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October 2020 Vol. 43, No. 9

# JED

Journal of Electromagnetic Dominance

# Europe's Counter-UAS Challenge

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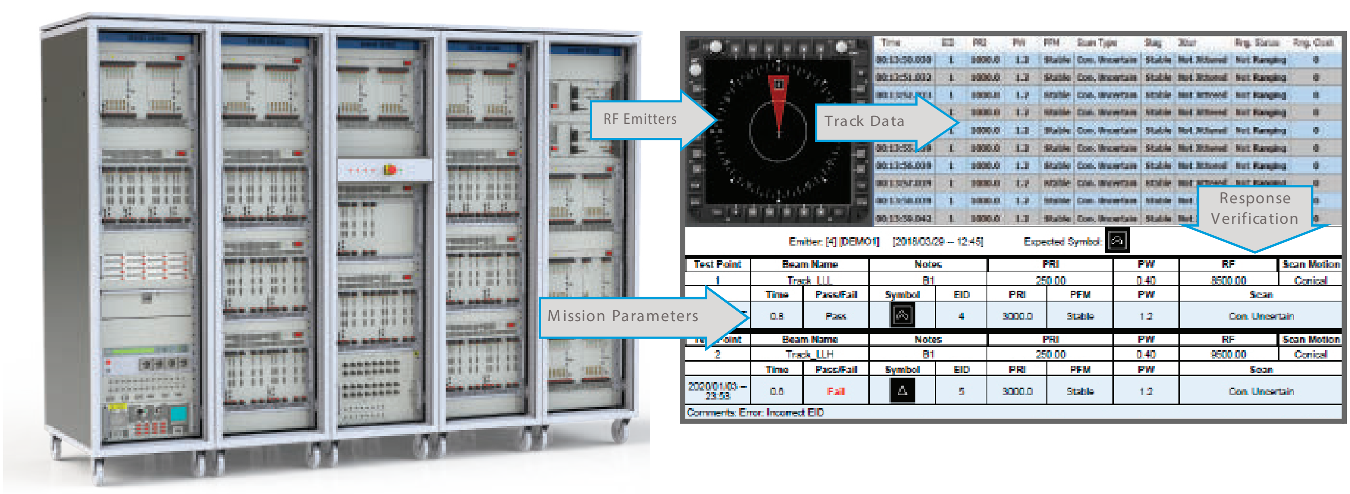


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ULTRA

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October 2020 • Volume 43, Issue 9



US ARMY



IN HARM'S WAY – *Sailors secure an AGM-88 anti-radiation missile on an EA-18G Growler, attached to the Shadowhawks of Electronic Attack Squadron (VAQ) 141, on the flight deck of the USS Ronald Reagan (CVN 76) in the Philippine Sea.*

PHOTO BY MASS COMMUNICATION SPECIALIST 3RD CLASS ERICA BECHARD, USN

## Departments



COVER PHOTO COURTESY OF POTUSHAFT/WIKIMEDIA COMMONS

# MATURING C-UAS

**Our cover story** this month, written by Andrew White, takes a look at Counter-UAS (C-UAS) developments in Europe. Considering the number of C-UAS systems available today, it's surprising to remember that the C-UAS market is just a little over five years old. The first systems to be offered were merely adaptations of vehicle-based counter-RCIED jammers. These RCIED jammers were relatively inexpensive, they already covered the frequencies used by most commercial drones, and they were already in production. Today, there are hundreds of C-UAS solutions offered around the world, and they vary in size, operational range and sophistication. So far, this has been an incredibly rapid evolution for such a young market.

In July 2019, the *USS Boxer* was operating in the Persian Gulf. An Iranian UAS managed to fly within 1,000 yards of the LHD before it was downed with RF jamming from a Light Marine Air Defense Integrated System (LMADIS) C-UAS system onboard the *Boxer.* How did the US Navy manage to "integrate" a C-UAS capability onto the *Boxer?* The LMADIS was housed on a two-seat MRZR all-terrain vehicle that was parked (with aircraft chocks under the wheels) at the end of the *Boxer's* 843-foot flight deck. This was a quick and clever solution for providing a much needed C-UAS solution for the ship. Yet it also illustrates how far we are from truly integrating a wide range of mature C-UAS solutions onto large, complex weapons systems.

In October 2017, less than two years before the LMADIS downed the Iranian drone, ISIS released video footage that showed one of its quadcopter drones dropping two incendiary munitions on a Syrian government weapons depot housed in a sports stadium near Mayadeen in the eastern part of the country. The ammunition burned and exploded for hours. It was one of many drone attacks ISIS has documented in Syria and Northern Iraq beginning in 2016.

These two examples illustrate the diverse nature of the C-UAS challenge. Today, one segment of the C-UAS market is focused on integrating this capability into larger air defense systems. This enables utilization of more advanced sensors and targeting capabilities than a typical stand-alone C-UAS system would have. These solutions are also bringing more non-kinetic technologies, such as high-power microwaves and high-energy lasers, into the C-UAS countermeasures suite. At the other end of the spectrum are small "wearable" C-UAS solutions featuring RF jammers, which are suited for special operations forces and similar applications where a small size, weight and power (SWAP) footprint is essential.

As the C-UAS market matures, some applications will eventually see electronic attack solutions technoligically converge with other RF systems, such as radios. Other C-UAS capabilities, particularly at the low-end, may remain discrete solutions because they are so small and inexpensive. These types of trends have happened with RCIED jammers, and I expect the same will hold true with C-UAS. In the meantime, the good news for military forces is that the C-UAS market will likely remain very dynamic with many new types of solutions being offered for many years. – *J. Knowles*

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# Calendar *Conferences & Courses*

This month, we have combined *JED*'s courses and conferences calendars in an effort to provide readers with the most comprehensive list of upcoming EW/SIGINT learning opportunities and events. Conferences will be denoted next to event dates; all calendar listings not labeled as a conference will be courses or webinars.

Due to the disruptions caused by COVID-19, some event organizers have chosen to change the dates and/or venues of their events and courses. Please contact the event or course provider to receive the latest details.

## OCTOBER

**Adaptive Arrays: Algorithms, Architectures and Applications**
October 5-8
Atlanta, GA
www.pe.gatech.edu

**AOC Live Professional Development Web Course: Electro-Optical/Infrared Sensor Engineering**
October 5-28
8 sessions, 1300-1600 EST
www.crows.org

**SIGINT Fundamentals**
October 6-7
Denver, CO
www.pe.gatech.edu

**AOC Virtual Series Webinar: Specific Emitter Identification (SEI)**
October 8
1400-1500 EST
www.crows.org

**AUSA Virtual 2020 Annual Meeting Conference**
October 12-14
www.ausa.org

**Electronic Warfare Data Analysis – Online**
October 12-15
www.pe.gatech.edu

**Modeling and Simulation of Phased Array Antennas – Online**
October 13-15
www.pe.gatech.edu

**Introduction to ISR Concepts, Systems and T&E**
October 13-16
Atlanta, GA
www.pe.gatech.edu

**9th Annual AOC Pacific Conference – Virtual**
October 19-21
www.fbcinc.com/e/aocpacific/

**Precision Strike Symposium – Virtual Conference**
October 20
www.precisionstrike.org

**Airborne EW System Integration – Online**
October 20-22
www.pe.gatech.edu

**Radar Warning Receiver System Design and Analysis**
October 20-22
Atlanta, GA
www.pe.gatech.edu

**EURONAVAL – Virtual Conference**
October 20-23
www.euronaval.fr

**AOC Virtual Series Webinar: Introduction to Radar Pulse Deinterleaving**
October 22
1400-1500 EST
www.crows.org

**Fundamentals of Radar Signal Processing – Online**
October 26-29
www.pe.gatech.edu

**Basic RF Electronic Warfare Concepts**
October 27-29
Atlanta, GA
www.pe.gatech.edu

*continued on page 10*

# Calendar *Conferences & Courses* *cont'd.*

## NOVEMBER

**Radar Cross Section Reduction**
November 2-4
Atlanta, GA
www.pe.gatech.edu

**Radar Principles**
November 2-6
Swindon, UK
www.cranfield.ac.uk

**Test and Evaluation of RF Systems – Online**
November 3-5
www.pe.gatech.edu

**Phased Array Radar Systems**
November 3-6
Atlanta, GA
www.pe.gatech.edu

**AOC Virtual Series Webinar: High Power RF/HPM Directed Energy Weapons**
November 5
1400-1500 EST
www.crows.org

**2020 DE Systems Virtual Symposium Conference**
November 16-19
www.iitsec.org

**Communications Principles**
November 16-20
Swindon, UK
www.cranfield.ac.uk

**Communications Systems**
November 30 - December 4
Swindon, UK
www.cranfield.ac.uk

**Survivability**
November 30 - December 4
Swindon, UK
www.cranfield.ac.uk

**vIITSEC – Virtual Symposium Conference**
November 30 - December 4
www.iitsec.org


## DECEMBER

**EWONLINE: 13th Electronic Warfare Symposium Conference**
December 1-2
www.cranfield.ac.uk

**SIGINT Fundamentals**
December 1-2
Atlanta, GA
www.pe.gatech.edu

**Cyber Warfare/Electronic Warfare Convergence**
December 1-3
Atlanta, GA
www.pe.gatech.edu

**AOC Professional Development Course: RF Theory for ES Operations**
December 6-7
Washington, DC
www.crows.org

## JANUARY

**European Microwave Week 2020 Conference**
January 10-15
Jaarbeurs Utrecht, the Netherlands
www.eumwa.org

**Surface Navy Association 33rd Annual National Symposium Conference**
January 12-14
Arlington, VA
www.navysna.org

**AOC Virtual Series Webinar: An Overview of IADS (Integrated Air Defense Systems)**
January 14
1400-1500 EST
www.crows.org

**TechNet Augusta Conference**
January 25-28
Augusta, GA
www.afcea.org

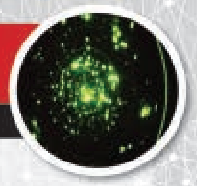
*AOC courses are noted in red. For more info or to register, visit crows.org. Items in blue denote AOC Chapter courses.*

# FEATURED LIVE COURSES

## Electro-Optical/Infrared Sensor Engineering

*Dr. Phillip Pace*

Mondays & Wednesdays
**13:00 – 16:00 EDT | October 5 – 28, 2020**
This course presents the fundamentals of electro-optical (EO) & infrared (IR) sensor technology, its analysis and its application to military search, track and imaging systems.



## Hands-on Introduction to Radar and EW

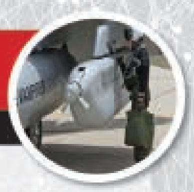
*Dr. Warren Du Plessis*

Dates TBD
**Times TBD | December 2020**
This course will provide a hands-on introduction to radar and a number of important EW concepts.

## Advanced Electronic Warfare - Concepts & Development

*Kyle Davidson*

Dates TBD
**Times TBD | December 2020**
This course is designed to educate students in the contemporary concepts, challenges, and technological advances in the field of Electronic Warfare (EW).



## Advanced Principles of Electronic Warfare

*Dave Adamy*

Mondays & Wednesdays
**13:00 – 16:00 EDT | May 3 – 26, 2021**
This Advanced Electronic Warfare course has eight three hour sessions. It is designed for individuals who have completed a fundamental EW course or have significant experience in the field.

## RF Theory for ES Operations

*Dr. Patrick Ford*

Dates TBD
**Times TBD | December 2020**
This course will also provide a survey of propagation modeling techniques and an update on modern RF operating trends.

## Tactical Battlefield Communications

*Dave Adamy*

Dates TBD
**Times TBD | December 2020**
This course covers techniques for setting up intercept and jamming links for Electronic Warfare (EW) against ground to ground enemy communication signals, UAV command and data links, cell phone links and weapon control links (including IEDs).

## Fundamental Principles of Electronic Warfare

*Dave Adamy*

Mondays & Wednesdays
**13:00 – 16:00 EDT | April 5 – 28, 2021**
This is an introductory Electronic Warfare course in eight three hour sessions. It provides insight into the whole electronic warfare field at the systems and operational level.

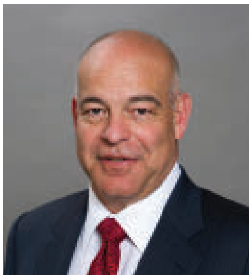
## C4ISR Requirements, Principles, and Systems

*Dr. Clayton Stewart*

Mondays & Wednesdays
**13:00 – 16:00 EDT | June 7 – 30, 2021**
This 24 hour web based course delivers a thorough overview promoting an understanding and building a successful Command, Control, Communications, Computers, Intelligence, Surveillance, Reconnaissance (C4ISR) architecture.

*= Web Course, no travel required!*

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



# MULTI-DOMAIN OPS

**As many of** you may know by now, we have decided to cancel our 57th Annual AOC International Symposium and Convention, due to the COVID-19 pandemic. The theme of this year's event was "All Domain Operations – Integrating Across the Spectrum." We chose this theme because it describes how the US and its allies will fight in the future.

The DOD is embracing Multi-Domain Operations (MDO) as its overarching operational concept for the next several decades, much as Air-Land Battle dominated the final years of the Cold War. MDO began with the Army (it was originally termed Multi-Domain Battle), and the Marine Corps, Air Force and Navy are embracing the concept, as well. MDO will take Joint operations to the next level: exploiting any electromagnetic sensor on any platform operating in any domain (air, land, sea and space) to rapidly (in seconds or minutes) generate battlespace information for the mission commander. Using this information, the mission commander can quickly attack targets with kinetic or non-kinetic weapons in the same way.

Under MDO, the DOD will migrate from the kill chains that it uses today to a much faster kill web. We have many of the sensors and effectors needed to realize the first generation of MDO. And the DOD is actively pursuing the high-speed data communications network under the Joint All-Domain Command and Control (JADC2) initiative. Over the next 10-15 years, the DOD will continue to develop more sensors and effectors that provide the stand-off ranges US forces need to find and engage targets within an adversary's A2/AD threat environment.

MDO is predicated on attaining Electromagnetic Spectrum Superiority in the early stages of a conflict – similar to how Air-Land Battle doctrine of the past depended on establishing Air Superiority as a pre-condition for subsequent phases. Because of this need for EMS Superiority, the DOD is growing its investment in EMS Operations (EMSO) – not only in capabilities but across the EMS Enterprise in areas such as personnel, training, organizations and leadership. The DOD's EMSO Cross Functional Team (CFT) is leading much of this work at the Joint level, and the Services are also investing in EMSO within their respective organizations. Within OSD, the CIO last month issued DOD Directive 3610.01 on EMS Enterprise Policy, which will help connect EMSO strategy and governance to the larger DOD bureaucracy.

MDO will help the US present a credible conventional deterrent to its near-peer and regional competitors. The reality is, however, that the US cannot fight future large-scale conflicts alone. Alliances matter, and the US must engage its many allies and security partners as soon as possible to ensure that every coalition weapons platform is an active part of the high-speed MDO kill web. This will require a new level of "buy in" – both in terms of "mindset" as well as materiel investment – from potential coalition members.

MDO marks a new chapter for the global AOC community. In order to realize its potential, we must embrace MDO together. – *Muddy Watters*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# AOC INTERNATIONAL SYMPOSIUM & CONVENTION

## EVENT CANCELLATION NOTICE

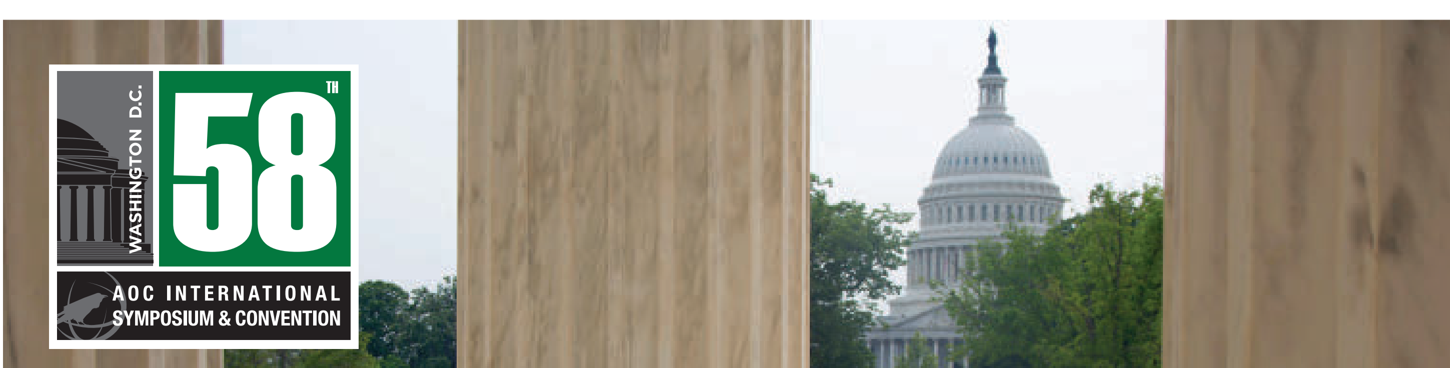
**The AOC Board of Director's Executive Committee has chosen to cancel the 57th Annual AOC International Symposium & Convention scheduled for December 8-10, 2020, in Washington DC.** This decision was made after careful consideration of COVID-19 public health guidelines, multiple discussions with key stakeholders, and a thorough analysis of alternative solutions. There was an overwhelming consensus that a virtual iteration of our in-person event would fall short of our community's standard for business engagement and networking.

While the COVID-19 global pandemic has upended aspects of daily life around the globe, the AOC continues to support our members, exhibitors, and sponsors. During the past few months, the AOC has assessed our usual operations and opportunities to adapt and evolve into new business areas. The AOC Board, Staff, and Chapters remain focused on advancing our mission and delivering value in all aspects of our community in new and innovative ways. These will be launched in the coming weeks as new initiatives aimed at Advancing Electromagnetic Warfare TOGETHER.

In the meantime, the AOC continues to provide a myriad of solutions supporting our geographically distributed community:

- The **Journal of Electromagnetic Dominance** (JED) continues to provide analysis and insight into the latest trends in Electromagnetic Warfare (EW)
- The **AOC Virtual Series Webinars** are faithfully providing bite-sized educational sessions on technical topics relevant to EW
- **AOC Professional Development Courses** continue to bring world-class EW education to remote audiences around the globe
- **AOC Virtual Summits** are bringing senior military & government policymakers together with industry eager to support the needs of the warfighter

...and many more!




**SAVE THE DATE! NOV 30 – DEC 2, 2021**

## UK TYPHOON RADAR UPGRADE TO ADD EA CAPABILITY

The UK is moving ahead with plans to equip the Royal Air Force's (RAF's) Eurofighter Typhoon multirole fighter with an advanced active electronically scanned array (AESA) radar that will deliver powerful electronic warfare (EW)/electronic attack (EA) capabilities alongside more traditional air-to-air and air-to-surface modes.

Under a £317 million Long Lead Time Activity (LLTA) 5B contract awarded by Eurofighter GmbH, BAE Systems will work with the UK radar arm of Leonardo (Edinburgh) to finalize the development and integration of the so-called European Common Radar System (ECRS) Mk 2 system into Typhoon. ECRS Mk 2 represents the conjoining of two lines of development: a Ministry of Defence-funded program of investment in the maturation and de-risking of advanced fighter radar going back more than 15 years; and the knowledge acquired by Leonardo through the development of its Vixen e-scan radar family (most notably the ES 05 Raven multi-mode AESA radar being supplied to Saab for the Gripen E/F fighter).

Working with Air Command, Defence Equipment and Support, and the UK Defence Science and Technology laboratory, Leonardo has progressively matured the key technologies and techniques underpinning ECRS Mk 2 through the course of an extended Assessment Phase risk-reduction program. Funded through a series of incremental 'slices', this has over time given confidence that the capability sought by the RAF can be delivered by industry within acceptable program and cost bounds.


EUROFIGHTER GMBH PHOTO

One of the key differentiators for ECRS Mk 2 is a new high-power multifunction array. According to Leonardo, the number of transmit/receive modules (TRMs) in the array face is significantly greater than comparable AESAs, enabling the simultaneous operation of EW and wideband EA functionality alongside traditional air-to-air and air-to-surface radar modes. The wide field of regard repositioner, using a circular rotating drive on the forward bulkhead, will increase scan volume, allow for variable polarization, and optimize maximum power on target across the field of regard.

ECRS Mk 2 will incorporate a new multi-channel receiver – delivering significant increases in bandwidth, channel and data capacity – together with a dedicated EW receiver and an EA techniques generator developed by Leonardo's EW business in Luton. The EW and EA functionality within ECRS Mk 2 will be fully integrated into the platform's Praetorian defensive aids subsystem suite under BAE Systems' leadership.

Under LLTA 5B, BAE Systems Air sector is taking responsibility for the physical integration of the ECRS Mk 2 radar into the Typhoon airframe, and functional integration into the aircraft's weapon system. The largest part of the contract – about 60% by value – will be flowed down to Leonardo's Radar and Advanced Targeting business at Crewe Toll, Edinburgh, to finalize development of the radar, build test and evaluation assets, and procure long lead items for series production.

