the radars (and hence in danger of being destroyed) in order to provide effective jamming.

ESCORT JAMMING

(Although support jamming aircraft often work in numbers of two or more, we are going to use a single support jamming aircraft in our figures this month on order to simplify.) If the jamming aircraft is placed with the protected formation as shown in **Figure 1,** the protection is effective because the threat radar has its main beam pointed directly at the formation. However, the support jamming aircraft (which typically carries external jamming pods) has a very large radar cross section, which makes it an easier target for the weapon system. Once the escort jammer is destroyed, there is no support jamming protection for the formation, and the remaining aircraft must rely on their self-protection jammers to defeat the threats.

MODIFIED ESCORT JAMMING

If the jamming aircraft is placed close to the boresight of a threat radar, as shown in **Figure 2,** its received jamming power in the radar is many dB stronger than it would be if the radar were receiving the jamming power in a side-lobe, as in standoff jamming. For protection, the jammer is kept beyond the lethal range of the radar's associated weapons. This technique is called "modified escort jamming."

Consider some typical numbers. If a new-generation radar provides a missile lethal range of 200 km, as compared to a 30 km lethal range in a legacy weapon system, the jamming-to-signal ratio achieved will be reduced by 16 dB. This will not provide adequate protection for the formation of aircraft. And if the jamming signal is received in the threat radar's side lobe, the protection will be further reduced by the side-lobe isolation on the order of 20 dB.

If the jammer were right on the threat radar's bore-sight, the J/S would be increased by the 20 dB, but that would only be for a single threat radar. If the jamming antenna beam width is narrowed (as is anticipated in the next-generation of AESA-based jammers), the jamming effectiveness will be further improved.

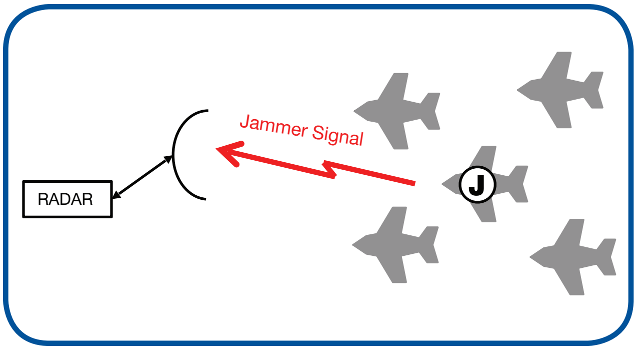


Figure 1: Escort jamming places a support jamming aircraft within a formation of attack aircraft to provide jamming protection.

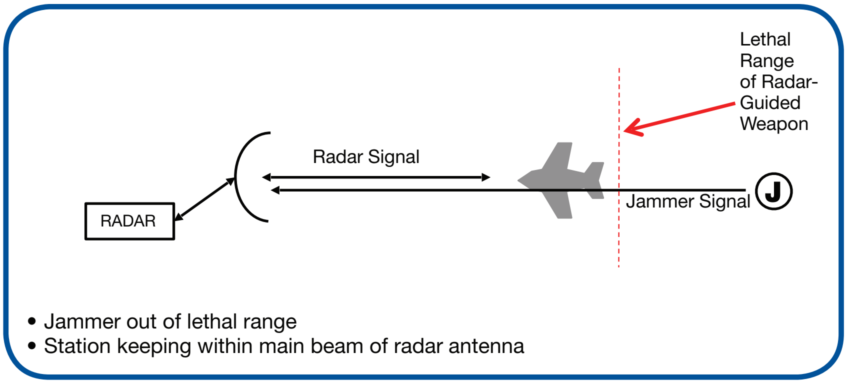


Figure 2: Modified escort jamming places the support jamming aircraft within the main beam of the threat radar but beyond the lethal range of the associated weapons.

MODIFIED ESCORT STATION KEEPING

If the jammer is away from the threat radar bore-sight as shown in **Figure 3**, there will be a reduction of the received jamming power. This angular offset is the cross-range error as shown in the figure. The error angle is:

$$\theta = \text{asin}\ (CRE / R_J)$$

Where: θ is the offset angle from the bore-sight in degrees,
CRE is the cross-range placement error of the jammer in km, and
R_J is the range from the threat radar to the jammer in km.

