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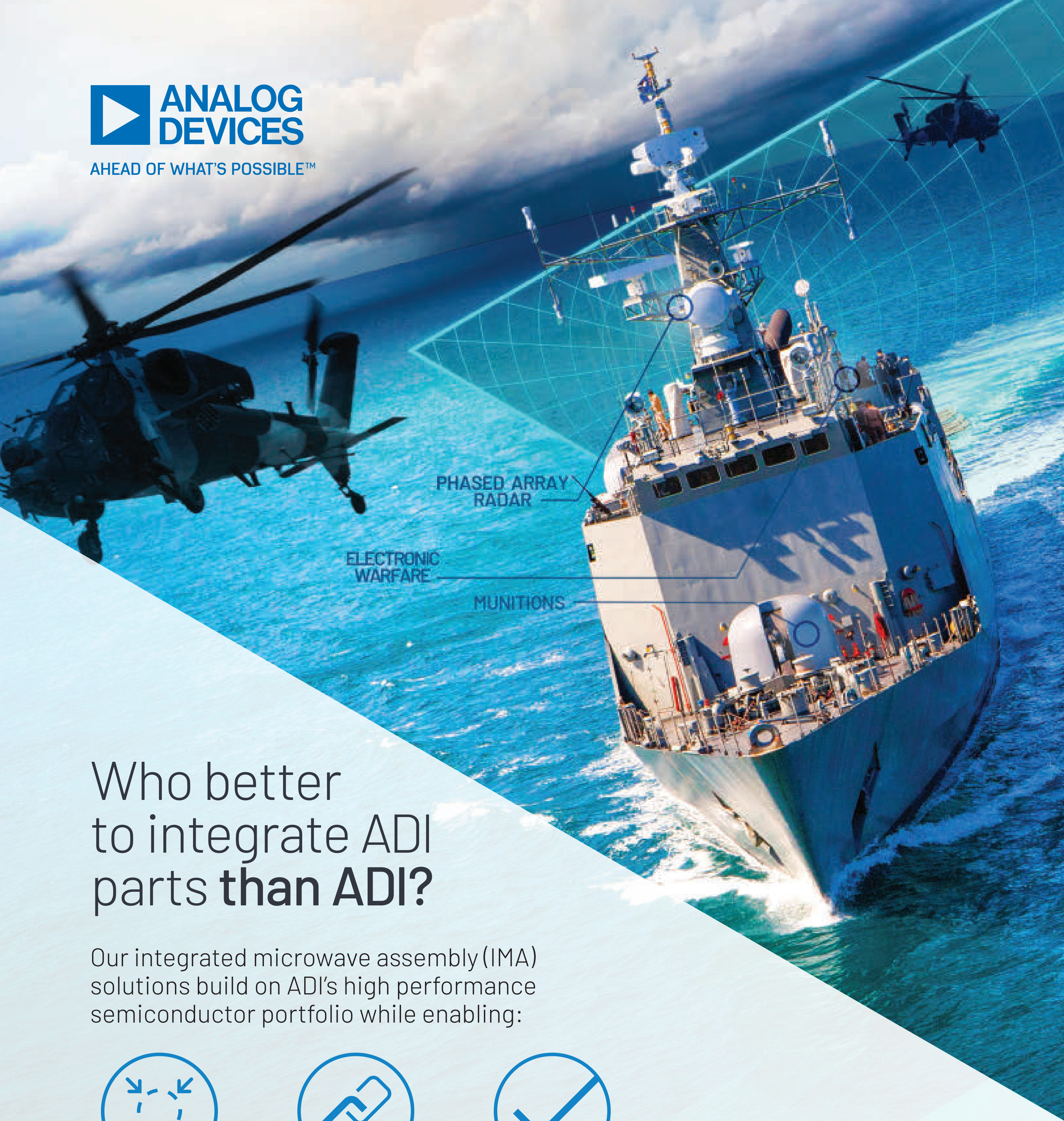
September 2020 Vol. 43, No. 8

JED

Journal of Electromagnetic Dominance

The US Air Force Embraces EMSO

- Technology Survey: EW and SIGINT Tuners
- Australia Signs on for NGJ Low Band Cooperation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MUNITIONS