ECRS Mk 2 pre-production assets are expected to begin flight testing on Typhoon in 2022. Initial operating capability with the RAF is planned shortly after 2025, with 40 Tranche 3 Typhoon aircraft currently in line to receive the new radar. – *R. Scott*

## WHITE PAPERS SOUGHT FOR US ARMY AIRBORNE SIGINT SENSORS

The Consortium Management Group, Inc. (Washington, DC) Consortium for Command, Control and Communications in Cyberspace (C5) has issued a Request for White Papers (RWP) for the US Army's Multi-Domain Sensing System (MDSS) High Accuracy Detection and Exploitation System (HADES) Electronic Intelligence (ELINT) and Communication Intelligence (COMINT) Sensors requirements. The MDSS is intended to mitigate the Army's deep-sensing gap by providing platform-agnostic survivable airborne sensors that support Multi-Domain Operations (MDO). The focus is on six capability areas: Platforms; Sensors; Integrated Intelligence, Fires, Electronic Warfare, Cyber and Mission Command; Processing, Exploitation, and Dissemination (PED); Data Transport; and Cyber and Electromagnetic Spectrum (EMS) Resiliency.

As part of the MDSS system-of-systems, HADES will develop and integrate multiple sensor capabilities on medium to high altitude platforms. The current effort is focused on ELINT and COMINT sensors. According to the RFW, "based upon Government-executed market research, current ELINT and COMINT sensing technologies do not meet MDSS/HADES sensing requirements and all materiel solutions will require enhancements to increase performance." In April, the Project Director (PD) Sensors-Aerial Intelligence (PD SAI) within the Program Executive Office

Intelligence Electronic Warfare & Sensors (PEO IEW&S) (Aberdeen Proving Ground, MD) had issued a request for information (RFI) for MDSS/HADES seeking information on existing technologies and Non-Developmental Items (NDIs) that could satisfy its requirements.

The MDSS/HADES effort will encompass three phases: Phase 1 (8 months), Phase 2 (24 months), and Phase 3 (12 months). Two or more vendors will be selected for Phase 1 based upon the review of white papers and scoring of filmed/videotaped lab demonstrations. Phase 1 will provide for detailed and sensor-specific testing to validate performance and identify paths for sensor enhancements. The validation will be conducted either through flight demonstration or Government lab testing. This will be followed by a down-selection to no more than two sensor solutions for Phases 2 and 3. The down-selected vendor(s) will build approximately two prototypes during Phase 2, as well as implement proposed-enhancement paths over a twenty-four-month timeframe.

Although "the Government is willing to entertain either solo ELINT or solo COMINT capability solutions, if two solo solutions are pursued during Phase 2, vendors will be required to partner during Phase 3 so a holistic HADES SIGINT solution can be flight tested on a Contractor Owned Contractor Operated (COCO) aircraft." The RFW also cautions that since, "proposed solutions will be required to be an integrated holistic solution under Phase 3, open architecture and open interfaces will be an important focus."

The estimated total funding for the effort is expected to be $49 million allocated under Other Transaction Authority (OTA) over the three phases. The RWP number is: C5-21-RWP-2001. – *J. Haystead*

## SAGE ESM FLIES ON SEAGUARDIAN UAS

General Atomics Aeronautical Systems, Inc. (GA-ASI) has revealed the integration of Leonardo's SAGE 750 electronic support measure (ESM) system onto its MQ-9B SeaGuardian unmanned aerial system (UAS). The two companies will now offer SAGE 750 as an off-the-shelf ESM option for potential SeaGuardian customers.

SAGE is a digital ESM system developed by Leonardo's UK business to meet demands for radar-band electronic surveillance, signal analysis, threat classification and precision emitter geolocation. The system uses parallel wideband and channelized digital receivers to achieve enhanced sensitivity, fine frequency

## ARMY C5ISR CENTER RELEASES RFI FOR AIR LAUNCHED EFFECTS

The Army Combat Capabilities Development Command (CCDC) Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance and Reconnaissance (C5ISR) Center (Aberdeen Proving Ground, MD), has released a Request for Information (RFI) to identify "novel and highly capable technologies and enablers that can inform S&T development" and program acquisition of Air Launched Effects (ALEs). ALEs are a family of small (< 10lb) and Large (< 30lb) air vehicles intended to operate with other manned and unmanned platforms to Detect, Identify, Locate, Report (DILR), and deliver lethal and non-lethal effects against threats.

As noted in the RFI, in order to "gain and maintain overmatch in the future conflict," Army Aviation determined that it "must modernize and distribute its Reconnaissance, Surveillance, Target Acquisition (RSTA) and lethality." The ALE family is a major element of this development initiative as part of the overall Future Vertical Lift (FVL) Future Attack Reconnaissance Aircraft (FARA) capability. The C5ISR Center is currently working on Science and Technology (S&T) planning and development of the ALE capability to deliver coordinated and distributed sensing and effects across Electro-Optical (EO), Infrared (IR) and Radio Frequency (RF) portions of the electromagnetic spectrum.

The RFI lists specific technology areas of interest based on "core functional domains that span sensors, effectors and enablers across the spectrum for both ALE small and large." They include: hardware for primary ALE mission payloads; hardware, software, and/or techniques for enabling distributed collaborative teaming capabilities, including cyber protection and radio systems/data links; software/algorithms that enable the ALEs to react and adapt autonomously; multi-mode/multi-function technologies, which may consist of common payloads; and Modular Open Systems Architecture (MOSA). The RFI also includes payload size weight and power (SWaP), Technology Readiness Level (TRL) targets, and other detailed requirements information for each technology area of interest.

As explained by LTC Anthony Freude, Future Attack Reconnaissance Aircraft (FARA) Integration Lead at the FVL Cross Functional Team (CFT) (June, 2020 *JED*), although the Army continues to work through the requirement, they have determined that the plan will include acquiring four different categories of ALE payloads addressing DLIR; Disrupt; Decoy; and Lethal (kinetic capability) missions. "We haven't yet actually picked the payloads by name, type or company, as we're just getting up and starting, but all together, the effects will be quite profound."

As this issue of *JED* went to press, a virtual industry day for the ALE effort was expected to be held on September 28th, with a final Phase II RFI to be posted within 30 days after the event. According to the RFI, S&T investment timeframes may start as early as FY21 and span thru FY25 and beyond. The ALE effort is on a Mid-Tier Acquisition timeline, with the transition path to a Program of Record (POR) dependent on the ability to demonstrate relevancy and applicability of the technology or capability to the ALE Concept of Operations (CONOPS), technology maturity timeline, and cost/risk to mature and procure the product. – *J. Haystead* measurement and very high probability of intercept in the frequency range 2-18 GHz (with options for C/D and K band extensions). The receiver architecture provides for instantaneous emitter detection and electronic intelligence-grade measurement accuracy.

SeaGuardian is a variant of the GA-ASI MQ-9B SkyGuardian UAS specifically configured for maritime ISR missions. GA-ASI completed an initial set of over-water tests off Southern California in mid-September using the first MQ-9B configured for the maritime mission.

According to GA-ASI, the integration of SAGE on SeaGuardian marks the first time that one of the company's UASs has featured a fully-integrated tactical ESM capability. The addition of SAGE will allow operators to collect data on selected emitters, supporting operators locate and track both land-based and maritime radars.

Aside from SAGE, other sensors fitted to SeaGuardian include the GA-ASI Lynx synthetic aperture radar, a Raytheon SeaVue XMC surveillance radar, a Raytheon Multi-Spectral Targeting System, a Shine Micro Automatic Identification System, an Ultra sonobuoy receiver and a General Dynamics Mission Systems-Canada sonobuoy processor. – *R. Scott*

## SAAB OFFERS NEW LIGHTWEIGHT STAND-IN JAMMER FOR FINLAND'S HX PROGRAM

Saab has disclosed the development of a new miniaturized air-launched stand-in jammer system as part of its offer for Finland's HX fighter program. Known as the Lightweight Air-launched Decoy Missile (LADM), the new capability would be integrated with Saab's Gripen E/F fighter as part of an airborne electronic attack package to enable penetration of the A2/AD screen, and support the suppression of enemy air defenses/destruction of enemy air defenses. The new decoy/stand-in jammer would be employed alongside Saab's newly-developed Electronic Attack Jammer Pod (EAJP).

*The Gripen E/F could use its Arexis EA pod (mounted under the wing) in conjunction with its ES-05 Raven AESA radar to jam adversary radars.* SAAB

The HX program plans the acquisition of new multi-role fighters to replace the Finnish Air Force's ageing fleet of F/A-18 Hornets. Saab is bidding the Gripen E/F in competition with Boeing (F/A-18E/F Super Hornet), Dassault (Rafale), Eurofighter (Typhoon) and Lockheed Martin (F-35A Lightning II), with a final selection to be made by the Finnish government in 2021.

Saab has now revealed that its HX proposition includes both the EAJP escort jamming pod, a prototype of which began flight testing in 2019, and the new LADM. "The new decoy missile will be a highly capable stand-in jammer for the most demanding missions," said the company. "It will act as a force multiplier as it reduces the number of missiles and aircraft required to complete a mission. The decoy missile can jam or create false targets for acquisition, tracking, fire control and airborne radars."

As part of the HX proposal, the payload of the new decoy missile would be largely developed in Finland, providing for the expansion of the Saab Technology Centre in Tampere. Saab has already established a deep technical partnership with Aalto University, where more than 10 research projects are ongoing within the areas of advanced sensors and artificial intelligence.

The EAJP and LADM were originally conceived under the umbrella of Saab's AREXIS program. Both systems exploit technologies already being used in the Gripen E/F's MFS-EW integrated EW suite. – *R. Scott*

## IN BRIEF

The US Naval Information Warfare Center (NIWC) Atlantic has awarded **S2 Corporation** (Bozeman, MT), a $9 million contract to prototype and demonstrate a broadband electromagnetic spectrum receiver system. The contract, awarded under the Defense Advanced Research Projects Agency's (DARPA's) Providence initiative, covers an 18-month Phase 1 base period and an 18-month Phase 2 option period. The option period, if exercised, will bring the cumulative value up to approximately $21 million. DARPA's Strategic Technology Office released the Providence Broad Agency Announcement (BAA) in October 2019. The BAA sought innovative proposals in the technical areas of naval surface warfare, electronic warfare, battlespace surveillance, machine learning, intelligent systems, and ultra-wideband receiving.

**Lockheed Martin** (Fort Worth, TX) has awarded a production contract to **BAE Systems** (Nashua, NH) contract for Lot 15 and 16 of the ASQ-239 EW suite for the F-35 program. The contract covers long lead, sustainment, spares and retrofit kits. BAE Systems has delivered more than 500 ASQ-239 systems for the program.

The Defense Advanced Research Projects Agency (DARPA) has awarded three contracts, so far, for its Secure Advanced Framework for Simulation and Modeling (SAFE-SiM) program. The Agency awarded the contracts to **L3Harris** in Colorado Springs, CO ($22.2 million), **Radiance Technologies** in Huntsville, AL ($10.1 million) and **Cole Engineering** in Orlando, FL ($9.1 million). As described in the contract announcements, the Agency's SAFE-SiM effort "seeks to build a government-owned and controlled, faster-than-real time modeling and simulation (M&S) capability for theater-wide, mission-level M&S. This capability would enable rapid analysis supporting senior-level decisions for concept of operations development, force structure composition, resource allocation and targeted technology insertion."

The US Air Force's **423rd Mobility Training Squadron** (Joint Base McGuire-Dix-Lakehurst, NJ) has issued a Request for Quotes (RFQ) for a Virtual Reality Threat Trainer for the

United States Air Force Expeditionary Operations School (USAF EOS) to help train Mobility Air Forces crews. According to the program's Statement of Work, "The purpose is to use a virtual reality platform for threat academics, building scenarios, and evaluating simulated MAF missions that are planned in threat areas in order to observe the threat from the aircrew's perspective. In order to be on the leading edge in training, we need software that is physics based and has a complete database of classified threats for air, ground, sea and electronic. We need software that models each component of a threat system, i.e., each individual radar system of a SAM and that is capable of modeling the correct individual pulse rate of the separate radars used in a launch sequence. In order to best meet training needs, we would like the capability to create flight plans and environments with a full running war scenario or ingest planned routes such as JUMPS and PFPS files." The Solicitation Number is Virtual_Reality_Threat_Trainer_20200820. Responses were due September 24. The contracting point of contact is Jeremy Botkin, 609-754-3008, e-mail jeremy.botkin@us.af.mil.

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The US Navy's **Naval Surface Warfare Center, Crane Division** (Crane, IN) is planning to set up a consortium related to "Strategic and Spectrum Missions." The division has issued a Request for Solutions to identify a consortium manager that will enter into a nine-year Other Transaction (OT) agreement with the Navy. According to the solicitation, Spectrum Missions include, "...a wide variety of engineering, logistics and maintenance support for complex Electronic and Infrared Warfare systems and Platform Defense Systems to include maritime electronic warfare (EW), radar technologies, expeditionary EW, Infrared/Radio Frequency (IR/RF) systems technologies and airborne electronic attack systems." Areas of interest include improvements in microelectronics test and verification methodologies; machine learning; multispectral sensing; ensuring trusted FPGA devices; modeling and simulation; secure design of Radio Frequency (RF) and Optoelectronic (OE) microelectronics; research methods to encourage public/private co-development of system-on-chip (SoC); microelectronics and electronic warfare-focused workforce development for universities, DOD and small businesses; spectrum warfare technologies research related to cognitive/adaptive, distributed/networked multi-spectral sensors, high power RF, spectral agility, low probability of intercept communications, RF and infrared countermeasures, and coherent RF transmission; and spectrum warfare technologies research related to advanced and custom optics, advanced threat assessment and exploitation efforts.

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The US Marine Corps' **Marine Air Ground Task Force Training Command** (MAGTF-TC) is expected to release two RFPs for EW services during upcoming exercises. The first of these seeks vehicle-mounted Electronic Warfare Support (ES) services during MAGTF Warfighting Exercises (MWX) to effectively train exercise units during Service Level Training Exercises (SLTE). The

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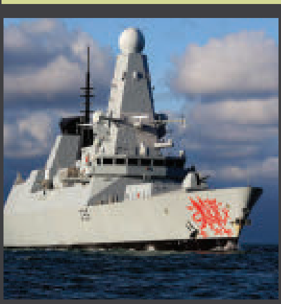

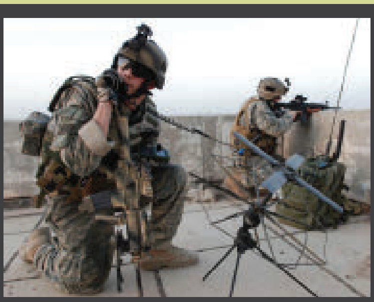

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MAGTF-TC wants to passively identify, characterize, locate and record MAGTF communication assets simultaneously across the full spectrum of tactical communications from 30 MHz to 6 GHz. The MAGTF-TC will use the collected data as a training aid as well as using it to model near-peer competitor detection capabilities in the electromagnetic spectrum (EMS). The MAGTF-TC will also use this data to provide precise technical information to Adversary Forces' electronic attack assets during training exercises at the Marine Corps Air Ground Combat Center (MCAGCC) (Twentynine Palms, CA). Under a separate solicitation, the MAGTF-TC is seeking use of six manpack ES systems and related training for USMC units. These systems will provide direction finding coverage from 30-500 MHz (desired coverage is 3 MHz – to 1.7 GHz) for units at the company level and below. The Solicitation Number for the ES Monitoring Service is M6739920QES21. The Solicitation Number for the manpack DF services is M6739920Q0058. The MAGTF-TC is expected to release the RFPs soon.

The **Defense Advanced Research Projects Agency** (DARPA) has announced plans to hold a Proposers' Day event for its Quantum Apertures Program on October 2. According to a program description, "The objective of the **Quantum Apertures** program is to develop a novel radio receiver and aperture system utilizing a quantum sensor as the receiving element. This receiver system will be portable, programmable over a very large frequency range, and more sensitive than what classical systems can achieve at similar size and temperature. The quantum-based receiving elements will use highly excited "Rydberg" atomic states which have programmable sensitivity over a large range of frequencies and amplitudes. The radio frequency spectrum can be read out using several optical readout methods. The final receiver system will be comprised of a phase-sensitive array of such elements, lasers to program the sensor and read out radio signals, and processing electronics." The Proposers' Day will be held via Webcast at the unclassified level. Program officials may be contacted via e-mail at darpa-sn-20-64@darpa.mil.

The Air Force Life Cycle Management Center (Wright-Patterson AFB, OH) has awarded a $17.7 million other transaction prototype project agreement to **Applied Technology Associates** (Albuquerque, NM) to develop and deliver a ground-based Directed Energy Weapon (DEW) prototype for the purpose of fixed-site Air Force Air Base Air Defense against Group 1 and Group 2 unmanned aerospace system (UAS) threats. In October 2019, the company introduced its Low-Cost Counter-Unmanned Aerial System for Targeting (LOCUST) system. According to a company description, "LOCUST detects and identifies UAS threats using active and passive radio frequency (RF) and electro-optical infrared (EOIR) sensor subsystems, and it negates the threats using intelligent electronic attack (EA) and high energy laser (HEL) effectors." Under the contract, which runs through September 2021, a further $63.4 million could be awarded if all options are exercised.

# Europe Steps Up C

**By Andrew White**

**The European Counter** Unmanned Aerial System (C-UAS) market continues to promise significant growth for armed forces and security agencies seeking to not only protect critical national infrastructure at home but also forward deployed personnel operating abroad. Some of the most notable European programs, which continue to be pursued over the course of 2020 despite some hold ups associated with the ongoing COVID-19 pandemic, include procurement efforts in Denmark, Finland, Germany and Lithuania to name just a few. However, despite benefiting from several years of frantic research, development and procurement activities, the European C-UAS market remains in a relatively early stage of development, as customers continue to tweak requirements to support an ever-expanding envelope of potential mission sets. A one-size-fits-all solution appears as far away as ever in terms of a C-UAS capability.

*The ability to detect, track and neutralize small UAS, such as this Russian Eleron-3 (above), continues to present problems for armed forces across Europe.* RUSSIAN FEDERATION MOD

Nevertheless, European defense departments and industry continue to explore emerging technologies designed to satisfy urgent operational requirements arising from theaters around the world. Specific areas of interest include Artificial Intelligence (AI) and Machine Learning (ML) algorithms designed to assist in the recognition of threats; autonomous capabilities to help counter swarms of UAS; high-definition (HD) and three-dimensional (3D) sensors and radars; and finally, the integration of C-UAS systems into wider air defense networks.

## STILL MATURING

Rheinmetall Air Defense Systems Program Manager, Matthias Diem, described how the European C-UAS market is reaching a mature level. "The first wave of the market was quite simple; stand-alone sensor solutions from various vendors were installed in the field without any networked capability and concept of operations," he said. "Today, we reach the second wave of the market where we can see that C-UAS solutions must be integrated into higher echelons to allow multi-agency capabilities. High degrees in automation and low false alarm rates are key but also essential is the efficient use of C-UAS staff. This second wave has reached certain countries in Europe which are now preparing the third wave – fully integrated C-UAS systems with the capability to integrate highly autonomous effectors."

According to Diem, the most critical capability gap facing the C-UAS market in Europe is the lack of a complete local air picture. New sensor technologies, he said, are capable of filling this gap for stationary and mobile military platforms. "There are sensors and systems on the market which are quite capable already," he explained, "but the seamless integration into a sophisticated C2 [command and control] system is the key to success. Only a redundant sensor fusion with the right effector mix – lethal and non-lethal for stationary and mobile platforms – will pave the way for the future of modern air defense. Many armed forces have recently suffered from a lack of this capability and are now evaluating the latest SHORAD [short range air defense] systems – with a high focus on mobile air defense capabilities," he added.

Referring to the contemporary operating environment, where forward-deployed armed forces continue to be threatened by the "wide use of weaponized drones," Diem described how C-UAS and wider air defense solutions must be equipped to handle "highly connected swarms of drones." "C-UAS equipped with AI features will be one the most crucial challenges to all air defense forces," he said. "Thus, customers are taking this into consideration while shaping their future requirements."

On July 30, Germany's Federal Office for Equipment of the Bundeswehr (BAAINBw) selected a consortium featuring Rohde & Schwarz, ESG and Diehl to supply an undisclosed number of "Guardion" C-UAS solutions. Designed to "detect, classify, identify and counter" small unmanned aerial vehicles, Guardion systems will be tasked with

# ounter-UAS Efforts

*The Ardronis equipment provides passive RF detection, direction finding and RF countermeasures for Guardion C-UAS solution.* ROHDE & SCHWARZ

the force protection of military bases around the World.