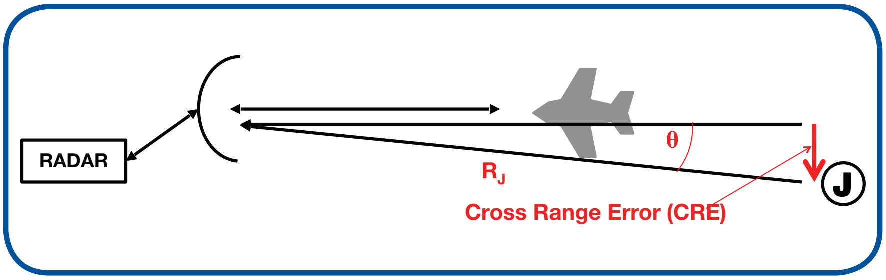


Figure 3: In modified escort jamming, the jamming-to-signal ratio is a function of the accuracy with which the jamming aircraft can be located near the bore-sight of the threat radar.

Now consider **Figure 4**. *Within* the main beam of an antenna, the gain vs. offset from boresight is very well described by the sin(x)/x function. Note that *outside* the main beam, the gain vs. angle is much less well behaved.

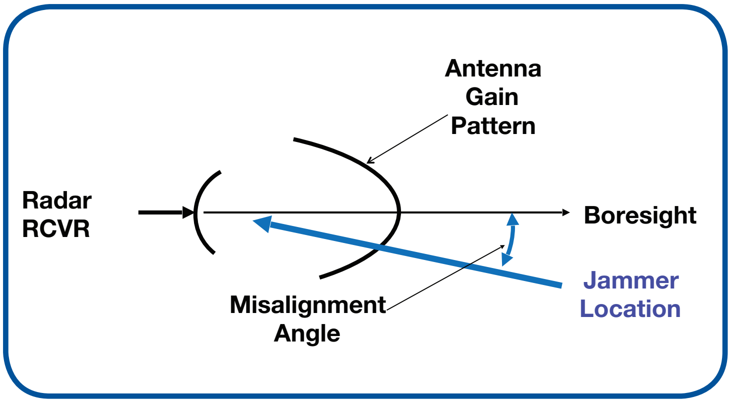


Figure 4: Ideally, the support jamming aircraft would be at the boresight of the threat radar. The reduction of the effective jamming power is a strong function of the jammer placement cross-range error.

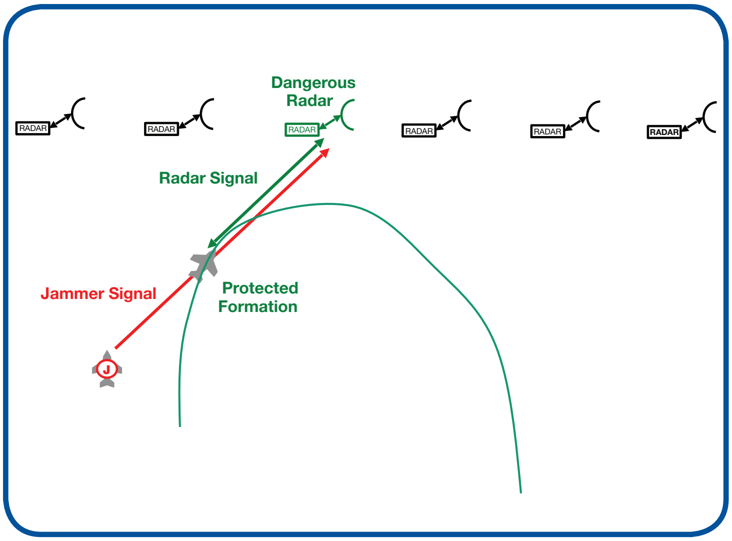


Figure 5: The modified escort jammer optimizes protection of a formation of attacking aircraft against a particularly dangerous threat radar.

The equation for the reduction in gain vs. angle from boresight is:

$$\Delta G = 12\ (\theta / \alpha)^2$$

Where: ΔG is the reduction from bore-sight gain in dB,
θ is the station keeping error angle in degrees, and
α is the 3 dB beam-width of the radar antenna in degrees.