Featuring Hensoldt's Spexer 2000D radar and Night Owl cameras, in addition to R&S's Ardronis direction finding equipment, Guardion detects radar, visual, RF and acoustic signatures of UAS targets and then processes data using ESG's Taranis C2 software. "Ardronis detects, classifies and determines the direction of drone remote controls, prohibits remote control between the pilot and the drone, thereby preventing the silent approach of unmanned aerial vehicles," a company spokesperson for Rohde & Schwarz described in a statement. The system can "detect and prevent unauthorized situations with UAS by continuously monitoring the frequency bands used by unmanned vehicle remote controls and generating an alert when a remote control is activated. This gives security personnel the earliest possible warning, saving valuable time for clarifying the situation," it added.

Ardronis also provides the Guardion's countermeasures response, which jams the drone's C2 link and GPS receiver. "Detected and identified targets are neutralized by disrupting communication with the command post or satellite navigation system," according to the company. "When the radio link is interrupted, drones usually enter failsafe mode and are not able to continue flying. Ardronis only disrupts the control signals of UAVs previously identified as unauthorized, without affecting other radio links in the same frequency band. The system also uses effectors in the form of electromagnetic weapons or fired nets. Open architecture allows for the introduction of additional measures to detect and combat drones," the statement concluded.

## MOBILITY

Meanwhile, Norwegian company Kongsberg Defence and Aerospace continues to integrate solutions on board a variety of tactical ground vehicles as it considers more mobile applications for C-UAS technology in support of the German Armed Forces and the wider international market. The company's vice president for marketing and sales, land systems, Arne Gjennestad, explained how the UAS threat continues to grow as does the capability to defend against such threats. "This is currently a key requirement in many programs," he said. "There is no solution that fits all requirements, threats and scenarios. We need to have a flexible toolbox with different capabilities." He went on to explain, "There are also systems that will be designated C-UAS systems, specifically for high-value targets. But for regular units, there may not be available funding, personnel or space to buy, operate or mount a C-UAS capability. So it is important that C-UAS kits can be an add-on in order to allow the customer to achieve cost-effective solutions using what he already has, with no more manning or no more equipment."

Kongsberg is currently working with the German Armed Forces to provide a capability to protect tactical ground vehicles against UAS operating as part of the NATO Very High Readiness Joint Task Force (VJTF) deployment to Eastern Europe in January 2023. "After studies of different concepts, the BAAINBw (acquisition organization) launched a competitive tender, including a test and demonstration firing. The contract was awarded in December 2019 after an international bidding process. The program is now running in accordance with an agreed program execution plan," Gjennestad confirmed.

Kongsberg's solution comprises a C-UAS capability integrated onto the company's own Protector remote weapon station (RWS), which will use a Heckler & Koch 40-mm Automatic Grenade Launcher with programmable airburst munitions to defeat target UAS. "The RWS is connected to a radar sensor, which provides surveillance of the airspace for detection and tracking of UAS," he said. "After detection of the UAS, the Protector Fire Control system provides a target priority list focused on the highest threatening target at that particular time. The operator is then able to directly slew the RWS's C-UAS payload onto the selected target before automatic tracking is conducted by a multi-sensor tracker, which uses the best available sensor or a combination of these to follow the target. Options include radar, thermal imager or visual imager, assisted by the Laser Range Finder. When engaging the target, the grenades will be programmed to explode in a specific pattern based on direction of movement of the target," Gjennestad added.

The solution also includes Hensoldt's Spexer 2000 3G radar, following its selection by the German Armed Forces. Kongsberg's solution for the Germany Armed Forces will not include a soft-kill capability. "The program is moving forward in accordance with an agreed program plan. The complete German system should be operational and part of their VJTF participation 2023," Gjennestad confirmed.

Gjennestad also explained how Kongsberg could integrate a 30-mm x 113-mm cannon with airburst/proximity ammunition into the Protector C-UAS solution, in order to provide end users with several choices for engaging UAS based on their characteristics. Further integration of additional sensors includes integration with additional radars and acoustic sensors which remain ongoing efforts for the company.

Kongsberg is also considering the integration of tactical C-UAS on board unmanned ground vehicles (UGVs). Gjennestad said, "The ability for an operator to control several Protector systems at the same time via a multi-station control, as well as the ability to have a secure fire control for remote/wireless control of the RWS, provides an opportunity for UGVs."

## INTEGRATED SOLUTIONS

In the UK, Leonardo continues to work on a three-year C-UAS contract on behalf of the Royal Air Force (RAF) following its down-selection in September 2019. Managed in conjunction with the MOD's Defence Equipment & Support Future Capability Group, the Counter-Drone Research Program is aimed at "reinvigorating" research and development in terms of understanding requirements for a "future core capability which will be able to respond to rapidly-evolving threats posed by hostile drones," according to a company statement. The program, which officially started in the first half of 2020, is tasked with understanding how C-UAS operators will be able to detect, track, identify and defeat rogue drones in the future operating environment.

*Leonardo's Falcon Shield remains in service with the UK MoD as well as the Italian MoD. The company is also working with the Royal Air Force to consider how to improve C-UAS technology into the future.* LEONARDO

Last month, the company announced that it had delivered the first of four complete baseline ORCUS C-UAS systems to the RAF for evaluation. According to a statement from the MOD, successful testing of the full range of integrated detect, track, ID, and defeat technologies, enabled the program to achieve an Initial Operating Capability. Understood to include technology from Leonardo as well as sub-contractors Metis Aerospace and SRC Inc., the ORCUS utilizes a modular architecture that comprises radar, electro-optic and radio frequency sensors to detect and track UAS, and an electronic attack subsystems to defeat the target. While the ORCUS is currently part of the RAF study program, the RAF is ultimately seeking a C-UAS capability to protect air bases both at home and abroad.

Leonardo's sales manager for integrated sensing and protection, Andy Roberts, described how the European market continues to increase with interest in both and civil applications. "Whilst these are likely to have different requirements in terms of performance and the potential utility of effectors," he said, "it is something we are continuing to monitor closely. The market is also becoming more informed as time progresses, this means that customers are refining their requirements, which is a great enabler for us in industry."

*Chess Dynamics' AirGuard system can be configured for fixed or mobile applications.* CHESS DYNAMICS

Leonardo's offering, Falcon Shield, is already in service with the RAF, as well as the Italian Army and the Italian Air Force in a force protection role having benefited from critical lessons learned while performing similar protection duties at London Heathrow and Gatwick airports in 2018.

Falcon Shield comprises an integrated system of sensors and effectors, capable of detecting, tracking, identifying and defeating drones at long range. As Roberts explained, "It draws on our abilities as a system integrator to utilize best-of-breed detection technologies, coupled with our thermal imaging and electronic warfare technologies to provide a capability that can both identify and defeat drones before they are able to have a physical or surveillance effect on the user." He added, "We continue to monitor the development of drone technologies so as to enable future enhancements to both our detection and defeat capabilities. We are also looking at methods of deployment of these technologies to suit a number of different operational scenarios."

Positioning itself as a systems integrator in the European and international C-UAS market is the UK's Chess Dynamics, with sales director Dave Eldridge describing how today, customers are able to choose between "hundreds" of C-UAS capabilities. Reiterating that the C-UAS market is unlikely to ever see a "silver bullet" solution, Eldridge explained how the future of C-UAS solutions will require the technology to be integrated into larger air defense networks, allowing them to contribute towards and benefit from combined air pictures.

"C-UAS can't afford to stand outside of that," Eldridge warned before suggesting the integration of tactical C-UAS systems into more operational and strategic air defense networks might slow down procurement programs in the future. "A properly structured C-UAS military program is probably going to happen in the next two years. But as has been the case to now, urgent operational requirements will continue to be the trend instead of proper equipment evaluation," Eldridge added.

In order to keep pace with Europe's rapidly emerging C-UAS market, Chess continues to observe a series of emerging

technologies, including 3D radars and HD thermal imaging sensors, both of which would increase operating efficiency. "HD thermal imaging is becoming available and moving forward," he said. "In the future, all sub-systems sensors are going to be HD, be they thermal imagers or day cameras." Chess is also exploring the ability of AI and ML algorithms to assist in the automatic detection and classification of targets through its subsidiary Vision4ce. Such a capability means customers would be able to create a UAS threat library. "Video classification to us is a gamechanger," he stressed.

According to Eldridge, the more sub-systems and sensors which can be integrated into a wider C-UAS and air defense solution, the better it will be. "In the military context, it's all about understanding what system is right for a particular application. Systems must also be agnostic to defeat and detection mechanisms, providing end users with a service capability."

In terms of defeat mechanisms, Eldridge explained how directed energy was quickly becoming a plausible solution in addition to RF jammers and hard-kill munitions and missiles. "Soft kill is responsible for 95% of solutions out there at the moment," he said. "But if a drone is coming on a pre-programmed flight path, it's no good taking out its navigation systems. Military doctrine therefore, will require end users to be able to hand off to a directed energy or kinetic solution in the future."

Thales is another major European solutions provider which is focused on exploiting Big Data, Connectivity, AI and Cyber Security to further enhance C-UAS solutions in the future. "We fully expect the market to develop, and indeed we are working on very innovative developments in the C-UAS field for deployment across the next 10 years, including countering swarms of drones," said a company spokesman. "These are drones that act in total coordination with one another mimicking the behavior of certain biological organisms like bees or starlings."

Unable to provide further details due to competitive sensitivities, the Thales spokesperson confirmed how the company continued to offer up its ForceShield C-UAS system, which comprises an air defense system designed to intercept any air threats, from small UAS up to combat aircraft. It includes a command, control and communications suite, which is networked to hard-kill effectors, including Starstreak and Light Multirole missiles.

Another Thales offering is EagleShield which comprises a multi-sensor solution capable of detecting, identifying, classifying and neutralizing rogue drones flying at low altitude at ranges of up to 7 km. This solution also incorporates the Gamekeeper holographic radar which provides 3D coverage over a 90-degree field of view and can be networked to infrared and RF sensors which refine the system's threat identification and classification performance "using sophisticated real-time data fusion techniques to determine the exact type of unmanned aircraft involved," the spokesperson said.

## WEARABLE UAS DETECTION

At the lowest tactical level, Danish C-UAS specialist MyDefence Communications is in the process of equipping Lithuanian forces with C-UAS solutions which can be worn on the soldier, integrated on board vehicles or operated in a fixed-site configuration to protect operating bases.

The company's CEO, Dan Hermansen, described several established as well as emerging C-UAS mission areas, including critical infrastructure protection, border control, point protection and wearable security.

"In the European MODs," he said, "there is a clear lack of C-UAS capabilities. With the exception of special forces, land forces in general are missing out on equipment for countering low, slow and small air threats. The same goes for naval and air forces, which paints a picture of a serious gap in the armed forces, as equipment used for early warning and self-protection is missing." He said the Technology Readiness Level (TRL) of most systems is already at TRL 9, now is a good time for MoDs to progress their procurement plans and make specific calls for action.

MyDefence solutions include the Wingman-105 Small Handheld/Wearable Drone Detector, which is supported by the Watchdog 200 Networked RF Sensor. Comprising a lighter weight version of MyDefence's Wingman-100, the -105 model is capable of detecting drone threats out to a range of approximately 1,000m through 60-degree directional 2.4GHz and 5.8GHz ISM band antennas. Hermansen described how the Wingman-105 could be worn around the wrist, providing end users with non-audible alerts of UAS in the immediate area. The capability also includes the AA100 external Active Antenna (AA100) – an omni-directional antenna which can be added on for 360-degree coverage and lower ISM-band frequencies, dependent upon customer preferences. The AA100 was originally developed in 2017 in cooperation with the US Army to cover normal ISM-bands, with multiple parallel active receiver chains designed to make the solution versatile enough to quickly counter threats in new frequency areas.

Based on the rapid developing UAS-threat from ISIS and other violent extremist organizations around the World, the frequency band around 1.2-1.3 GHz was quickly added to the solution, making it capable of detecting drones using analog video for FPV goggles, Hermansen

*MyDefence Communications is in the process of delivering an undisclosed number of Wingman man wearable C-UAS solutions to the Lithuanian MoD.*

MYDEFENCE

described. "In a matter of days, the new drone threats were available in the library and the Wingmans were updated in theater with the Field Upgrade Tool FT100 simply by downloading the new firmware from a secure site and copying it to an SD-card for firmware update to start." The newest accessory to the Wingman family is the Vibrator Dongle VD100, which was custom developed for the Lithuanian MOD to enable troops to stay protected from drones without jeopardizing stealth.

MyDefence has also designed the Watchdog 200 (WD200) as its "next evolution" for the C-UAS market, comprising a portable solution featuring direction finding and the Iris C2 system. In stand-alone mode, the WD200 quad mount features four mounted and perpendicular sensors covering 360 degrees with an accuracy of 5 degrees RMS. When two or more tripods are networked, the system achieves the ability to geolocate RF transmitters and thereby start tracking drones and pilots based on their RF emissions.

In August, MyDefence hosted a demonstration for the Danish MOD that illustrated the capabilities of the Watchdog system with geolocation capability. A total of three quad mounts were used to cover a larger area, sharing data across a wireless network to demonstrate how both drone and pilot can effectively be geolocated in real-time, Hermansen described. This new geolocation feature will be released to customers later this year, and further end-user trials have been planned in Europe, Middle East and North America in the coming months, he added.

## KEEPING PACE WITH DRONE TECHNOLOGY

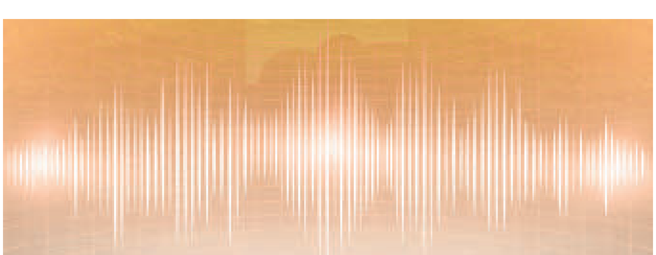
According to Leonardo's Andy Roberts, the next five to 10 years in the European C-UAS market will see continued requirements for such capabilities: "Drone technology continues to develop and so therefore will the requirement to counter those used to cause damage either maliciously or accidentally. I think this will be true in both the military and the civil space," he concluded.

Similarly, Chess Dynamics' Dave Eldridge believes the future of the European C-UAS market will be focused on achieving reductions in operating costs, as well as an increasing focus on the military market. "Up to now, the market has been reactionary," he said. "But I can see that changing as the market moves rapidly forward. Military C-UAS requirements will become more and more a part of everyday training disciplines similar to awareness in counter-improvised explosive device (C-IED) expertise, which has become ingrained in many armed forces over recent years. C-UAS will be similar," he surmised.

According to Rheinmetall's Diem, C-UAS will prove a great enabler for wider Ground Based Air Defense systems in the future. Referring to a "renaissance" in air defense, he concluded: "It is absolutely clear by now that armed forces need to regain their capabilities to protect and defend their assets by VSHORAD. This renaissance will drive the market demand but also significant innovations."

# 2021 EW/SIGINT Resource Guide

Welcome to the 2021 Electronic Warfare and Signals Intelligence Resource Guide. This guide is the print snapshot of the AOC's online EW/SIGINT Resource Guide, edited by *JED* editors. It is designed to list companies and organizations that manufacture products or provide services in the areas of electronic warfare and signals intelligence. This year, we added some new categories.



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## ABOUT THIS GUIDE

This guide was assembled by JED's editorial staff, based on our own research and from updated information provided to us by companies. Though we have attempted to produce a comprehensive listing, we expect this guide to continue to grow. If your company conducts business in the EW or SIGINT markets and it does not appear in this year's guide, please see the note below on how to have your company listed.

## HOW TO USE THIS GUIDE

The guide's first section contains a "company listing," in which companies are featured in alphabetical order. The second section includes product and service categories, roughly organized by components/subsystems, software and services. The third section lists the companies in each category. Refer back to the company section for website and location data on listed companies.

## GET LISTED

If your company is missing or your data requires additional updates, please provide your information to us via e-mail to JEDeditor@naylorcom so we may update our files. Please note that our next print guide will appear in October 2020, however, the online resource guide is live year-round at www.ewsigint.net.

# #

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www.3db-labs.com

**3SDL**
www.3sdl.com

# A

**Aaronia AG**
www.aaronia.com

**Abaco Systems**
www.abaco.com

**Acromag**
www.acromag.com

**Adamy Engineering**
dave@lynxpub.com

**Advanced Electronics Company – Military Systems Business Unit**
www.aecl.com

**Advanced Microwave Inc.**
www.advmic.com

**Advanced Protection Systems**
www.apsystems.tech

**Advanced Testing Technologies Inc.**
www.attinet.com

**Advantech**
www.advantech.com

**AECOM**
www.aecom.com

**Aegis Corea**
www.aegiscorea.en.ec21.com

**Aero Telemetry**
www.aerotelemetry.com

**Aeromaoz**
www.aeromaoz.com

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www.aeronix.com

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www.aethercomm.com

**Airborne Systems Limited**
www.airborne-sys.com

**Airborne Tactical Advantage Company**
www.atacusa.com

**AirScan Inc.**
www.airscan.com

**AKON, Inc.**
www.akoninc.com

**Alaris Antennas**
www.alarisantennas.com

**Albrecht Telecommunications**
www.albrecht-telcom.ch

**Alion Science and Technology**
www.alionscience.com

**Alker Optical Equipment**
www.alker.co.uk

**Allen-Vanguard Corp.**
www.allenvanguard.com

**Alpha Design Technologies Pvt. Ltd.**
www.adtl.co.in

**American Microwave Corp.**
www.americanmicrowavecorp.com

**Ampex**
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**Amplifier Solutions Corp.**
www.amplifiersolutions.com

**AmpliTech**
www.amplitechinc.com

**Amplus Corporation**
www.amplus-corp.com

**AMT Microwave Corp.**
www.amt-microwave.com

**Analog Devices Inc.**
www.analog.com

**Anaren, Inc.**
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**Anatech Electronics**
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**Annapolis Micro Systems, Inc.**
www.annapmicro.com

**Anritsu**
www.anritsu.com

**ANSYS, Inc.**
www.ansys.com

**Antenna Authority**
www.antennaauthorityinc.com

**Antenna Experts**
www.antennaexperts.in

**Antenna Products**
www.antennaproducts.com

**Antenna Research Associates**
www.ara-inc.com

**AntiDrone**
https://anti-drone.eu

**APITech**
www.apitech.com

**ApisSys**
www.apissys.com

**ApolloShield**
www.apolloshield.com

**Applied EM Inc.**
www.appliedem.com

**Applied Radar Inc.**
www.appliedradar.com

**Applied Research Associates**
www.ara.com

**Applied Systems Engineering Inc.**
www.applsys.com

**Applied Technology Institute (ATI)**
www.aticourses.com

**Applied Thin Film Products**
www.thinfilm.com

**AR RF/Microwave Instrumentation**
www.arworld.us

**ARA, Inc.**
www.ara-inc.com

**ARC Technologies**
www.arc-tech.com

**Arctan, Inc.**
www.arctan-group.com

**Argon ST, a Boeing Company**
www.argonst.com

**Armtec Defense Technologies**
www.armtecdefense.com

**ARS Products**
www.arsproducts.com

**ArtSYS360**
www.artsys360.com

**ASELSAN Inc.**
www.aselsan.com.tr

**Assemblies Inc.**
www.assembliesinc.net

**Association of Old Crows**
www.crows.org

**Astronautics C.A. Ltd.**
www.astronautics.co.il

**Astronics**
www.astronics.com

**ATDI**
www.atdi.com

**Atkinson Aeronautics and Technology Inc.**
www.ataero.com

**Atlanta Micro**
www.atlantamicro.com

**Atos**
www.atos.net

**ATS Cases**
www.atscases.com

**Avalon Electronics, Inc.**
www.avalonelectronics.co.uk

**AVdef – Avition Defence Service**
www.avdef.fr

**Azure Summit Technology**
www.azuresummit.com

# B

**B&K Precision**
www.bkprecision.com

**Babcock International Group, Defence and Security Div.**
www.babcockinternational.com

**BAE Systems**
www.baesystems.com

**BARCO**
www.barco.com

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www.base2engineering.com

**BATS**
www.bats.be

**Battelle**
www.battelle.org

**Battlespace Simulations, Inc.**
www.bssim.com

**BC Systems**
www.bcpowersys.com

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**Berkeley Nucleonics Corp.**
www.berkeleynucleonics.com

**BIRD Aerosystems**
www.birdaero.com

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www.bird-technologies.com

**BittWare**
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www.bjgelectronics.com

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www.blacksagetech.com`

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**Booz Allen Hamilton, Inc.**
www.boozallen.com

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www.boydcorp.com

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**BSC Filters**
www.dovermpg.com/bscfilters

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**CEA Technologies**
www.cea.com.au

**CellAntenna Corp.**
www.cellantenna.com

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www.cerbair.com

**Chemring Australia**
www.chemring.com.au

**Chemring Countermeasures UK**
www.chemringcm.com

**Chemring Countermeasures USA**
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www.fei-elcomtech.com
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www.flexcomw.com
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**Fractal Antenna Systems**
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www.fsant.de

## G

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**General Dynamics Mission Systems**
www.gdmissionsystems.com
**Genesis EW Ltd.**
https://genesisew.wixsite.com/genesis-ew
**Georgia Tech Research Institute**
www.gtri.gatech.edu
**GEW Technologies (Pty) Ltd.**
www.gew.co.za
**Giga-tronics Inc.**
https://go-asg.gigatronics.com
**Good Will Instrument Co. Ltd.**
www.gwinstek.com
**Gowanda Components Group**
www.gowandacomponentsgroup.com

## H

**HARP**
www.harparge.com
**Hascall-Denke**
www.hascall-denke.com
**HawkEye 360**
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**HAVELSAN**
www.havelsan.com.tr
**Hegarty Research LLC**
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**Hensoldt**
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**HIK Vision**
www.en.hikrobotics.com
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**Horizon Technologies**
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**HUBER+SUHNER AG**
www.hubersuhner.com
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www.novaskycn

## I

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**http://iacit.com.br**
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**I.F. Engineering Corp.**
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**IFI – Instruments for Industry Inc.**
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**IKHANA Aircraft Services**
www.ikhanagroup.com
**IMI Systems**
www.imisystems.com
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www.impactcases.com
**INDRA**
www.indracompany.com
**INNOSYSTEC GmbH**
www.innosystec.de
**Innovative Integration**
www.innovative-dsp.com
**Intel Product Solutions Group**
www.intel.com
**Intelligent Automation Inc.**
www.i-a-i.com
**Interface Concept**
www.interfaceconcept.com
**Invisible Interdiction**
**http://invisidiction.com**
**iRF Solutions**
www.irf-solutions.com
**ISPAS AS**
www.ispas.biz
**ITA International**
https://ita-intl.com
**iVeia, LLC**
www.iveia.com
**IW Microwave**
www.iw-microwave.com
**IZT GmbH**
www.izt-labs.de

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www.jabil.com
**Jackson Labs Technologies, Inc.**
www.jackson-labs.com
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www.gojbm.com
**JEM Engineering**
www.jemengineering.com
**Jenkins Engineering Defence Systems**
www.jeds.com.au
**Jersey Microwave**
www.jerseymicrowave.com
**JFW Industries**
www.jfwindustries.com
**Jordan Electronic Logistic Support – Electronic Warfare**
www.jels-tech.com
**JT4 LLC**
www.jt4llc.com

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**Kerberos International**
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**Keysight Technologies**
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**Kihomac, Inc.**
www.kihomac.com
**Kirintec**
www.kirintec.com
**KMIC Technology, Inc.**
www.kmictech.com
**Knowles Precision Devices**
www.knowlescapacitors.com
**Kranze Technology Solutions, Inc. (KTS)**
www.kranzetech.com
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www.kratosdefense.com
**Krytar Inc.**
www.krytar.com

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**L3Harris Technologies**
www.l3harris.com
**Lacroix**
www.lacroixds.com
**Laird Technologies**
www.lairdtech.com
**LCR Embedded Systems**
www.lcrembeddedsystems.com
**Leidos, Inc.**
www.leidos.com
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www.leonardocompany.com
**Lexatys**
www.lexatys.com
**Link Microtek**
www.linkmicrotek.com
**Linwave Technology**
www.linwave.co.uk
**Liteye Systems, Inc.**
www.liteye.com
**Littelfuse**
www.littelfuse.com
**Lockheed Martin**
www.lockheedmartin.com
**LOG.IN Srl**
www.loginshowroom.com
**Logus Microwave**
www.logus.com
**LS Telcom**
www.lstelcom.com

## M

**MacAulay-Brown – Alion Science**
www.macb.com
**MACOM**
www.macom.com
**MagiQ Technologies, Inc.**
www.magiqtech.com
**ManTech International Corp.**
www.mantech.com
**MarServices GmbH**
www.marservices.de
**MASS**
www.mass.co.uk
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**MC Countermeasures Inc.**
www.mc-cm.com
**MCTech**
www.mctech-jammers.com
**MECA Electronics**
www.e-meca.com
**MegaPhase**
www.megaphase.com
**Meggitt**
www.meggitt.com
**MEMtroncs Corp.**
www.memtronics.com

**Mercer Engineering Research Center**
www.merc-mercer.org

**Mercury Electronic Warfare Ltd.**
www.mercuryew.com

**Mercury Systems**
www.mrcy.com

**Meritis Group**
www.meritis.ch

**MES S.p.A.**
www.mesroma.it

**MESL Microwave**
www.meslmicrowave.com

**Metamagnetics**
www.mtmgx.com

**Metis Aerospace Ltd.**
www.metisaerospace.com

**Micro Lambda Wireless, Inc.**
www.microlambdawireless.com

**Micronetixx, P.A.**
www.micronetixx.com

**Microphase Corp.**
www.microphase.com

**Microwave Amplifiers Ltd.**
www.microwaveamps.co.uk

**Microwave Applications Group**
www.magsmx.com

**Microwave Communications Laboratories**
www.mcli.com

**Microwave Dynamics**
www.microwave-dynamics.com

**Microwave Engineering Corp.**
www.microwaveeng.com

**Microwave Filter Company**
www.microwavefilter.com

**Microwave Products Group**
www.dovermpg.com

**Microwave Specialty Company**
www.microwavespecialty.com

**Mid-Atlantic RF Systems**
www.midatlanticrf.com

**Midwest Microwave Solutions Inc.**
www.mms-rf.com

**Military Optical RF Equipment Ltd.**
www.eimore.co.il

**MILMEGA, a Teseq Company**
www.milmega.co.uk

**Milso AB**
www.milso.se

**Mini-Circuits**
www.minicircuits.com

**Mission Microwave**
www.missionmicrowave.com

**The Mitre Corporation**
www.mitre.org

**Mitsubishi Electric Corp.**
www.mitsubishielectric.com

**Modern Technology Solutions, Inc.**
www.mtsi-va.com

**Momentive Performance Materials**
www.momentive.com

**Montena Technology sa**
www.montena.com

**Motorola Solutions – Applied Technology Division**
www.motorolasolutions.com

**MRSL**
www.mrsl.com

**Multiconsult SRL**
www.multi-consult.com

**mWave Industries, LLC**
www.mwavellc.com

**My-konsult**
www.mykonsult.com

**MyDefence Communication**
http://mydefence.dk

## N

**N-Ask Incorporated**
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**Nallatech, Inc., a subsidiary of Interconnect Systems Inc.**
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**Narda Safety Test Solutions**
www.narda-sts.com

**National Instruments Corp. (NI)**
www.ni.com

**NEC Network and Sensor Systems, Ltd.**
www.necnets.co.jp

**NEL Frequency Controls, Inc.**
www.nelfc.com

**Netline Communications Technologies**
www.netlinetech.com

**New Wave Design & Verification**
www.newwavedv.com

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## O

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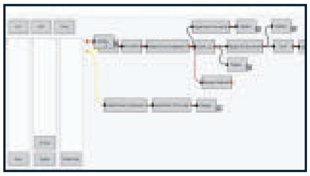
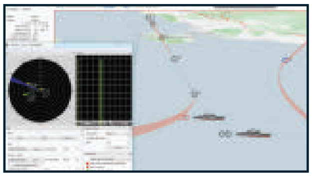
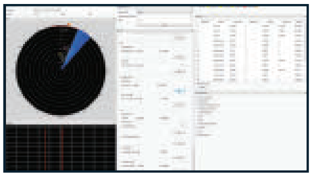
### E-PRS Framework



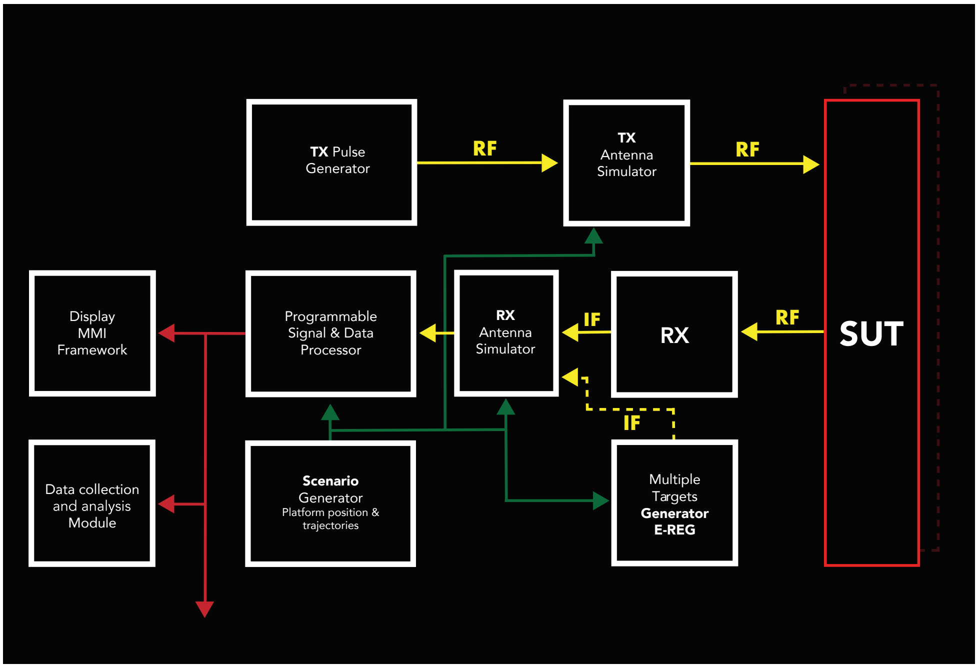
### Scenario Configuration



### Track Lost



### System Architecture

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**QinetiQ Ltd.**
www.QinetiQ.com
**Qnion Co., Ltd.**
www.qnion.com
**Qorvo**
www.qorvo.vom
**QRC Technologies**
www.qrctech.com
**QuantiTech**
www.quantitech.com
**Quarterwave Corp.**
www.quarterwave.com
**QuinStar Technology, Inc.**
www.quinstar.com

# R

**R.A. Wood Associates**
www.rawood.com
**RADA USA**
www.radausa.com
**Radiall**
www.radiall.com
**Radio Reconnaissance Technologies**
www.radiorecon.com
**Radixon**
www.radixon.com
**RADX Technologies, Inc.**
www.radxtech.com
**Rafael – Advanced Defense Systems LTD, Land & Naval Systems Division**
www.rafael.co.il
**Rantelon**
www.rantelon.ee
**Raytheon**
www.raytheon.com
**Red Rapids**
www.redrapids.com
**Renaissance Electronics Corp.**
www.rec-usa.com
**Research Associates of Syracuse (RAS)**
www.ras.com
**Research Electronics International (REI)**
www.reiusa.net
**Reut Systems & Technologies (RST)**
www.rst-tech.co.il
**RF COM Sistemas Ltda.**
www.rf.com.br
**RF Engines Ltd.**
www.rfel.com
**RF Industries**
www.rfindustries.com
**RF Logic**
www.rflogic.net
**RFcore Co, Ltd.**
www.rfcore.com
**RFHIC USA**
www.rfhic.com
**RH Laboratories**
www.rh-labs.com
**Rheinmetall Defence**
www.rheinmetall-defence.com
**Rincon Research Corporation**
www.rincon.com
**Rising Edge Technologies**
www.risingedge.com
**Riverside Research Institute**
www.riversideresearch.org
**Rodale Electronics Inc.**
www.rodaleelectronics.com
**Rodelco Electronics Corp.**
www.rodelco-usa.com
**Rohde & Schwarz GmbH & Co. KG**
www.rohde-schwarz.com
**Rotating Precision Mechanisms, Inc.**
www.rpm-psi.com
**RUAG – Aerospace**
www.ruag.com
**Rubisoft**
www.rubisoft.fr

# S

**S2 Corp.**
www.s2corporation.com
**Saab**
www.saabgroup.com
**Safran Electronics and Defense**
www.safran-electronicsdefense.com
**Sagax Communications**
www.sagax communications.com
**Sage Millimeter**
www.sagemillimeter.com
**SAIC**
www.saic.com
**Samel 90**
www.samel90.com
**Santa Barbara Infrared Inc.**
www.sbir.com
**SATIMO**
www.satimo.com
**Schaefer Electronics**
www.schaeferpower.com
**Scientific Research Corp.**
www.scires.com
**SEA**
www.sea.co.uk
**Sechan Electronics Inc.**
www.sechan.com
**Select Fabricators**
www.select-fabricators.com
**Selex Galileo, Inc. (a Leonardo-Finmeccanica Company)**
www.selexgalileo.com
**Sensofusion**
www.sensofusion.com
**SensorCom Inc.**
www.sensorcominc.com
**Seqtor ApS**
www.seqtor.com
**Serpikom**
www.serpikom.eu
**SESP Group**
www.sesp.com
**Seven Technologies Group**
www.7techgroup.com
**Shakespeare Military Products**
www.shakespeare-military.com
**Shoghi Communications Ltd.**
www.shoghi.co.in
**Sierra Nevada Corp.**
www.sncorp.com
**Signal Antenna Systems Inc.**
www.signalantenna.com
**Signal Hound**
www.signalhound.com
**SignalCore Inc.**
www.signalcore.com
**Silentium Defence**
www.silentium defence.com.au
**Silver Palm Technologies**
www.silverpalmtech.com
**Simulation Technologies**
www.simtechinc.com
**SimVentions**
www.simventions.com
**SINTIS Technology Ltd.**
www.sintistechnology.com
**Sivers IMA AB**
www.siversima.com
**SkySafe**
www.skysafe.io
**Skyworks Solutions**
www.skyworksinc.com
**SMAG Mobile Antenna Masts GmbH**
www.smam.de
**Smiths Interconnect**
www.smithsinterconnect.com
**Solid State Devices, Inc.**
www.ssdi-power.com
**Southwest Antennas**
www.southwestantennas.com
**Southwest Microwave**
www.southwest microwave.com

**Southwest Research Institute (SwRI)**
www.swri.org

**Spatial and Spectral Research**
www.ssrllc.us

**Spectra Research**
www.spectra-research.com

**Spectranetix Inc.**
www.spectranetix.com

**Spherea GmbH**
www.spherea.de

**Spirent Communications**
www.spirent.com

**SRC, Inc.**
www.srcinc.com

**SRI International**
www.sri.com

**Steatite Antennas**
www.steatite-antennas.co.uk

**SteelRock Technologies**
www.sruav.co.uk

**SunCastle Microwave, LLC**
www.suncastle microwave.com

**Sundance DSP**
www.sundancedsp.com

**SURVICE Engineering Co.**
www.survice.com

**Syncopated**
www.syncopated products.com

**Syncopated Engineering**
www.syncopatedengr.com

**Syntonic Microwave Corp.**
www.syntonicmicrowave.com

**Sypris Solutions**
www.sypris.com

**Systematic**
www.systematic.com

**Systems & Processes Engineering Corp. (SPEC)**
www.spec.com

# T

**TACO Antenna**
www.tacoantenna.com

**Tabor Electronics**
www.taborelec.com

**Tampa Microwave, a subsidiary of Thales Defense and Security**
www.tampamicrowave.com

**Tata Advanced Systems Limited (TASL)**
www.tataadvanced systems.com

**Tata Power Strategic Electronics Division**
www.tatapowersed.com

**TCI International, Inc.,** an SPX Company
www.tcibr.com

**TE Connectivity**
www.te.com

**TechComm**
www.techcommdf.com

**Tech Resources, Inc. (TRI)**
www.trimilford.com

**TEK Microsystems, Inc.**
www.tekmicro.com

**Tektronix, Inc.**
www.tek.com

**Teledyne Defense Electronics**
www.teledynedefense electronics.com

**Teleplan Globe Defence**
www.teleplanglobe.no/ defence

**TeleRadio Engineering Pte Ltd.**
www.skydroner.com

**Ten-Tec**
www.tentec.com

**Terma A/S**
www.terma.com

**Terra Hexen Group**
www.terrahexen.com

**TEVET**
www.tevetllc.com

**Texas Instruments**
www.ti.com

**Textron Systems Corporation**
www.textronsystems.com

**Textron Systems Electronic Systems LTD UK**
www.textronsystems.com

**Thales**
www.thalesgroup.com

**Thermacore**
www.thermacore.com

**Thermodyne Cases & Racks**
www.thermodyne.com

**ThinkRF**
www.thinkrf.com

**Times Microwave Systems**
www.timesmicrowave.com

**TINEX AS**
www.tinex.no

**TJR Global**
www.trjglobal.com

**TMC Design Corp.**
www.tmcdesign.com

**TMD Technologies Ltd.**
www.tmd.co.uk

**Top Aces**
www.topaces.com

**Toyon Research Corp.**
www.toyon.com

**Transformational** Security LLC
www.powerfulsecurity.com

**TRD Consultancy Pte Ltd.**
www.trd.com

**Tri Star Engineering, Inc.**
www.star3.com

**Triad RF Systems Inc.**
www.triadrf.com

**TriaSys Technologies Corp.**
www.triasys.us

**Trident Systems Inc.**
www.tridsys.com

**Trival Antene**
www.trivalantene.si

**TrustComm**
www.trustcomm.com

**TSF5**
www.tsf5.com

**Tsunami Cases**
www.tsunamicase.com

**TTE Filters**
www.tte.com

**TUALCOM, Inc.**
www.tualcom.com

**TÜV SÜD**
www.tuv-sud.com

# U

**U B Corp.**
www.ubcorp.com

**Ultra Electronics – Australia**
www.ultra-electronics.com.au

**Ultra Electronics – Herley**
www.ultra-herley.com

**Ultra Electronics Limited – EWST**
www.ultra-cis.com

**Ultraview Corp.**
www.ultraviewcorp.com

**United Monolithic Semiconductor**
www.ums-gaas.com

## COMPANY LISTINGS

**URC Systems**
www.urc-systems.cz
**US Dynamics Corp.**
www.usdynamicscorp.com
**US Technologies-Aldetec**
www.ust-aldetec.com

## V

**VadaTech, Inc.**
www.vadatech.com
**Vadum Inc.**
www.vaduminc.com
**Valkyrie Enterprises LLC**
www.valkyrie.com
**Varilog Research, Inc.**
www.varilog.com
**Vecicma Networks**
www.vecima.com
**Verint**
www.verint.com
**ViaSat, Inc.**
www.viasat.com
**VIAVI Solutions, Inc.**
www.viavisolutions.com
**Vicor Corp.**
www.vicorpower.com
**Virtualabs srl**
www.virtualabs.it

## W

**W.L. Gore and Associates, Inc. (Gore)**
www.gore.com/cables
**Wang Electro-Opto Corp.**
www.weo.com
**Warfare Solutions LLC**
www.warfaresolutions.com
**Warrior Support Solutions, LLC**
www.warriorss.com
**Wavepoint Research, Inc.**
www.wavepointresearch.com
**WDS Radar**
www.wdsradar.com
**Wenteq Microwave Corporation**
www.wenteq.com
**Werlatone, Inc.**
www.werlatone.com
**WGS Systems, Inc.**
www.wgssystems.com
**WhiteFox Defense Technologies, Inc.**
www.whitefoxdefense.com
**Wide Band Systems Inc.**
www.widebandsystems.com
**Wideband Systems, Inc.**
www.wideband-sys.com
**Winchester Interconnect**
www.winconn.com
**Windfreak Technologies, LLC**
www.windfreaktech.com
**Wolfspeed**
www.wolfspeed.com
**Wright Technologies Inc.**
www.wrighttec.com
**Wyle Laboratories, Inc.**
www.wyle.com

## Z

**Zarges, Inc.**
www.zargesusa.com
**Z Microsystems, Inc.**
www.zmicro.com

# 2020 EW/SIGINT Resource Guide

## CATEGORY LISTINGS

ISTOCK.COM/LUBUSHKA

# PRODUCT/SERVICE LISTINGS

ISTOCK.COM/LUBUSHKA

## RF MICROWAVE COMPONENTS & SUBSYSTEMS

### Antennas/Arrays

Aero Telemetry
Alaris Antennas
AMT Microwave Corp.
Antenna Authority
Antenna Experts
Antenna Research Associates
APITech
Applied EM Inc.
ARA, Inc.
CAL-AV Labs Inc.
CEA Technologies
Cobham
COJOT
Communications & Power Industries, Inc (CPI)
Cubic Nuvotronics
Dayton-Granger
Defence Research and Development Canada
Electro-Metrics
ET Industries
ETS-Lindgren
European Antennas
First RF Corp.
Flann Microwave
Fractal Antenna Systems
FS Antennentechnik GmbH
Hascall-Denke
HUBER+SUHNER AG
IFI – Instruments for Industry Inc.
JEM Engineering
Jenkins Engineering Defence Systems
Kratos
L3Harris – Linkabit
L3Harris – Randtron Antenna Systems
Leonardo
Link Microtek
MEDAV GmbH
Meggitt
Micronetixx, P.A.
Mercury Systems
Microwave Applications Group
Microwave Engineering Corp.
Microwave Specialty Company
Microwave Technologies Inc.
Montena Technology sa
mWave Industries, LLC
NovAtel
Ocean Microwave Corp.
Octane Wireless
PCTEL Inc.
Phasor Innovation PTY Ltd.
QuinStar Technology, Inc.
Radio Reconnaissance Technologies
Rantelon
Rincon Research Corporation
Rockwell Collins
Rohde & Schwarz GmbH & Co. KG
Rubisoft
Saab
SATIMO
Seqtor ApS
Shakespeare Military Antenna Products
Signal Antenna Systems Inc.
SMAG Mobile Antenna Masts GmbH
Southwest Antennas
Steatite Antennas
SunCastle Microwave LLC
TACO Antenna
Tech Resources, Inc.
TechComm
TECOM Industries, Inc.
Transformational Security LLC
Trival Antene
U B Corp.
Ultra Electronics – Herley
Wang Electro-Opto Corp.