Remember that this equation only works within the main beam. When signals are in the side-lobes, the gain vs. angle data needs to be captured from anechoic chamber testing.

Figure 5 shows a larger scale view of the engagement. There are normally multiple threat radars that might be impacted by a stand-off jammer, but the modified escort jammer only counters a single next-generation radar that has very long range. In this case, the modified escort jammer would focus on this specific threat. The other threats would need to be covered by other jammers (which might also be modified escort jammers).

The J/S formula for a modified escort jammer is:

$$J/S = ERP_J - ERP_S + 71 - \Delta G - 20 \text{ Log } R_J + 40 \text{ Log } R_T - 10 \text{ Log } RCS$$

Where: ERP_J is the effective radiated power of the jammer in dBm,
ERP_S is the effective radiated power of the threat radar in dBm,
ΔG is the reduction in gain from the offset of the jammer from the radar bore-sight,
R_J is the range from the threat radar to the jammer in km,
R_T is the range from the threat radar to the protected formation in km, and
RCS is the radar cross section of an aircraft in the targeted formation in m^2.

WHAT'S NEXT

Next month, we will continue our discussion of jamming geometries. For your comments and suggestions, Dave Adamy can be reached at dave@lynxpub.com.

FEATURED LIVE COURSES

Introduction to Radar Systems

Kyle Davidson

Mondays, Wednesdays, & Fridays
13:00 – 16:00 EDT | July 29 – August 9, 2019
This course introduces the audience to radar systems in a military context, with a focus on search and tracking radars associated with modern day threats.

SPACE EW

Dave Adamy

Mondays, Wednesdays, & Fridays
13:00 – 16:00 EDT | September 4 – 20, 2019
In the eight sessions of this course, we will cover the nature of EW in space and go on to work practical EW problems appropriate to the space environment.

EW Modeling and Simulation

Dave Adamy

Mondays & Wednesdays
13:00 – 16:00 EST | March 2 – 25, 2020
This is a practical course in which the basic concepts and techniques of Electronic Warfare modeling and simulation are presented and applied to practical problems.

Airborne Expendables/UAS Capabilities and Potential

Dr. Patrick Ford

Mondays & Wednesdays
13:00 – 16:00 EDT | August 19 – 28, 2019
This course provides attendees with a strong foundation in expendables/sUAS, from basic airframe classes and capabilities, to EW potential, to the current FAA airframe and pilot certification/flight approval process.

21st Century Electronic Warfare, Systems, Technology, and Techniques

Dr. Clayton Stewart

Mondays, Wednesdays, & Fridays
13:00 – 17:00 EST | February 3 – 21, 2020
This course offers a comprehensive overview of modern electronic (EW) warfare systems, technology, and techniques.

Intermediate Electronic Warfare

EW EUROPE 2020

Dr. Clayton Stewart

Friday & Saturday | 08:00 – 17:00 BST
June 19 – 20, 2020 | Liverpool, UK
We will begin with a historical perspective and introduce use of radar, integrated air defense system, early EA functions and conclude with an overview of modern EA, ES, and EP.

= Web Course, no travel required!

56TH AOC INTERNATIONAL SYMPOSIUM & CONVENTION

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Fundamental Principles of Electronic Warfare

Dave Adamy
Saturday & Sunday
08:00 – 17:00 EDT | October 26 – 27, 2019

Advanced Principles of Electronic Warfare

Dave Adamy
Thursday & Friday
08:00 – 17:00 EDT | Oct 31 – Nov 1, 2019

Machine Learning for Electronic Warfare

Kyle Davidson
Saturday & Sunday
08:00 – 17:00 EDT | October 26 – 27, 2019

Electronic Countermeasures—Theory and Design

Kyle Davidson
Thursday & Friday
08:00 – 17:00 EDT | Oct 31 – Nov 1, 2019

FOR COURSE LISTINGS AND MORE VISIT **CROWS.ORG**

ASSOCIATION OF OLD CROWS *news*

NSWC CRANE HOSTED NATIONAL LEADERS FOR 11TH ANNUAL ELECTRONIC WARFARE CONFERENCE

By NSWC Crane Corporate Communications

Naval Surface Warfare Center, Crane Division (NSWC Crane) hosted the 11th Annual Electronic Warfare (EW) Capability Gaps and Enabling Technologies Conference with the Association of Old Crows (AOC) from May 14-16 at NSWC Crane.