### Antenna Mounts/ Support Structures

Cobham
Dayton-Granger
IKHANA Aircraft Services
Hascall-Denke
L3Harris – Randtron Antenna Systems
Rotating Precision Mechanisms, Inc.
SMAG Mobile Antenna Masts GmbH
Steatite Antennas
TECOM Industries, Inc.

### Antenna Radomes

CEA Technologies
Cobham
Dayton-Granger
HUBER+SUHNER AG
IKHANA Aircraft Services
L3Harris – Randtron Antenna Systems
Meggitt – Baltimore
Steatite Antennas
TECOM Industries, Inc.

### Active RF Components

AKON, Inc.
Analog Devices Inc.
Anaren, Inc.
Applied Thin Film Products
Cobham
Comtech PST
Crane Aerospace & Electronics
EM Research
ET Industries
I.F. Engineering Corp.
Jabil Defense and Aerospace Services
Jersey Microwave
L3Harris – Electron Device Division
L3Harris – Narda-Miteq
MACOM
Mercury Systems
Micro Lambda Wireless, Inc.
Phasor Innovation PTY Ltd.
Pole/Zero Corp.
Rodelco Electronics Corp.
Tektronix, Inc.
Teledyne Defense Electronics
TRAK Microwave
US Dynamics Corp.
Wolfspeed

### Analog-to-Digital Converter Boards

Abaco Systems
ApisSys
Analog Devices Inc.
Annapolis Micro Systems, Inc.
Avalon Electronics, Inc.
Bittware, Inc.
CEA Technologies
Cobham
Curtiss-Wright Defense Solutions
Delphi Engineering Group
Dynamic Signals LLC
Interface Concept
Innovative Integration
Intersil
iVeia, LLC
Mercury Systems
Pentek
Protium Technologies, Inc.
Red Rapids
Rockwell Collins
Spectrum Signal Processing
Sundance DSP
TEK Microsystems, Inc.
Tektronix, Inc.
Teledyne Defense Electronics
Texas Instruments
Themis

Ultraview Corp.
VadaTech, Inc.
X-COM Systems, LLC

### Digital-to-Analog Converter Boards

Abaco Systems
Analog Devices Inc.
Annapolis Micro Systems, Inc.
Bittware, Inc.
Cobham
Curtiss-Wright Defense Solutions
Delphi Engineering Group
Innovative Integration
Interface Concept
Intersil
iVeia, LLC
MACOM
Mercury Systems
Red Rapids
Tektronix, Inc.
Teledyne Defense Electronics
X-COM Systems, LLC

### Semiconductor Integrated Circuits

Cobham Sensor Systems
Hittite Microwave
Intersil
MACOM
Tektronix, Inc.
Teledyne Defense Electronics

### Digital Signal Processors

Abaco Systems
Analog Devices Inc.
Annapolis Micro Systems, Inc.
BAE Systems
BittWare
Colorado Engineering Inc.
Curtiss-Wright Defense Solutions
Dynamic Signals LLC
ELDES S.r.l. – Radar Division
Intel Product Solutions Group
Interface Concept
iVeia, LLC
Mercury Systems
Protium Technologies, Inc.
RFEL LTd.
Rockwell Collins

### ASICs

Cobham
Mercury Systems
Tektronix, Inc.
Teledyne Defense Electronics

### FPGAs and FPGA Boards

Abaco Systems
Annapolis Micro Systems, Inc.
ApisSys
Applied Radar Inc.
BAE Systems
BittWare
Colorado Engineering Inc.
Curtiss-Wright Defense Solutions
Extreme Engineering Solutions
Delphi Engineering Group
Dynamic Signals LLC
Galleon Embedded Computing
Innovative Integration
Interface Concept
Intel Product Solutions Group
iRF Solutions
iVeia, LLC
Keysight Technologies
Mercury Systems
Nallatech, Inc.
New Wave Design & Verification
Parsec
Pentek
Red Rapids
Rincon Research Corporation
TEK Microsystems, Inc.
Ultraview Corp.

### Frequency Converters

AKON, Inc.
Analog Devices Inc.
Anaren, Inc.
Applied Radar Inc.
Cobham
Crane Aerospace & Electronics
CTT, Inc.
EM Research
FEI-Elcom Tech
I.F. Engineering Corp.
iRF Solutions
Jersey Microwave
K&L Microwave, Inc.
KMIC Technology, Inc.
Kratos
L3Harris – Microwave West
L3Harris – Narda-Miteq
Mercury Systems
Norden Millimeter
NuWaves Engineering
Planar Monolithics Industries, Inc.
Red Rapids
Renaissance Electronics Corp.
SignalCore
TRAK Microwave
Ultra Electronics – Herley
Wright Technologies, Inc.

### Frequency Synthesizers

AKON, Inc.
Analog Devices
Anritsu
Berkley Nucleonics
Cobham
Crane Aerospace and Electronics
EM Research
FEI-Elcom Tech
iRF Solutions
Kratos
L3Harris – Narda-Miteq
MagiQ Technologies Inc.
Mercury Systems
Micro Lambda Wireless, Inc.
NEL Frequency Controls, Inc.
Novatech Instruments
Phase Matrix
Planar Monolithics Industries, Inc.
Renaissance Electronics Corp.
RFcore Co, Ltd.
Rodelco Electronics Corp.
SignalCore
Sivers IMA AB
Tabor Electronics
Teledyne Technologies
TRAK Microwave
Ultra Electronics – Herley
Ultraview Corp.
Wide Band Systems Inc.

### Oscillators

Analog Devices Inc.
Cobham
dB Control
EM Research
FEI-Elcom Tech
Jackson Labs Technologies Inc.
Jersey Microwave
Kratos
L3Harris – Narda-Miteq
MACOM
Mercury Systems
Micro Lambda Wireless, Inc.
Microwave Dynamics
NEL Frequency Controls, Inc.
Norden Millimeter
Pascall Electronics Limited
Phase Matrix
Qorvo
QuinStar Technology, Inc.
Renaissance Electronics Corp.
Sivers IMA AB
Skyworks Solutions
Syntonic Microwave
TRAK Microwave
Ultra Electronics – Herley
Vectron International

### Low Noise Amplifiers

AKON, Inc.
Amplifier Solutions Corp.
AmpliTech
Analog Devices
APITech
ARS Products
Atlanta Micro
Ciao Wireless, Inc.
Cobham
CTT, Inc.
Custom MMIC
Elite RF
Endwave Corp.
ERZIA Technologies SL
Herotek, Inc.
Jersey Microwave
K&L Microwave, Inc.
Keragis
KMIC Technology, Inc.
L3Harris – Narda-Miteq
MACOM
Mercury Systems
Microwave Communications Laboratories
Microwave Dynamics
Norden Millimeter
NuWaves Engineering
Pascall Electronics Limited
Pasternak
Planar Monolithics Industries, Inc.
Pole/Zero Corp.
Qorvo
QuinStar Technology, Inc.
Renaissance Electronics Corp.
RFHIC
Rodelco Electronics Corp.
Sage Millimeter
Smiths Interconnect
Teledyne Defense Electronics
TRAK Microwave
Triad RF Systems Inc.
Ultra Electronics – Herley
US Dynamics Corp.
US Technologies-Aldetec
Wenteq Microwave Corporation
Wolfspeed
Wright Technologies, Inc.

### Passive RF Components

American Microwave Corp.
Analog Devices Inc.
Anaren, Inc.
Anritsu
APITech
Applied Thin Film Products
Bird Technologies
Cobham
Coleman Microwave Company
Crane Aerospace & Electronics
Cubic Nuvotronics
Dayton-Granger
Dielectric Labs
Dow-Key Microwave
Ducommun Technologies
Emhiser Research, Inc.
Endwave Corp.
ET Industries
Herotek, Inc.
Honeywell Aerospace
HUBER+SUHNER AG
I.F. Engineering Corp.
Jabil Defense and Aerospace Services
JFW Industries
K&L Microwave, Inc.
Kratos
Krytar, Inc.
L3Harris – Narda-Miteq
Lexatys
Link Microtek
Logus Microwave
Lorch Microwave
MACOM

MECA Electronics
Mercury Systems
Microphase Corp.
Microwave Applications Group
Microwave Communications Laboratories
Microwave Engineering Corp.
Microwave Products Group
Pascall Electronics Limited
Picosecond Pulse Labs
Planar Monolithics Industries, Inc.
Q Microwave, Inc.
Qorvo
QuinStar Technology, Inc.
Radiall
Renaissance Electronics Corp.
RH Laboratories
Rodelco Electronics Corp.
Skyworks Solutions
Smiths Interconnect
Solid State Devices, Inc.
Teledyne Defense Electronics
TRU Corp.
TTE Filters
Werlatone, Inc.

### Converters and Mixers

Advanced Microwave Inc.
AKON, Inc.
Anaren, Inc.
Anritsu
Cobham
EM Research
FEI-Elcom Tech
I.F. Engineering Corp.
Jersey Microwave
KMIC Technology, Inc.
L3Harris – Narda-Miteq
Mercury Systems
QuinStar Technology, Inc.
RH Laboratories
Rodelco Electronics Corp.
Teledyne Defense Electronics
US Technologies-Aldetec

### Couplers

Anaren, Inc.
ARS Products
Atlanta Micro
BJG Electronics
Cobham
Cubic Nuvotronics
DynaWave Inc.
ET Industries
Ferrite Microwave Technologies
Honeywell Aerospace
HUBER+SUHNER AG
I.F. Engineering Corp.
K&L Microwave, Inc.
Krytar Inc.
L3Harris – Narda-Miteq
MECA Electronics
Mercury Systems
Microwave Communications Laboratories
Microwave Engineering Corp.
Planar Monolithics Industries, Inc.
Precision Connector
Qorvo
Radiall
RF Industries
Rohde & Schwarz GmbH & Co. KG
Southwest Microwave
TE Connectivity
Werlatone, Inc.
Winreak Technologies, LLC

### Fiber-Optic Cable

Alker Optical Equipment
Assemblies, Inc.
HUBER+SUHNER AG
Meggitt Defense Systems
W.L. Gore & Associates, Inc. (Gore)

### Fiber-Optic Connectors

Assemblies, Inc.
BJG Electronics
HUBER+SUHNER AG
Meggitt Defense Systems

### Filters and Diplexers

AKON, Inc.
Anatech Electronics
Atlanta Micro
BSC Filters
Cobham
Coleman Microwave Company
Cubic Nuvotronics
Dayton-Granger
Endwave Corp.
ET Industries
Ferrite Microwave Technologies
Gowanda Components Group
Honeywell Aerospace
HUBER+SUHNER AG
KMIC Technology, Inc.
L3Harris – Narda-Miteq
Lexatys
Link Microtek
Lorch Microwave
MECA Electronics
MEMtroncs Corp.
Mercury Systems
Metamagnetics
Micro Lambda Wireless, Inc.
Micronetixx, P.A.
Microphase Corp.
Microwave Communications Laboratories
Microwave Engineering Corp.
Microwave Filter Company
Microwave Products Group
OEwaves
Physical Optics Corp.
Picosecond Pulse Labs
Plexsa Manufacturing
Pole/Zero Corp.
Q Microwave, Inc.
Syntonic Microwave
Werlatone, Inc.

### Power Dividers/Combiners

Anatech Electronics
Anaren, Inc.
Cobham
Comtech PST
Cubic Nuvotronics
EMS Technologies, Inc.
ET Industries
HUBER+SUHNER
I.F. Engineering Corp.
JFW Industries
K&L Microwave, Inc.
Krytar, Inc.
L3Harris – Narda
MECA Electronics
Mercury Systems
Micronetixx, P.A.
Microwave Applications Group
Microwave Communications Laboratories
Microwave Engineering Corp.
Planar Monolithics Industries, Inc.
QuinStar Technology, Inc.
Renaissance Electronics Corp.
Rodelco Electronics Corp.
Rohde & Schwarz GmbH & Co. KG
Teledyne Defense Electronics
TTE Filters
Werlatone, Inc.

### RF Switches

Aethercomm, Inc.
AKON, Inc.
Alaris Antennas
Analog Devices
APITech
Atlanta Micro
Cobham
Comtech PST
Dow-Key Microwave
iRF Solutions
JFW Industries
Kratos
L3Harris – Narda-Miteq
MACOM
Microwave Applications Group
Microwave Products Group
Mini-Circuits
Pasternack Enterprises
Rohde & Schwarz GmbH & Co. KG
Skyworks Solutions

### RF Absorptive Materials/ Shielding

ARC Technologies
Boyd Corporation
Cuming Microwave Corp.
ETS-Lindgren

Select Fabricators
Zarges, Inc.

**RF Cables/ Cable Assemblies**

Anatech Electronics
Assemblies Inc.
Cablex PTY Ltd.
Carlisle Interconnect Technologies
CDM Electronics
Cobham
Custom Cable Assemblies, Inc.
Dayton-Granger
FLEXCO Microwave
HUBER+SUHNER AG
Insulated Wire (IW)
MECA Electronics
MegaPhase
Micro-Coax, Inc.
Molex
Montena Technology sa
Radiall
RF Industries
RF Logic
TE Connectivity
Teledyne Defense Electronics
Times Microwave Systems
TRU Corp.
W.L. Gore & Associates, Inc. (Gore)

**RF Connectors and Adapters**

Acewavetech
Amphenol RF
BJG Electronics
BTC Electronics
Cinch Connectivity Solutions
Cobham
Custom Cable Assemblies
Delta Electronics Mfg. Corp.
Digi-Key
Dynawave Inc.
Fairview Microwave
Gigalane
Hermetic Solutions
Huber + Suhner
Insulated Wire (IW)
JFW Industries
Krytar
Maury Microwave
Meca Electronics
Megaphase
Microwave Communications Laboratories Inc.
Molex
Pasternack
Radiall
Sage Millimeter
Santron
Smiths Interconnect
Southwest Microwave
Spectrum Elektrotechnik GmbH
TE Connectivity
Times Microwave Systems

**Waveguides**

Anatech Electronics
Cobham
Dow-Key Microwave
Ferrite Microwave Technologies
Honeywell Aerospace
K&L Microwave, Inc.
Keragis
Link Microtek
Micronetixx, P.A.
Microwave Applications Group
Microwave Communications Laboratories
Microwave Engineering Corp.
Montena Technology sa
Q Microwave, Inc.
Smiths Interconnect
Steatite Antennas
Teledyne Defense Electronics
Ultra Electronics – Herley

**Digital Frequency Discriminators**

AKON, Inc.
Anaren, Inc.
CSIR – DPSS
L3Harris – Narda-Miteq
Mercury Systems
Teledyne Defense Electronics
Triasys
TUALCOM, Inc.
Wide Band Systems Inc.

**Digital RF Memories**

Anaren, Inc.
Annapolis Micro Systems, Inc.
CSIR – DPSS
Curtiss-Wright Defense Solutions
L3Harris
Mercury Systems
Reut Systems and Technologies (RST)
Saab
Systems & Processes Engineering Corp. (SPEC)
TEK Microsystems, Inc.
Ultra Electronics – Herley

**Integrated Microwave Assemblies**

AKON, Inc.
American Microwave Corp.
Anaren, Inc.
APITech
ARS Products
Cobham
Comtech PST
Crane Aerospace & Electronics
CTT Inc.
Dow-Key Microwave
ERZIA Technologies SL
FEI-Elcom Tech
Jabil Defense and Aerospace Services
Kratos
L3Harris
LaBarge, Inc.
Lexatys
Lorch Microwave
Mercury Systems
Microphase Corp.
Microwave Applications Group
Microwave Products Group
NEL Frequency Controls, Inc.
Planar Monolithics Industries, Inc.
Quarterwave Corp.
Renaissance Electronics Corp.
RFcore Co, Ltd.
Rockwell Collins
Rodelco Electronics Corp.
Tektronix, Inc.
Teledyne Defense Electronics
Ultra Electronics – Herley
US Dynamics Corp.

**RF Receivers**

AKON, Inc.
Anaren, Inc.
Argon ST
Atos
BAE Systems
Chemring Technology Solutions
Clearbox Systems
Cobham
Communications & Power Industries, Inc (CPI)
Communications Audit UK Ltd.
Curtiss-Wright Defense Solutions
D-TA Systems
Dayton-Granger
Digital Receiver Technology
ELDES S.r.l. – Radar Division
Epiq Solutions
Emhiser Research Inc.
FEI-Elcom Tech
iRF Solutions
IZT GmbH
Jersey Microwave
Kratos
L3Harris – Linkabit
Leonardo DRS
MEDAV GmbH
Mercury Systems
Mid-Atlantic RF Systems
National Instruments Corp. (NI)
Norden Millimeter
Plextek Consulting
Radio Reconnaissance Technologies
Raytheon
RFEL Ltd.
Rockwell Collins
Rohde & Schwarz GmbH & Co. KG
Kratos
Signal Hound
Spectranetix, Inc.
Spectrum Signal Processing
Tampa Microwave
Teledyne Defense Electronics
Ten-Tec
Triasys
Trident Systems Inc.
Ultra Electronics – Herley

**RF Tuners**

AKON, Inc.
ASELSAN
Atlanta Micro
Chemring Technology Solutions
Cobham
Communications Audit UK Ltd.
CyberRadio Solutions
D-TA Systems Inc.
Digital Receiver Technology diminuSys
Elektrobit
Epiq Solutions
FEI-Elcom Tech
FS Antennentechnik GmbH
iRF Solutions
IZT GmbH
Leonardo DRS
Mercury Systems
Mid-Atlantic RF Systems
Midwest Microwave Solutions Inc.
Norden Millimeter, Inc.
NuWaves Engineering
Pentek
R.A. Wood Associates
Radixon
Rockwell Collins
Rohde & Schwarz GmbH & Co. KG
Saab Medav
Silver Palm Technologies
Syntonic Microwave Corp.
Systems & Processes Engineering Corp. (SPEC)
Teledyne Defense Electronics
Zeta Associates

**Signal Conditioners**

ARS Products
Cobham
Pole/Zero Corp.
Rantelon
RFEL Ltd.
Teledyne Defense Electronics
Terma

**Displays**

Aeromaoz
Astronautics C.A. Ltd.
BARCO
Curtiss-Wright Defense Solutions
Ecrin Systems
L3Harris
Lockheed Martin
Meggitt Defense Systems

Precision Display Technologies
Terma
Z Microsystems, Inc.

### Solid-State Power Amplifiers

Aero Telemetry
Aethercomm, Inc.
Applied Systems Engineering Inc.
AR RF/Microwave Instrumentation
BC Systems
Cobham
Communication Power Corporation
Comtech PST
CTT, Inc.
dB Control
Diamond Microwave
Elite RF
Emhiser Research, Inc.
Empower RF Systems
ERZIA Technologies SL
ETL Systems
ETM Electromatic Inc.
Exodus Advanced Communications
IFI – Instruments for Industry Inc.
Keragis
KMIC Technology, Inc.
Kratos
L3Harris – Narda-Miteq
Linwave Technology
MACOM
Mercury Systems
Microwave Amplifiers Ltd.
Microwave Dynamics
Mid-Atlantic RF Systems
MILMEGA, a Teseq Company
Mission Microwave
NEC Network and Sensor Systems, Ltd.
NuWaves Engineering
OPHIR RF
Protium Technologies, Inc.
Qorvo
Quarterwave Corp.
Rantelon
RFHIC
Rodelco Electronics Corp.
Rohde & Schwarz GmbH & Co. KG
Smiths Interconnect
Teledyne Defense Electronics
Thales Microwave and Imaging Systems
TMD Technologies Ltd.
Triad RF Systems Inc.
Triton Services Inc.
US Technologies-Aldetec
WDS Radar

### GaN/GaAs Transistors

Analog Devices Inc.
MACOM
Mercury Systems
Northrop Grumman
NXP
Qorvo
United Monolithic Semiconductor
Wolfspeed

### TWTs

Communications & Power Industries, Inc (CPI)
dB Control
L3Harris – Electron Devices Division
NEC Network and Sensor Systems, Ltd.
Photonis Defense, Inc.
Teledyne Defense Electronics
Thales Microwave and Imaging Systems
TMD Technologies Ltd.

### TWT Assemblies

Applied Systems Engineering Inc.
Cobham
Communications & Power Industries, Inc (CPI)
Comtech PST
dB Control
ETM Electromatic Inc.
IFI – Instruments for Industry Inc.
L3Harris – Electron Technologies, Inc.
L3Harris – Narda-Miteq
NEC Network and Sensor Systems, Ltd.
Photonis Defense, Inc.
Quarterwave Corp.
Teledyne Defense Electronics
Thales Microwave and Imaging Systems
TMD Technologies Ltd.

### Microwave Power Modules (MPMs)

Communications & Power Industries, Inc (CPI)
dB Control
L3Harris – Electron Devices Division
NEC Network and Sensor Systems, Ltd.
Photonis Defense, Inc.
Teledyne Defense Electronics
Thales Microwave and Imaging Systems
TMD Technologies Ltd.
WDS Radar

### Power Supplies

APITech
BC Systems
Behlman Electronics
Communications & Power Industries, Inc (CPI)
Crane Aerospace & Electronics
dB Control
ETM Electromatic, Inc.
Schaefer Electronics
Vicor Corp.

### Data Recorders

Ampex
Annapolis Micro Systems, Inc.
Avalon Electronics, Inc.
Conduant Corp.
Curtiss-Wright Defense Solutions
D-TA Systems Inc.
Delphi Engineering Group
DSPCon, Inc.
Dynamic Signals LLC
Galleon Embedded Computing
IZT GmbH
Keysight Technologies
L3Harris – Communications Systems - East
Leonardo DRS
Mercury Systems
Novator Solutions AB
Pentek
PROCITEC GmbH
RADX Technologies, Inc.
Rincon Research Corporation
Rising Edge Technologies
Rohde & Schwarz GmbH & Co. KG
Scientific Research Corp.
Serpikom
Shoghi Communications Ltd.
Signami-DCS – EW/Range
Sypris Solutions
TEK Microsystems
Tektronix, Inc.
Wideband Systems Inc.
X-COM Systems, LLC

### Signal Analysis Systems

Annapolis Micro Systems, Inc.
Berkley Nucleonics
Cobham
COMSEC LLC
Hensoldt South Africa
Innovative Signals Technology (ISigTech)
ITAS A/S
IZT GmbH
Keysight Technologies
Mercury Systems
Novator Solutions AB
Patria
PROCITEC GmbH

RADX Technologies, Inc.
Rantelon
Rincon Research Corporation
Rockwell Collins
Rohde & Schwarz GmbH & Co. KG
Serpikom
Signal Hound
X-COM Systems, LLC

### Transport Cases

ATS Cases
CP Cases
ECS Composites
Impact Cases
Pelican Cases
Tsunami Cases
Thermodyne
Zarges

## TEST EQUIPMENT

### Oscilloscopes

B&K Precision Corp.
Berkley Nucleonics
Dynamic Signals LLC
Keysight Technologies
National Instruments Corp. (NI)
Rohde & Schwarz GmbH & Co. KG
Tektronix, Inc.
Teledyne Defense Electronics

### Signal Generators

Anritsu
B&K Precision Corp.
Berkley Nucleonics
Cobham
Dynamic Signals LLC
FEI-Elcom Tech
ISPAS AS
IZT GmbH
Keysight Technologies
Mercury Systems
National Instruments Corp. (NI)
Novatech Instruments
Phase Matrix
RADX Technologies, Inc.
Rohde & Schwarz GmbH & Co. KG
Signal Hound
Tabor Electronics
Tektronix, Inc.
Textron Systems Corporation
Varilog Research, Inc.

### Spectrum Analyzers

Aaronia AG
Anritsu
B&K Precision Corp.
Berkley Nucleonics
Cobham
COMSEC LLC
Epiq Solutions
ESPY Corp.
Good Will Instrument Co., Ltd.
Keysight Technologies
National Instruments Corp. (NI)
RADX Technologies, Inc.
Research Electronics International (REI)
Rohde & Schwarz GmbH & Co. KG
Signal Hound
Tektronix, Inc.
ThinkRF
WhiteFox Defense Technologies, Inc.

### Power Meters

Anritsu
Keysight Technologies
Krytar, Inc.
Mercury Systems
Rohde & Schwarz GmbH & Co. KG
Werlatone, Inc.

### Network Analyzers

Anritsu
DaqScribe Solutions, LLC
Keysight Technologies
RADX Technologies, Inc.
Rohde & Schwarz GmbH & Co. KG
Tektronix, Inc.

### Automatic Test Equipment

Advanced Testing Technologies Inc.
ARS Products
Astronics
Berkley Nucleonics
Cobham
COMSEC LLC
Dow Key Microwave Corp.
ELDES S.r.l. – Radar Division
Electronic Systems
INDRA
Keysight Technologies
L3Harris
Leonardo DRS
Meggitt Defense Systems
Mercer Engineering Research Center
MES S.p.A.
National Instruments Corp. (NI)
RADX Technologies, Inc.
Rodale Electronics Inc.
Rohde & Schwarz GmbH & Co. KG
RUAG – Aerospace
Signal Hound
Spirent Communications
Tabor Electronics
Tech Resources, Inc.
Tektronix, Inc.
Textron Systems Corporation
TRU Corp.
ViaSat, Inc.
VIAVI Solutions, Inc.

## EO/IR COMPONENTS & SUBSYSTEMS

### IR Detectors

Defense Research Associates, Inc.
Leonardo DRS
Textron Systems Electronic Systems LTD UK

### Fine-Track Sensors

BAE Systems
L3Harris
Northrop Grumman
Teledyne Defense Electronics

## EW & SIGINT SYSTEMS

### Radar Warning Receivers (RWRs) and ESM Systems

Aeronix, Inc.
Argon ST
ASELSAN
BAE Systems
BEL – Bharat Electronics Ltd.
Elbit Systems
Elettronica SpA
ELTA Systems Ltd.
HawkEye 360
Hensoldt
INDRA
L3Harris
Leonardo
Lockheed Martin
Microwave Technologies Inc.
Northrop Grumman
Patria
RADA USA
Rafael – Advanced Defense Systems Ltd.
Raytheon
Saab
Sierra Nevada Corp.
Silentium Defence
Teledyne Defense Electronics
Telemus
Thales Airborne Systems
TINEX AS
Ultra Electronics – Australia
VIAVI Solutions, Inc.

### RWR and ESM – Antennas

AMT Microwave Corp.
ASELSAN
BAE Systems
BEL – Bharat Electronics Ltd.
Cobham
Elbit Systems
Electro-Metrics
First RF Corp.
Fractal Antenna Systems
IFI – Instruments for Industry Inc.
JEM Engineering
L3Harris – Randtron Antenna Systems
Link Microtek
Microwave Specialty Company
Rafael – Advanced Defense Systems Ltd.
Rohde & Schwarz GmbH & Co. KG
Saab – Electronic Defence Systems
Steatite Antennas

### RWR and ESM – Receivers

Aeronix
Argon ST
Atos
Cobham
Elettronica SpA
ELTA Systems Ltd.
ESROE Limited
FEI-Elcom Tech
Leonardo
Lockheed Martin
Mercury Systems
Microwave Technologies Inc.
Northrop Grumman
Plextek Consulting
Rafael – Advanced Defense Systems Ltd.
Saab
Sierra Nevada Corp.
Systems & Processes Engineering Corp. (SPEC)
Thales
Teledyne Defense Electronics
Telemus
Trident Systems Inc.
TUALCOM, Inc.

### Radar Jammers

ASELSAN
BAE Systems
BEL – Bharat Electronics Ltd.
Elbit Systems
Elettronica SpA
ELTA Systems Ltd.
INDRA
L3Harris Technologies
Leonardo
MC Countermeasures Inc.
MyKonsult
Northrop Grumman
QinetiQ Ltd.
Rafael – Advanced Defense Systems Ltd.
Raytheon
Rodale Electronics Inc.
Saab
Southwest Research Institute
Thales Airborne Systems

### Radar Jammers – Antennas

AMT Microwave Corp.
ASELSAN
BAE Systems
BEL – Bharat Electronics Ltd.
Cobham

# The Big Thing in RFSoC is Here.

*(And it's only 2.5 inches wide!)*

## Small | Powerful | Deployable

Pentek's Model 6001 FPGA board lets you quickly develop and deploy RFSoC technology, while optimizing your system for SWaP.

Mounted on your custom carrier or Pentek's proven 3U VPX carrier, the new QuartzXM® comes pre-loaded with a full suite of IP modules, robust software, and fully integrated hardware — all geared to shorten time to market and reduce design risk.

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- **QuartzXM eXpress Module** speeds migration to custom form factors
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- **Dual 100 GigE** interfaces for extreme system connectivity
- **Robust Factory-Installed IP** for waveform generation, real-time data acquisition and more
- **Board Resources** include PCIe Gen.3 x8 and 16 GB DDR4 SDRAM
- **Navigator® Design Suite** BSP and FPGA design kit for seamless integration with Xilinx Vivado®

***All this plus FREE lifetime applications support!***

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Elbit Systems
Electro-Metrics
First RF Corp.
Fractal Antenna Systems
IFI – Instruments for Industry Inc.
JEM Engineering
L3Harris – Randtron Antenna Systems
Link Microtek
Microwave Specialty Company
Rafael – Advanced Defense Systems Ltd.
Steatite Antennas
Times Microwave Systems

### Radar Jammers – DRFMs

Anaren, Inc.
CSIR – DPSS
Curtiss-Wright Defense Solutions
L3Harris
Leonardo
MC Countermeasures Inc.
Mercury Systems
Military Optical RF Equipment Ltd.
Rafael – Advanced Defense Systems Ltd.
Saab
TEK Microsystems, Inc.
Ultra Electronics – Herley

### Radar Jammers – Exciters

Cobham
Elbit Systems
ELTA
FEI-Elcom Tech
L3Harris
Mercury Systems
Microwave Products Group
Northrop Grumman
Rafael – Advanced Defense Systems Ltd.

### Radar Jammers – Power Amplifiers

Aethercomm, Inc.
Applied Systems Engineering Inc.
Communications & Power Industries, Inc (CPI)
Comtech PST
dB Control
Empower RF Systems
ERZIA Technologies SL
L3Harris – Electron Device Division
Leonardo
MACOM
Photonis Defense, Inc.
Qorvo
Teledyne Defense Electronics
Thales Microwave and Imaging Systems
TMD Technologies Ltd.

### Airborne Active RF Decoys

BAE Systems
Hensoldt
Leonardo
Rafael – Advanced Defense Systems Ltd.
Raytheon
Systems & Processes Engineering Corp. (SPEC)
Thales Airborne Systems

### EW Suite Managers/ Controllers

BIRD Aerosystems
Leonardo
Northrop Grumman
Rafael – Advanced Defense Systems Ltd.
Terma

### Passive Missile Warning Systems

BAE Systems
Elbit Systems
Hensoldt
Lockheed Martin
MBDA
Northrop Grumman
Saab
Thales Airborne Systems

### Active (Pulse Doppler) Missile Warning Systems

ELTA Systems Ltd.
Leonardo – Airborne and Space Systems Division
Thales

### Laser Warning Systems

Collins Aerospace
ELTA Systems Ltd.
Leonardo
Saab

### Directed IR Countermeasures (DIRCM) Systems

BAE Systems
BIRD Aerosystems
Elbit Systems
Elettronica SpA
INDRA
Leonardo
Northrop Grumman

### DIRCM – Fine-Track Sensors

Defense Research Associates, Inc.
ElectroOptic Industries Ltd.
Leonardo DRS

### DIRCM – Lasers

BAE Systems
CILAS
Coherent Nufern
DILAS
Elbit Systems
Leonardo
Leonardo Daylight Solutions
Lockheed Martin
Northrop Grumman
Pendar Technologies
Pranalytica

### Airborne Decoy Dispensers

ASELSAN
BAE Systems
Cobham
Extant Aerospace
Hensoldt
IMI Systems
Leonardo
MBDA
Meggitt Defense Systems
MES SpA
Petards Group
Rodale Electronics Inc.
Saab
Terma
Thales Airborne Systems

### Airborne IR Decoys/ Countermeasures Flares

Armtec Defense Technologies
Chemring Countermeasures UK
Chemring Countermeasures USA
Esterline Defense Technologies
IMI Systems
Lacroix Defense and Security
MBDA
Rheinmetall Defence

### Airborne Chaff Countermeasures

Armtec Defense Technologies
Chemring Countermeasures UK
Cherming Countermeasures USA
Esterline Defense Technologies
IMI Systems
Lacroix Defense and Security

### Maneuvering Air-Launched Decoys

IMI Systems
Raytheon

### Anti-Radiation Homing Missiles

Lockheed Martin
Northrop Grumman
Raytheon

### Naval Decoy Launchers

Lacroix Defense and Security
Lockheed Martin
Rafael – Advanced Defense Systems Ltd.
Rheinmetall Defence
Safran Electronics and Defense
SEA
Sechan Electronics
Terma

### Naval IR Decoys

Armtec Defense Technologies
Chemring Countermeasures UK
Chemring Countermeasures USA
Lacroix Defense and Security
Rafael – Advanced Defense Systems Ltd.
Rheinmetall Defence

### Naval Chaff Countermeasures

Armtec Defense Technologies
Chemring Countermeasures UK
Chemring Countermeasures USA
Lacroix Defense and Security
Rafael – Advanced Defense Systems Ltd.
Rheinmetall Defence

### Naval RF Reflector Decoys

Airborne Systems Limited
Elbit Systems EW and SIGINT – Elisra
Rafael – Advanced Defense Systems Ltd.

### Active RF Naval Decoys

BAE SYSTEMS Australia
L3Harris
Leonardo
Lockheed Martin
Rafael – Advanced Defense Systems Ltd.
Thales

### Multispectral Obscurants/ Smoke

Armtec Defense Technologies
Chemring Countermeasures UK
Chemring Countermeasures USA
L3Harris
Lacroix Defense and Security
Rheinmetall Defense

### Communications ESM Systems

ASELSAN
BAE Systems
Chemring Technology Solutions
Comsearch
CRFS
Decodio AG
Defence Research and Development Canada
Digital Receiver Technology
Elettronica SpA
ELTA Systems Ltd.

Epiq Solutions
ESPY Corp.
EWA Government Systems, Inc.
General Dynamics Mission Systems
Hensoldt South Africa
INDRA
IZT GmbH
Kerberos International
Kratos
L3Harris
L3Harris Narda Safety Test Solutions
L3Harris TRL Technology
Leonardo DRS
Lockheed Martin
LS Telcom
Metis Aerospace Ltd.
Microwave Products Group
N-Ask Incorporated
Netline Communications Technologies
Northrop Grumman Corp.
Peralex
PLATH GmbH
Professional Development TSCM Group
Radixon
Raytheon
Research Electronics International (REI)
Rincon Research Corporation
Rohde & Schwarz GmbH & Co. KG
Saab Medav
Seqtor ApS
Serpikom
Shoghi Communications Ltd.
Sierra Nevada Corp.
Southwest Research Institute
Spectranetix, Inc.
Tata Advanced Systems Limited (TASL)
Tata Power Strategic Electronics Division
TCI International, Inc.
Thales
ThinkRF
URC Systems
VIAVI Solutions, Inc.

### Comms ESM – Antennas

Alaris Antennas
AMT Microwave Corp.
Antenna Authority
Antenna Experts
Antenna Research Associates
Antenna Systems and Solutions
Applied EM Inc.
ARA, Inc.
CEA Technologies
Cobham
COJOT
Defence Research and Development Canada
Electro-Metrics
ET Industries
ETS-Lindgren
European Antennas
First RF Corp.
Flann Microwave
Fractal Antenna Systems
FS Antennentechnik GmbH
JEM Engineering
L3Harris
Leonardo DRS
Link Microtek
Micronetixx, P.A.
Mercury Systems
Microwave Engineering Corp.
Microwave Specialty Company
Microwave Technologies Inc.
Ocean Microwave Corp.
Octane Wireless
PCTEL Inc.
PLATH GmbH
QuinStar Technology, Inc.
Radio Reconnaissance Technologies
Rantelon
Rockwell Collins
Rohde & Schwarz GmbH & Co. KG
Rubisoft
Saab
SATIMO
Steatite Antennas
TCI International, Inc.

### Comms ESM – Receivers

Argon ST
Atos
BAE Systems
Chemring Technology Solutions
Communications Audit UK Ltd.
Curtiss-Wright Defense Solutions
Deepwave Digital
Digital Receiver Technology
D-TA Systems
Emhiser Research Inc.
Enablia S.R.L.
Epiq Solutions
FEI-Elcom Tech
Herrick Technologies
iRF Solutions
IZT GmbH
Jersey Microwave
Kratos
L3Harris
L3Harris Narda Safety Test Solutions
Leonardo DRS
LOG.IN Srl
Mercury Systems
Mid-Atlantic RF Systems

Norden Millimeter
OEwaves
Per Vices Corp.
PLATH GmbH
Plextek Consulting
Radio Reconnaissance Technologies
Radixon
Raytheon
RFEL Ltd.
Rockwell Collins
Rohde & Schwarz GmbH & Co. KG
Saab Medav
Sagax Communications
SignalHound
Spectrum Signal Processing
Syncopated
Tampa Microwave
Teledyne Defense Electronics
Ten-Tec
Triasys
Wide Band Systems Inc.

## Communications Jammers

Aegis Corea
Albrecht Telecommunications
Allen-Vanguard Corp.
ASELSAN
BAE Systems
Chesapeake Technology Intl (CTI)
Cobham
DSE International
Elbit Systems
Elettronica SpA
ELTA Systems Ltd.
Enterprise Control Systems
Hensoldt
Hensoldt South Africa
Honeywell Aerospace
HP Marketing and Consulting
INDRA
Kerberos International
L3Harris
L3Harris TRL Technology
Leonardo
Lockheed Martin
Mitsubishi Electric Corp.
Motorola Solutions – Applied Technology
Netline Communications Technologies
PKI Electronic Intelligence
PLATH AG
Radixon
Rantelon
Raytheon
Rockwell Collins
Rohde & Schwarz GmbH & Co. KG
Samel 90
SESP Group
Shoghi Communications Ltd.
Sierra Nevada Corp.
Southwest Research Institute
Spectranetix, Inc.
Tata Advanced Systems Limited
Tata Power
Thales
URC Systems

## Comms Jammer – Antennas

Alaris Antennas
Applied EM Inc.
CEA Technologies
Cobham
COJOT
Defence Research and Development Canada
Electro-Metrics
ET Industries
ETS-Lindgren
European Antennas
First RF Corp.
Flann Microwave
Fractal Antenna Systems
FS Antennentechnik GmbH
JEM Engineering
L3Harris
Leonardo DRS
Link Microtek
Micronetixx, P.A.
Microwave Engineering Corp.
Microwave Specialty Company
Microwave Technologies Inc.
Ocean Microwave Corp.
Octane Wireless
PCTEL Inc. – Antenna Products
QuinStar Technology, Inc.
Radio Reconnaissance Technologies
Rantelon
Rockwell Collins
Rohde & Schwarz GmbH & Co. KG
Rubisoft
Saab
SATIMO
Seqtor ApS
Shakespeare Antennas
Steatite Antennas

## Comms Jammer – DRFMs

Anaren, Inc.
CSIR – DPSS
Curtiss-Wright
Defense Solutions
Epiq Solutions
L3Harris
Mercury Systems
Saab
Systems & Processes Engineering Corp. (SPEC)
TEK Microsystems, Inc.
Ultra Electronics – Herley

## Comms Jammer – Power Amplifiers

Aethercomm, Inc.
Amplifier Technology
Applied Systems Engineering Inc.
BC Systems
Comtech PST
CTT, Inc.
dB Control
Emhiser Research, Inc.
Empower RF Systems
IFI – Instruments for Industry Inc.
Keragis
KMIC Technology, Inc.
L3Harris
Linwave Technology
Mercury Systems
Microwave Amplifiers Ltd.
Mid-Atlantic RF Systems
MILMEGA, a Teseq Company
NEC Network and Sensor Systems, Ltd.
OPHIR RF
Photonis Defense, Inc.
Qorvo
Quarterwave Corp.
Rantelon
RF Core Co, Ltd.
RFHIC
Rodelco Electronics Corp.
Smiths Interconnect

## Counter-UAS Systems (EW)

Aaronia AG
Advanced Protection Systems
Alion Science and Technology
Allen-Vanguard
Atos
AntiDrone
ApolloShield
ArtSYS360
ASELSAN Inc.
BATS
Battelle
Blind Tiger
Broadfield Security Services
CACI
CellAntenna Corporation
CerbAir
Citadel Defense
CRFS
CTS Technology Co. Ltd.
D-Fend Solutions A.D. Ltd.
DeDrone
Department 13
DeTect Inc.
Diehl Defence
Drone Defence
DroneShield
Elbit Systems
Elettronica SpA
Elta Systems Ltd.
Enterprise Control Systems
HARP
Hensoldt
Hensoldt South Africa
High + Mighty International
HIK Vision
HP Marketing and Consulting
Hunan NovaSky Electronic Technology
IACIT
IMI Systems
Indra
Kirintec
L3 Technologies
Leonardo
Liteye Systems, Inc.
Lockheed Martin
LS Telcom
MCTech
Meritis Group
MyDefence Communication
Netline
Northrop Grumman
Orad
Phantom Technologies Ltd.
PKI Electronic Intelligence GmbH
Radio Hill Technologies
Rantelon
Rohde & Schwarz GmbH & Co. KG
Samel 90 PLC
Sensofusion
Serpikom
SESP Group
Sierra Nevada Corp.
Silentium Defence
SINTIS Technology Ltd.
Skysafe
SRC, Inc.
SteelRock Technologies
Teleradio Engineering
Terra Hexen
TCI International, Inc.
TRD Consultancy Pte Ltd.