The theme of the conference focused on "Achieving Freedom to Maneuver Leveraging Non-Kinetic Capabilities." The event provided an interactive forum for EW professionals from the military, government, industry, and academia to discuss technologies and capabilities related to EW programs, platforms and operations within the Electromagnetic Spectrum (EMS).

Rich Wittstruck, the Vice President of AOC, says the conference creates a space for EW national leaders to come together to tackle current and future challenges.

"The AOC's Annual Electronic Warfare Capability Gaps and Enabling Technologies Conference, co-sponsored by the Naval Surface Warfare Center Crane Division, provided a joint venue for technology, institutional and operations professionals to discuss, debate and strategize a call to action in advancing rapid acquisition, innovated TTPs and CONOPS/CONEMP for fleet design (FD), and distributed maritime operations (DMO)," says Wittstruck.

As home to the Navy's largest concentration of EW subject matter experts and state-of-the-art laboratories and equipment, NSWC Crane is nationally recognized as a leader in EW.

Wittstruck says bringing the experts to Crane gives attendees the opportunity to visit these advanced facilities.

Stacey Mervyn, a Division Manager at NSWC Crane, says concepts originating from past conferences have produced tangible solutions for the fleet.

"NSWC Crane is proud to have AOC as a partner to bring together people from diverse areas of expertise to discuss the toughest EW challenges," says Mervyn. "The 11th Annual EW Conference was a success again this year due to the passionate, mission-focused people that came together to explore solutions for the fleet. The presentations provided valuable insight into EW technology challenges from across the services as well as enlightened the audience on EW Science and Technology Roadmaps. Overall, the forum proved to be a successful motivator to EW professionals to provide innovative concepts and solutions to close the operational gaps for the warfighter."

NSWC Crane is a naval laboratory and a field activity of Naval Sea Systems Command (NAVSEA) with mission areas in Expeditionary Warfare, Strategic Missions and Electronic Warfare. The warfare center is responsible for multi-domain, multi-spectral, full life cycle support of technologies and systems enhancing capability to today's warfighter.

GRANITE STATE ROOST HOLDS ANNUAL BASEBALL GAME SOCIAL

The Granite State Roost held their annual Fisher Cats baseball game event on June 21 as the NH Fisher Cats took on the Trenton Thunder. Many attendees arrived early to participate in the opening ceremony by presenting the American flag during the National Anthem.

The Granite State Roost continues to provide opportunities for interaction among its membership by holding social events throughout the year. For additional information about the Granite State Roost, contact the chapter president, Mr. Duane Beaulieu, at duane.a.beaulieu@baesystems.com.

2019 AOC Virtual Series

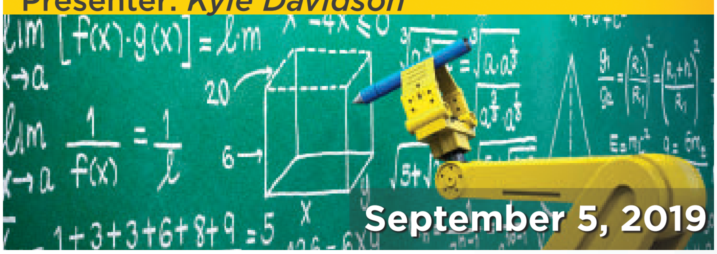
AOC VIRTUAL SERIES

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

An Introduction to RDF Methodologies
Presenter: *Paul Denisowski*

Evolving to the Next Generation of Multifunctional EW - Part II
Presenter: *Matthew Orr*

Intro to Machine Learning for EW
Presenter: *Kyle Davidson*



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RAF 100 Group and its EW Legacy
Presenter: *Thomas Withington*

The 3 Pillars of Electronic Warfare - Electronic Attack
Presenter: *Brian Hinkley*

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For more upcoming AOC Virtual Series Webinars, visit crows.org

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