## GPS Jammers

Defence Research and Development Canada
Elbit Systems
Empower RF Systems
L3Harris
Scientific Research Corp.
Thales

## ELINT Systems

Aeronix, Inc.
Avalon Electronics, Inc.
BAE Systems
BEL – Bharat Electronics Ltd.
DaqScribe Solutions, LLC
Elbit Systems
Elettronica SpA
ELTA Systems Ltd.
INDRA
iRF Solutions
Jordan Electronic Logistic Support – Electronic Warfare
L3Harris
Lockheed Martin
Microwave Technologies Inc.
Northrop Grumman
Patria
QinetiQ Ltd.

Rafael – Advanced Defense Systems Ltd.
Raytheon
Rockwell Collins
Rohde & Schwarz GmbH & Co. KG
Rubisoft
Saab
Sierra Nevada Corp.
Spectranetix, Inc.
Teledyne Defense Electronics
Telemus
Thales Airborne Systems
Ultra Electronics – Australia
VIAVI Solutions, Inc.

### ELINT Systems – Antennas

Alaris Antennas
AMT Microwave Corp.
Antenna Authority
Antenna Research Associates
Antenna Systems and Solutions
Applied EM Inc.
Azure Summit Technology, Inc.
CAL-AV Labs Inc.
CEA Technologies
Cobham
Communications & Power Industries,Inc (CPI)
Comtech PST
Defence Research and Development Canada
Electro-Metrics
ET Industries
ETS-Lindgren
European Antennas
First RF Corp.
Flann Microwave
Fractal Antenna Systems
FS Antennentechnik GmbH
HUBER+SUHNER AG
IFI – Instruments for Industry Inc.
JEM Engineering
Jenkins Engineering Defence Systems
L3Harris
Leonardo DRS
Link Microtek
Micronetixx, P.A.
Mercury Systems
Microwave Engineering Corp.
Microwave Specialty Company
Microwave Technologies Inc.
Ocean Microwave Corp.
Octane Wireless
PCTEL Inc. – Antenna Products
QuinStar Technology, Inc.
Radio Reconnaissance Technologies
Rafael – Advanced Defense Systems Ltd.
Randtron Antenna Systems
Rohde & Schwarz GmbH & Co. KG
Steatite Antennas
Telemus

### ELINT Systems – Tuners

AKON, Inc.
D-TA Systems Inc.
Epiq Solutions
FEI-Elcom Tech
iRF Solutions
Leonardo DRS
Mercury Systems
Midwest Microwave
NuWaves Engineering
R. A. Wood Associates
Rafael – Advanced Defense Systems Ltd.
Rockwell Collins
Rohde & Schwarz GmbH & Co. KG

### ELINT Systems – Receivers

Aeronix, Inc..
Argon ST
Atos
Chemring Technology Solutions
Cobham
Communications Audit UK Ltd.
D-TA Systems
Elbit Systems
Elettronica SpA
ELTA Systems Ltd.
Emhiser Research Inc.
FEI-Elcom Tech
iRF Solutions
IZT GmbH
Kratos
L3Harris
Leonardo DRS
Lockheed Martin
Mercury Systems
Mid-Atlantic RF Systems
Motorola Solutions – Applied Technology
Patria
Plextek Consulting
Rafael – Advanced Defense Systems Ltd.
Raytheon
Research Associates of Syracuse (RAS)
Rohde & Schwarz GmbH & Co. KG
Sierra Nevada Corp.
Teledyne Defense Electronics
Telemus
Thales
TUALCOM, Inc.
Wide Band Systems Inc.

### COMINT Systems

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Avalon Electronics, Inc.
BAE Systems
Chemring Technology Solutions
CRFS
Cubic Defense Systems
CyberRadio Solutions
DaqScribe Solutions, LLC
Decodio AG
Digital Receiver Technology
Elbit Systems
ELTA Systems Ltd.
ESPY Corp.
General Dynamics
Hensoldt
Hensoldt South Africa
Jordan Electronic Logistic Support – Electronic Warfare
L3Harris
L3Harris Narda Safety Test Solutions
Leonardo DRS
Lockheed Martin
LS Telcom
N-Ask Incorporated
Northrop Grumman
PLATH GmbH
PROCITEC GmbH
QinetiQ Ltd.
Radio Reconnaissance Technologies
Radixon
Raytheon
Rockwell Collins
Rohde & Schwarz GmbH & Co. KG
Rubisoft
Saab Medav
Sierra Nevada Corp.
Southwest Research Institute
Spectranetix, Inc.
Tata Advanced Systems
TCI International, Inc.
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### COMINT Systems – Antennas

Alaris Antennas
AMT Microwave Corp.
Antenna Authority
Antenna Research Associates
Antenna Systems and Solutions
Applied EM Inc.
ARA, Inc.
CAL-AV Labs Inc.
CEA Technologies
Cobham

Defence Research and Development Canada
Defence Systems
Electro-Metrics
ET Industries
ETS-Lindgren
European Antennas
First RF Corp.
Flann Microwave
Fractal Antenna Systems
FS Antennentechnik GmbH
HUBER+SUHNER AG
IFI – Instruments for Industry Inc.
JEM Engineering
Jenkins Engineering
L3Harris
Leonardo DRS
Link Microtek
Micronetixx, P.A.
Mercury Systems
Microwave Engineering Corp.
Microwave Technologies Inc.
Ocean Microwave Corp.
Octane Wireless
PCTEL Inc. – Antenna Products
PLATH GmbH
QuinStar Technology, Inc.
Radio Reconnaissance Technologies
Rantelon
Rohde & Schwarz GmbH & Co. KG
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Steatite Antennas
TCI International, Inc.

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Epiq Solutions
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iRF Solutions
IZT GmbH
Leonardo DRS
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Midwest Microwave Solutions Inc.
Radixon
Rockwell Collins
Rohde & Schwarz GmbH & Co. KG
Saab Medav
URC Systems
Zeta Associates

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Communications Audit UK Ltd.
CRFS
Cubic Defense Systems
Curtiss-Wright Defense Solutions
D-TA Systems
Deepwave Digital
Digital Receiver Technology
Emhiser Research Inc.
Enablia S.R.L.
ESPY Corp.
FEI-Elcom Tech
Hensoldt South Africa
Herrick Technology Labs
iRF Solutions
IZT GmbH
Jersey Microwave
Kratos
L3Harris – Linkabit
L3Harris Narda Safety Test Solutions
Leonardo DRS
MEDAV GmbH
Mercury Systems
Mid-Atlantic RF Systems
Norden Millimeter
OEwaves
Per Vices Corp.
PLATH GmbH
Plextek Consulting
Protium Technologies, Inc.
Radio Reconnaissance Technologies
Radixon
Raytheon
RFEL Ltd.
Rockwell Collins
Rohde & Schwarz GmbH & Co. KG
Roke Manor Research Ltd.
Sagax Communications
Spectrum Signal Processing
Syncopated
Syncopated Engineering
Tampa Microwave
Ten-Tec
Wide Band Systems Inc.
X-COM Systems, LLC

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BAE Systems
CEA Technologies
Communications Audit UK Ltd.
Cubic Defense Systems
DATONG plc
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ESPY Corp.
Hensoldt South Africa
INDRA
IZT GmbH
Jenkins Engineering Defence Systems
Kerberos International
L3Harris – Linkabit
L3Harris TRL Technology
Leonardo DRS
LS Telcom
MEDAV GmbH
Mitsubishi Electric Corp.
National Instruments Corp.
PLATH GmbH
QinetiQ Ltd.
QRC Technologies
Radio Reconnaissance Technologies
Rantelon
Raytheon
Rohde & Schwarz GmbH & Co. KG
Roke Manor Research Ltd (Chemring Group)
Serpikom
Shoghi Communications Ltd.
SRC, Inc.
Tata Advanced Systems Limited (TASL)
TCI International, Inc.
TechComm
Telemus
Thales Defense and Security

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NovAtel
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Textron Systems Corporation
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### EW Antenna Couplers

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Leonardo DRS
Rohde & Schwarz GmbH & Co. KG
Tech Resources, Inc.

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Defense Research Associates, Inc.
Rohde & Schwarz GmbH & Co. KG
RUAG – Aerospace
Textron Systems Electronic Systems LTD UK
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ELDES S.r.l. – Radar Division
EW Simulation Technology Ltd.
FEI-Elcom Tech
Giga-tronics
Hensoldt South Africa
Herrick Technology Labs
ITT Test and Support Systems
IZT GmbH
Keysight Technologies
Lockheed Martin – Aeronautics
MASS
Mercury Systems
National Instruments Corp.
Northrop Grumman Mission Systems
Rafael – Advanced Defense Systems Ltd.
Reut Systems and Technologies (RST)
Rohde & Schwarz GmbH & Co. KG
Scientific Research Corp.
SRC, Inc.
Tactical Technologies Inc. a Leonardo Company
Textron Systems Corporation
Thales Airborne Systems
TMC Design, Inc.
Ultra Electronics Limited – EWST
Varilog Research Inc.
ViaSat, Inc. – RF Simulation Group

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Keysight Technologies
Leonardo DRS
Northrop Grumman Amherst Systems
Rafael – Advanced Defense Systems Ltd.
Reut Systems and Technologies (RST)
Rohde & Schwarz GmbH & Co. KG
SRC, Inc.
Systems & Processes Engineering Corp. (SPEC)
Telemus
Textron Systems Corporation
Ultra Electronics Limited – EWST

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Scientific Research Corp.
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Corvus
CSIR – DPSS
Darkblade Systems Corporation
Défense Conseil International
Defense Engineering Corp.
Defense Research Associates, Inc.
DePriest Associates, Inc.
DEWC Pty Ltd.
DHPC Technologies
Dr. EW (Johnny Heikell)
Dynamic Analytics & Test, Inc.
Dynetics Inc.
ECS
Electronic Warfare Studying Group, Korean Institute of Electromagnetic Engineering & Science
ETL Technologies Ltd.
EW Solutions Ltd.
EWA – Electronic Warfare Associates
EWTS
FMV Test & Evaluation
Georgia Tech Research Institute
ITA International
JB Management, Inc.
Kihomac, Inc.
Kranze Technology Solutions, Inc. (KTS)
L3Harris
Leidos
LS Telcom
MacAulay-Brown – Alion Science
MarServices GmbH
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Mercer Engineering Research Center
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Milso AB
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My-konsult
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Riverside Research Institute
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RUAG – Aerospace
SAIC
Selex Galileo, Inc. (a Leonardo-Finmeccanica Company)
Spatial and Spectral Research
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Colorado Engineering Inc.
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Dynetics Inc.
ECS.
EMS Technologies, Inc. – Defense and Space
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IKHANA Aircraft Services
L3Harris
Leonardo – Airborne and Space Systems Division
Lockheed Martin – Rotary and Mission Systems (RMS)
LS Telcom
MacAulay-Brown – Alion Science
MarServices GmbH
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Motorola Solutions – Applied Technology
Northrop Grumman Mission Systems
Northeast Information Discovery, Inc.
Nova Systems
Overlook Systems Technologies, Inc.
Parry Labs
Phasor Innovation PTY Ltd.
Physical Optics Corp.
Qnion Co., Ltd.
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Reut Systems and Technologies (RST)
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Ultra Electronics – Australia
Valkyrie Enterprises LLC
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JB Management, Inc.
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Leonardo – Airborne and Space Systems Division
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LS Telcom
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Northrop Grumman Mission Systems
Parry Labs
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RUAG – Aerospace
Scientific Research Corp.
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Southwest Research Institute
Terma
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DCS Corp.
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Elettronica SpA
ESROE Limited
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Genesis EW

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INNOSYSTEC GmbH
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L3Harris TRL Technology
Leonardo – Airborne and Space Systems Division
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RUAG – Aerospace
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Spatial and Spectral Research
SRC, Inc.
Telemus
Terma
Textron Systems Corporation
TriaSys Technologies Corp.
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ESROE Limited
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Georgia Tech Research Institute
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EWTS
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ESPY Corp.
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L3Harris
L3Harris – Communication Systems-East
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ELTA Systems Ltd.
General Atomics
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Hensoldt South Africa
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L3Harris
L3Harris – Linkabit
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Parsons
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RFEL Ltd.
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Rohde & Schwarz GmbH & Co. KG
Scientific Research Corp.
Thales Airborne Systems
Thales Defense and Security
TINEX AS
ThinkRF
TriaSys Technologies Corp.
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**SIGINT Software Development**

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3SDL
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AMEWAS, Inc.
Amplus Corporation
Arctan, Inc.
Argon ST
Blue Ridge Envisioneering, Inc.
C&S Intelligence Services
CACI-SystemWare Inc.
Chemring Technology Solutions
Chesapeake Technology Intl (CTI)
Chordell Systems Ltd.
COMINT Consulting
Communications Audit UK Ltd.
COMSEC LLC
Concurrent Technologies
Cubic Defense Systems
Deepwave Digital
Decodio AG
Dreamlab Technologies AG
Elbit Systems EW and SIGINT – Elisra
ESPY Corp.
EWA Government Systems
General Dynamics Mission Systems
Genesis EW
Georgia Tech Research Institute
Hegarty Research LLC
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INNOSYSTEC GmbH
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Intelligent Automation Inc.
IZT GmbH
Jenkins Engineering Defence Systems
L3Harris
L3Harris – Communication Systems-East
L3Harris – Linkabit
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Leonardo DRS
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Northeast Information Discovery, Inc.
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Parsons
Peralex
Professional Development TSCM Group
QinetiQ Ltd.
QRC Technologies
Radio Reconnaissance Technologies
Raytheon – Space and Airborne Systems
Research Electronics International (REI)
RF Engines Ltd.
Rising Edge Technologies
Rohde & Schwarz GmbH & Co. KG
Rubisoft
SAIC
Scientific Research Corp.
SensorCom Inc.
Shoghi Communications Ltd.
Signami-DCS – EW/Range
SimVentions
Southwest Research Institute
Spatial and Spectral Research
Spectrum Signal Processing
SRI International
SRC, Inc.
TechComm
Teleplan AS
Thales Defense and Security
ThinkRF
Transformational Security LLC
TriaSys Technologies Corp.
TSF5
URC Systems
Varilog Research Inc.
WGS Systems, Inc.
X-COM Systems, LLC
Zeta Associates

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Georgia Tech Research Institute
JB Management, Inc.
Keysight Technologies
LS Telcom
Mass
Mercury Electronic Warfare Ltd.
Research Associates of Syracuse (RAS)

# Directed Energy Weapons – Other Considerations

By David C. Stoudt, Ph.D.

*This month, we will continue our discussion of "operationalizing" directed energy weapons by addressing areas such as collateral damage determination, modeling and simulation, and leadership engagement.*

## DEW COLLATERAL DAMAGE DETERMINATION

The potential for collateral damage is ever-present when using weapons in the vicinity of civilians, as well as military and civilian systems, and the processes and procedures for estimating the extent of this damage and accepting risk for conventional munitions is well established. This is not the case with directed energy weapons (DEW) employment, however. While much work has been done to enhance our understanding of DEW collateral damage thresholds, which informs operational commanders of the risks involved in DEW use, more is required as DEW capabilities are starting to transition into Programs of Record (PORs).

The DOD Center of Excellence for studying the biological effects of high-energy laser (HEL) and RF weapon (RFW) DEW systems is located on Joint Base Fort Sam Houston, TX. The Air Force 711th Human Performance Wing (711 HPW) is part of the Air Force Research Laboratory headquartered at Wright Paterson AFB (Dayton, OH) and has a 40-year history of studying the effects of laser and microwave radiation on biological specimens to understand the effects of these directed energy systems on human beings. Besides defining the fundamental effects of DE exposure on biological tissues, this group provides essential modeling, simulation, and assessment tools for collateral effects assessment. The Navy component is the Naval Medical Research Unit San Antonio (NAMRU-SA), a subordinate unit to the Naval Medical Research Center (NMRC) (Silver Spring MD) conducts gap-driven research in directed energy, craniofacial and combat casualty care toward improving the survival, operational readiness and safety of DOD personnel engaged in routine and expeditionary operations. There are indications that the Army will establish a presence at the Tri-Service Research Laboratory (TSRL), as well. NAMRU-SA, the Air Force's 59th Medical Wing, the US Army Institute of Surgical Research, and Army Futures Command are focused on establishing standards of care for directed energy-related injuries. Both Navy and Air Force activities, along with future Army efforts, will require additional funding to meet the biological and medical demands of a new warfighting capability on battlefield.

Important thresholds must be determined and codified within DOD, such as thresholds for significant damage to the eyes or skin, how these thresholds are used in collateral damage estimation, what are reversible and non-reversible effects, and what (if any) impacts do RFWs have on people. TSRL is designed to increase the military's capabilities for studying the effectiveness of DEW, research ways to protect service members from DE devices, and improve health and safety standards for safe exposure to directed energy. It is important to remember that the US is not the only country actively developing DEW capabilities for their warfighters. In 2018, the Air Force promulgated DEW occupational safety guidance in Air Force Instruction 91-401, "Directed Energy System Safety." This provides the requirements for directed energy system safety certification and guidance for establishing a directed energy safety program.

## DEW MODELING AND SIMULATION

The DOD organizations responsible for DEW modeling and simulation (M&S) have made significant technical advancements over the last decade or so. However, the ability to fully model how a DEW engages a target, and the resulting impact on overall mission objectives, is still nascent. Clearly, more focus and resources are required to develop, validate and standardize the M&S tools that are critical to demonstrating DEW operational effectiveness to the acquisition community and warfighters. Such tools will be required to add technical credibility to DEW capabilities for simulation exercises and wargames. In 2015, Bob Work as the Deputy Secretary of the US Department of Defense and Gen Paul Selva as the Vice Chairman of the Joint Chiefs of Staff recognized the importance of effective wargaming during inter-war periods, stating that wargames "...help us imagine alternative ways of operating and envision new capabilities that might make a difference on future battlefields. When creatively and rigorously applied, wargames help us to think through and begin to resolve complex military challenges, foster the testing of new strategic and operational concepts, stimulate debate, and inform investments in new capabilities." It is critical that the DEW technical community, in close coordination with warfighters, develop the means to effectively integrate DEW capabilities into high-level exercises and wargames and ensure a structure to avoid "…rigging games to favor a specific outcome, or create self-fulfilling, self-congratulatory, self-deluding, or self-limiting prophecies," according to Work and Selva. Although exploration of this topic could fill volumes, here I will introduce only a few examples of current activities.

A typical 1v1 model that is used to help understand the outcome of an RFW engagement is the Joint Radio-Frequency Effect Model (JREM). Developed by AFRL and the Army Research Laboratory (ARL), this model incorporates the best attributes of previous RFW models, such as the Directed Radio Frequency Energy Assessment Model (DREAM) that was developed by the ARL, as well as AFRL's Radio Frequency Propagation and Target Effects Code (RFPROTEC) model. JREM uses the position and output from an RFW; fault-tree analysis for the target being evaluated; empirical test results of RF effects on target elements contained in that fault tree, which are normally summarized in Probability of Effect (Pe) curves; and electromagnetic M&S to understand how a given RFW engagement will affect the operation of targeted critical elements and to provide the resulting Pk for the overall target. However, since the outcome of an RFW engagement typically does not result in structural damage to the target, the burden is on the technical and intelligence communities to develop means to provide warfighters with sufficient Battle Damage Assessment (BDA) capabilities for determining the outcome of the engagement. For an RFW that is used as a strike capability, the Time Out of Action (TOA) must also be estimated so that the weaponeers understand how to fold the RFW engagement into the larger mission and/or campaign. The Navy and Air Force are currently working to integrate the output of engagement models, such as JREM, into mission-level models, such as Advanced Framework for Simulation Integration and Modeling (AFSIM).

The Services are also actively pursuing the development of HEL engagement models to demonstrate how a weapon will impact a target for a given scenario. The objective is to generate results that can be used in various simulations and exercises and provide data that feeds into mission and campaign models. To be useful, such models need to incorporate atmospheric conditions; specific target lethality for particular aimpoints; HEL weapon parameters, such as power, beam quality, system and tracking jitter; and the target dynamics. Since the laser can only engage one target at a time, each engagement in a raid or swarm is handled sequentially. To maximize weapon effectiveness, tactical decision aids would prioritize the order of targets, with a predetermined dwell time for a kill.

While many HEL engagement models are currently under development, no single tool has emerged as the standard. This fact has led to some confusion in the technical, warfighting and acquisition communities for assessing the operational utility of lasers in combat and appropriately playing HEL weapons in simulation exercises and wargames. That being said, individual HEL programs have developed credible M&S engagement tools. These tools, however, have yet to gain broad community acceptance. As with HEL lethality, the DE JTO has focused efforts on the development and standardization of HEL M&S tools.

## DEW POLICY CONSIDERATIONS

As it stands today, there are few policy impediments to the operational employment of DEWs. In fact, DOD policy is favorable for the fielding of both counter-material and counter-personnel DEWs, provided an appropriate weapons review process ensures that the weapon comports with appropriate treaties and international laws, that collateral damage is properly considered, and that formal CONOPS are developed to illustrate how the capability is intended to be used. The Law of War dictates that DEWs do not cause undo pain and suffering, are able to discriminate combatants from non-combatants, and provide a proportional response to the situation in which they are used. Fundamentally, the weapons review process is designed to determine if the DEW is militarily adequate, feasible and acceptable.

Often when HEL weapons are being transitioned to warfighters, there are concerns regarding the inadvertent illumination of satellites and the deleterious effects that may result. Fortunately, there is specific OSD (Policy) guidance on the process for assessing this potential risk and addressing various community concerns. In 2016, OSD(P)/Space Policy promulgated the DOD Instruction 3100.11, "Management of Laser Illumination of Objects in Space." The primary purpose of this instruction is to:

Establish policy, assign responsibilities and provide procedures in accordance with DODI 3100.10 for DOD management of risks associated with laser illuminations of objects in space;

Establish the requirement for a quantitative probabilistic risk assessment (PRA) process to categorize DOD-owned or -operated lasers that could direct energy above the horizon or in space, and implement risk acceptance standards for DOD-owned or -operated resident space objects (RSOs);

Establish an exempt category of lasers that do not require coordination, notification or permission before use due to the minimal risk they pose to RSOs; and

Provide guidance on the management of DOD-owned and -operated lasers that have transitioned from research, development, test and evaluation (RDT&E) status into DOD weapon systems.

The two most important factors of DODI 3100.11 are the establishment of a PRA process to realistically assess and manage risk to RSOs and language that addresses the issue of lasers transitioning out of RDT&E and into the hands of the warfighters. With full HEL integration into a DOD weapon system, the instruction states: "Operationally employ authorized DOD weapon systems without the need for further coordination, in accordance with applicable rules of engagement, and execute orders." The instruction goes on to state that continued coordination with applicable organizations is still required "...for testing, training, exercising, and maintenance of laser activities within an authorized DOD weapon system that lase above-the-horizon or in space." Thus, a fielded HEL weapon will need to incorporate an ability to test and train above the horizon. This requires a "satellite predictive avoidance" system that implements a process to determine discrete windows of time, for specific regions of space, that are safe for laser illumination above the horizon from a laser platform. It is important to note that such predictive avoidance capabilities are not required, or relevant, for operational RFWs.

The Standing Rules of Engagement (SROE) are outlined in the Secretary of Defense and Chairman of the Joint Chiefs of Staff, Instruction 3121.01b, "Standing Rules of Engagement/Standing Rules for the Use of Force for U.S. Forces" (13 June 2005; updated 18 June 2008). The current SROE is generally permissive of the inherent right of self-defense; however, the verbiage is couched in terms of "deadly force" where action will be taken against an adversary. Such SROE allow, for example, kinetic weapons to be used to engage an incoming watercraft if it is deemed an immediate threat to a Navy ship. However, the SROE actually predate the emergence of modern threats, such as terrorist-controlled UAS and hypersonic weapons, as well as the emergence of DEW on the battlefield, and they are well overdue for reevaluation, review, and update.

## LEADERSHIP ENGAGEMENT

It is critically important for DOD Service and acquisition leadership to keep in mind that DEWs are not just another in a line of kinetic energy weapons to take their place in the rank and file of existing capabilities on the battlefield, or a simple replacement for a particular gun or missile system. As discussed in earlier DE 101 columns, DEW effects on targets are very different than the kinetic effects that the operational community is used to factoring into their military planning. That being said, the onus is on the leadership of the DEW technical community to fund and execute the operations analysis required to translate DEW effects on targets into militarily usable outcomes that can be factored into the demanding operational scenarios warfighters will face in battle. Once this operational effectiveness is demonstrated, warfighters will begin to have trust in the DEW capabilities that are provided to them.

The DOD Services have recently taken extraordinary steps to advance the state of the art in DEW technology and provide the much-needed impetus to move these capabilities out of the laboratory and into the hands of warfighters. In 2016, the Navy promulgated SECNAV Instruction 5000.42, "Department of The Navy Accelerated Acquisition for the Rapid Development, Demonstration, and Fielding of Capability," which establishes a policy for the analysis and execution of rapid prototyping, experimentation, and demonstration (RPED) initiatives. This issuance was quickly followed by the establishment of the Navy Laser Family of Systems (NLFoS), with three HEL weapon systems that have already been installed or will eventually go on ships: the Solid State Laser – Technology Maturation system (SSL-TM), which is designed to be a 150-kW laser weapon that was installed on the USS Portland (LPD-27); the High Energy Laser and Integrated Optical-dazzler and Surveillance (HELIOS), a planned 60-kW laser weapon that will see its first test on an Arleigh Burke-class destroyer in 2021; and the Optical Dazzling Interdictor, Navy (ODIN) installed on the USS Dewey (DDG-105). In addition, the Marine Corps are currently evaluating a Compact Laser Weapons System (CLaWS), which is the first ground-based laser approved by the DOD weapon review process for use by warfighters on the ground.

The Army recently established the Army Rapid Capabilities and Critical Technologies Office (RCCTO) to expedite critical capabilities, such as DEWs and hypersonics, to the field to meet Combatant Commanders' needs. The Army RCCTO is rapidly accelerating activities to field DEWs by developing multiple combat prototypes that use a 50kW-class laser weapon integrated into Stryker vehicles. These will be fielded by fiscal year 2022.

In 2016, AFRL established the Strategic Development Planning and Experimentation Office, or SDPE, to significantly reduce the time required to move technologies, such as DEWs, from the laboratory and into the field. The SDPE office oversaw the testing of several RFW and HEL weapon capabilities and is making preparations for deploying those prototypes overseas.

## WHAT IT TAKES

The military is making the investments necessary to weaponize directed energy to address extant and emerging threats on the battlefield. Service activities will substantially advance the ruggedness of these capabilities and will significantly reduce the size, weight, power and cooling (SWAP-C) for these systems as they are integrated into operational platforms. However, much more work needs to be done to reduce the cost of these weapons, if they are to be distributed in a significant way across the battlespace. Getting these capabilities into the hands of the warfighters will be critical for providing the technical community with operational feedback on features they liked and where more work has to be done. Fortunately, most DEW tactical engagements in the near term are for relatively low-end threats, such as FIACs, mortars, and UASs. This relaxes to some degree the command and control requirements to integrate DEWs into combat. As DEW technology continues to mature and increase to the capability necessary to engage higher-end threats, more demands will be placed on the issues outlined in this column, such as a greater understanding of lethality and tactical decision aids. In addition to higher DEW power levels, long-term funding commitments, warfighter training, and combat-weapon-system integration with enhanced command and control, will be necessary for their successful employment.

# EW 101

## Space EW – Part 23

# Down-Link Intercept

By Dave Adamy

**Continuing our discussion from last month, we will now look at some issues relative to transmission from the satellite to the intercept site and the quality of the intercepted signal.**

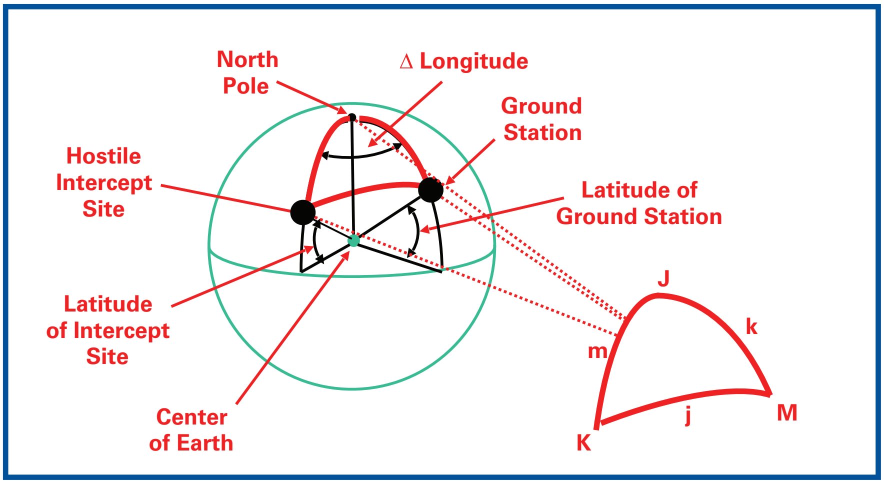


*Fig 1: A spherical triangle between the North Pole, the intercept site and the ground station location allows calculation of the offset angle of the intercept site antenna from the satellite down-link antenna bore-sight.*

## ANGLES RELATIVE TO THE HOSTILE INTERCEPT SITE

Now we will determine the angles related to the hostile intercept site.

**Figure 1** is a spherical triangle between the North Pole, the hostile intercept site and the ground station.

*Angle J* = the difference in longitude between the intercept site and the ground station = 1°

*Side m* is 90° - the latitude of the intercept site = 45°

*Side k* is 90° - the latitude of the ground station = 46°

From the spherical law of cosines for sides:

*Cos j* = cos m x cos k + sin m x sin k x cos J

= (cos 45°)(cos 46°) + (sin 45°)(sin 46°)(cos 1°)

= (.7071 x .6947) + (.7071)(.7193 (.99985)

= .4912 + .5085 = .9997

*Side j* = arc cos(.9997) = 1.40°

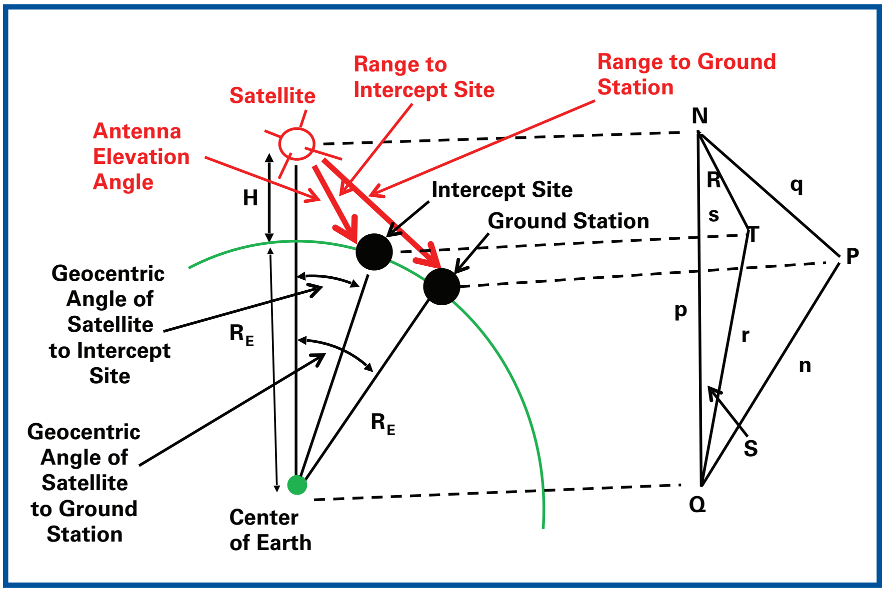


*Fig 2: The elevation of the antenna (above nadir) and the range from the satellite to the ground station can be calculated from this plane triangle.*

Now consider **Figure 2**, which has two planar triangles. One triangle is formed by the satellite, the center of the Earth and the intercept site; the other is formed by the satellite, the center of the Earth and the ground station. The boresight of the satellite antenna is aimed at the ground station, and the intercept site receives the satellite down-link at an offset angle from the boresight. We are going to calculate that offset angle to determine the satellite antenna gain in the direction of the intercept site.

We have already calculated *angle N,* which is the same as *angle D* in Figure 2 from last month's EW 101 column. It is 4.34°. This is the elevation of the satellite antenna boresight.

*Angle R* can be found from the planar triangle N, Q, T.

*Angle S* is the same as *side j* in Figure 1 (above) = 1.40°.

*Side r* = 6371 km
*Side p* = 6671 km
*Side s* is found from the planar law of cosines for sides:
$(\text{Side s})^2 = p^2 + r^2 - p\,r \cos S = 6671^2 + 6371^2 - (6671)(6371)(\cos 1.40°)$
$= 44{,}502{,}241 + 40{,}589{,}641 - 42{,}488{,}254 = 42{,}603{,}628$
Side s = 6527 km

Using the planar law of sines:
Sin R = (r sin S)/s = 6371 km x sin (1.40°) / 6527 km = .02385
Angle R = arc sin (.02385) = 1.37°

The hostile intercept site is away from the down link antenna boresight by
Angle N – Angle R = 4.34° - 1.37° = 2.97°

## GAIN OF THE DOWN-LINK ANTENNA IN THE DIRECTION OF THE HOSTILE INTERCEPT SITE

**Figure 3** shows the reduction in gain from the satellite down-link antenna boresight in the direction of the intercept site. This is given by the formula:

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

Where:
- $\Delta G$ is the reduction in gain from the antenna bore-sight in dB
- $\alpha$ is the 3-dB beamwidth of the antenna in degrees
- $\theta$ is the offset angle from the boresight in degrees

From last month, we know that the 3-dB beamwidth of the satellite antenna is 3.7° and the offset angle is 2.97°. Thus, the reduction in gain is:
$12(3.7 / 2.97)^2 = 12(1.55) = 18.6$ dB.

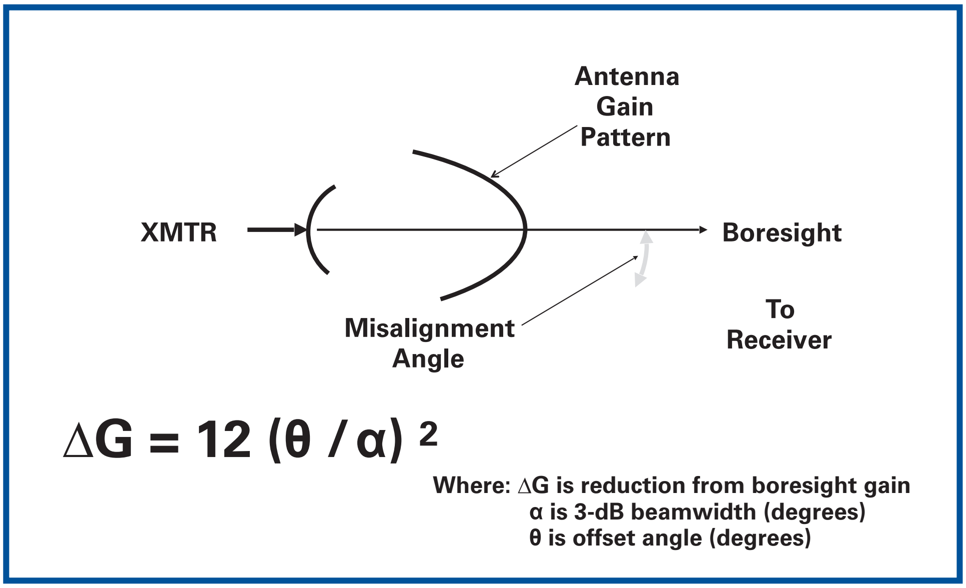


*Fig 3: The antenna gain to a receiver is reduced by a factor that is a function of the transmit antenna's 3-dB beamwidth and the offset of the receiver from the bore-sight of the transmitting antenna.*

This means the transmit antenna gain toward the intercept site is:
33.3 dBi – 18.6 dB = 14.7 dBi

## RECEIVED SIGNAL AT THE INTERCEPT SITE

$P_R = P_T + G_T$ **(toward receiver) – 32.44 – 20 log d – 20 log F +** $G_R$

Where:
- $P_R$ is the power received by the receiver at the intercept site in dBm
- $P_T$ is the down-link transmitter power in dBm = 200 Watts (i.e., 50 dBm)
- $G_T$ is the transmit antenna gain toward the receiver = 14.7 dBi
- *d* is the link distance between the satellite and the intercept site in km = 6527 km
- *F* is the link frequency = 2 GHz (i.e. 2000 MHz)
- $G_R$ is the receiving antenna gain at the intercept site (in dBi) = 29.8 dBi

$P_R = P_T + G_T$ (toward receiver) – 32.4 – 20 log d – 20 log F + $G_R$
= 50 dBm + 14.7 dBi – 32.4 – 20 log (6527) – 20 log (2000) + 29.8 dB
= 50 + 14.7 – 32.4 – 76.3 – 66 + 29.8
= -80.2 dBm

## WHAT IS THE QUALITY OF THE INTERCEPTED DOWN-LINK SIGNAL?

The minimum detectable signal of the receiver is:

**MDS = kTB + NF**

Where:
- *MDS* is the minimum detectable signal in dBm
- *kTB* is the thermal noise level in the receiver [which equals -114 dBm + 10 log(bandwidth / 1 MHz)]
- *NF* is the receiver system noise figure in dB

If the bandwidth of the intercept receiver is 10 MHz and its noise figure is 5 dB, the receiver's MDS would be: kTB + NF = -104 dBm + 5 dB = -99 dBm; it would receive this signal with a signal-to-noise ratio of:
-80.2 dBm – (-99 dBm) = 18.8 dB

## WHAT'S NEXT

This is a pretty high-quality intercept. Next month, we will look at measures the satellite could employ to prevent an enemy from intercepting the signal. For your comments and suggestions, Dave Adamy can be reached at dave@lynxpub.com.

## DIXIE CROW CHAPTER AWARDS 2020 AOC TEST & EVALUATION AWARD


*2020 AOC Test & Evaluation Award Winner Sydney Wells*

Sydney Wells faithfully serves as the lead simulator subject-matter-expert for the Electronic Warfare and Avionics Integrated Support Facility at Robins AFB. In this role, Sid oversees 150,000 square feet of lab space and over $450M worth of equipment as he supports test & evaluation for more than 30 EW systems. This includes nine CEESIMs, three A2PATS, four advanced emulators, and a novel programmable, expandable threat simulator. His efforts enable 24/7 T&E operations, thereby increasing survivability and lethality of our warfighters in contested environments.

Sid has also recently stepped into the role of lead engineer for the lab, incorporating new advanced threat emulators and guiding strategic efforts. Sid is leading the technical effort to provide a production contract to allow DoD-wide access to the highly demanded advance threat emulators. He is also leading efforts to posture the T&E community in preparations to support next-gen EW systems through a programmable, modular, and expandable EW system capable of direct-inject low-power RF engagement in a lab environment. Sid also serves as the technical point of contact for a digital IADS solution to provide RF-dense environments based on intelligence data, and he is working to provide vertical data correlation for all of these assets to increase confidence in the T&E systems.

Outside of the lab, Sid continues to seek education opportunities focused on RF and EMS. He is expanding his knowledge on the latest technologies and advanced techniques in the EW community. Sid has distinguished himself among his peers as an astute expert for all EW T&E needs. Congratulations, Sydney Wells! We are proud to have you representing our Dixie Crow Chapter!


*2020 AOC T&E Award Winner Sydney Wells & Adam Delestowicz, Dixie Crow Chapter President*

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The 2020 AOC Board of Directors elections are open from October 1-31, and the AOC needs you to do your part! Your participation is critical. Please exercise your right to vote for your AOC Board of Directors representatives by visiting www.crows.org, where you'll find a link to cast your ballot online, or a printable paper ballot which you may mail to the AOC HQ.

Online, you'll also find election information to help you make your choice, including descriptions of candidates' backgrounds, leadership styles and contributions to the AOC. The 2020 Nominating Committee carefully considered the impressive nominations it received before selecting this year's candidates. The slate of candidates was subsequently approved by the AOC Board of Directors. We are grateful to all of those who participated in this process and applaud those willing to submit their names for consideration.

Thank you for your continued support of AOC. Let your voice be heard by casting your vote for the new leaders of your association!

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12. Tax Status *(For completion by nonprofit organizations authorized to mail at nonprofit rates) (Check one)*
The purpose, function, and nonprofit status of this organization and the exempt status for federal income tax purposes:
☑ Has Not Changed During Preceding 12 Months
☐ Has Changed During Preceding 12 Months *(Publisher must submit explanation of change with this statement)*

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| 13. Publication Title | 14. Issue Date for Circulation Data Below |
|---|---|
| JED, The Journal of Electronic Defense | October 2020 |

| 15. **Extent and Nature of Circulation** | | | **Average No. Copies Each Issue During Preceding 12 Months** | **No. Copies of Single Issue Published Nearest to Filing Date** |
|---|---|---|---|---|
| a. Total Number of Copies *(Net press run)* | | | 14442 | 14060 |
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| f. Total Distribution *(Sum of 15c and 15e)* ▶ | | | 14393 | 14016 |
| g. Copies not Distributed *(See Instructions to Publishers #4 (page #3))* ▶ | | | 49 | 44 |
| h. Total *(Sum of 15f and g)* | | | 14442 | 14060 |
| i. Percent Paid *(15c divided by 15f times 100)* ▶ | | | 100 | 100 |

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Date 9/18/2020

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