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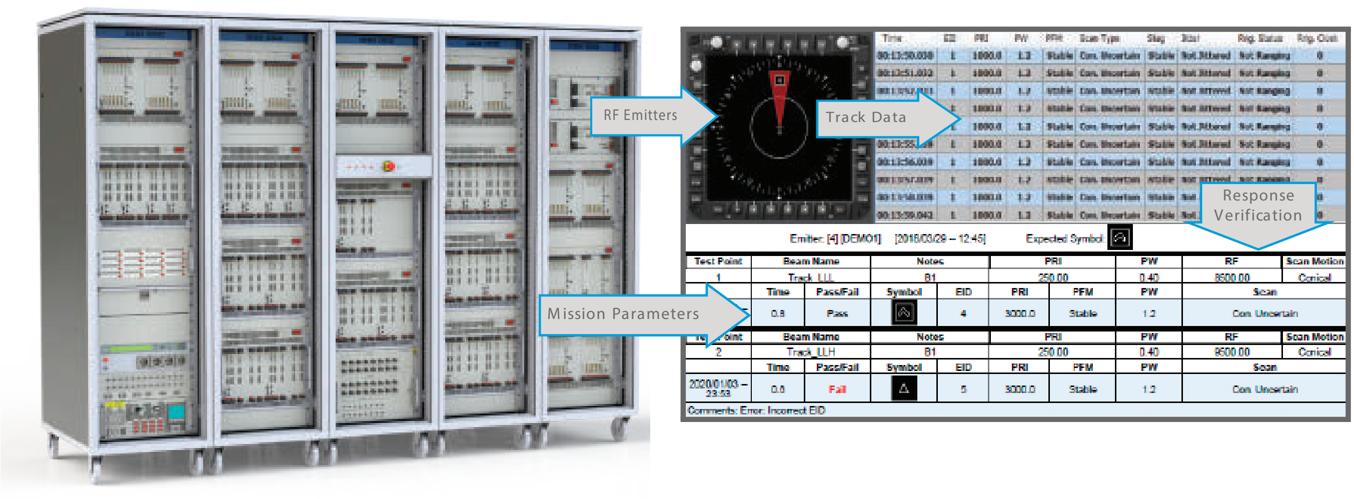

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ULTRA

JED
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After decades of EW atrophy, the US Air Force is embracing EMS Operations (EMSO) and trying to (re)build its EMS enterprise. This wide-ranging initiative penetrates into doctrine, organizations, leadership, training and other areas. How is this playing out, and what is the vision the Air Force is aiming for? USAF PHOTO

In this month's technology survey, we look at RF and microwave tuners designed for EW and SIGINT applications.

US AIR FORCE PHOTO

US Marines with Alpha Company, 1st Radio Battalion, I Marine Expeditionary Force Information Group (MIG), hike during a field exercise (FEX) at Marine Corps Base Camp Pendleton, CA. The FEX, conducted in May, was the culminating event of a three-week long course which involved several static team sites that provided specific military occupational specialty training, reinforcing the Marines' deployment capabilities and unit readiness within I MIG.

US ARMY PHOTO, JEAN S. HAN

Departments

COVER PHOTO COURTESY OF US AIR FORCE

RETHINKING SUPPLY CHAINS

Last month, *Air Force Magazine* published an informative interview with Vice Chairman of the Joint Chiefs of Staff Gen John Hyten. Toward the end of the Q&A, General Hyten talked about the depth of the US Industrial Base. He said, "It is a huge issue. Over the last 20 years, we've allowed the second- and third-tier supply chain to deteriorate significantly." He also explained, "One of the lessons we've learned the hard way from the coronavirus, is that when you have a supply chain that is dependent on Asia and China, and you really want to move fast, you have a difficult problem. We cannot have a supply chain that does that, so we have to rebuild it. That's going to take investment. But we can do that under the programs we have, if we do it smartly."

This got my attention. When the DOD began to embrace commercial off the shelf (COTS) technology in the 1990s, this policy was part of a larger acknowledgement that defense spending was not going to drive as much technology development in the electronics sector as it had during the Cold War. The world was just entering a mobile communications and personal computer revolution, and the DOD was inclined to piggyback on this trend rather than replicate it. For the past 25 years or so, the DOD has leveraged COTS technologies in most of its radios, EW systems, radars, EO/IR sensors, etc., while trying to manage the downsides, such as counterfeit parts and cyber security. As General Hyten indicated, however, the supply chain discussion is now expanding to include *availability,* as well.

The DOD's COTS policy has worked so far because the DOD is in the business of buying systems. It has left supply chain management of microelectronic components for its radars, EW systems and communications systems largely to the prime contractors who make them and sustain them. These US defense electronics primes are typically buying critical components from US sources. However, as China and other countries make further progress in GaN, FPGAs and other technologies, they are becoming very strong competitors in the global microelectronics market, and it introduces more supply chain risk. The DOD needs to update its supply chain strategy, especially in critical emerging technology areas, if it wants trusted components that are not affected by disruptions to the global supply chain or foreign government policies aimed at denying access to rare earth minerals.

Today, DARPA is making a huge investment in the next generation of microelectronics via its wide-ranging Electronics Resurgence Initiative (ERI). The DOD needs to protect the companies who will eventually manufacture these new technologies for use in radars, EW systems and communications systems. The DOD should not allow its future microelectronics supply chain to be undermined by a much more aggressive and much more influential China. General Hyten is certainly on the right track, but this problem may require a larger discussion that leads to a more comprehensive policy solution. – *J. Knowles*

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10 MHz in
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10 GbE SFP+
Signal Hound SM200C
Spectrum Analyzer / 100 kHz to 20 GHz
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Calendar *Conferences & Trade Shows*

SEPTEMBER

28th International Defence Industry Exhibition MSPO
September 8-10
Kielce, Poland
www.targikielce.pl

The Defense Show – Virtual
September 8-10
www.auvsi.org

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

Modern Day Marine – Virtual
September 22-24
www.marinemilitaryexpos.com

2020 Virtual DE Systems Symposium
September 28 – October 2
www.deps.org

CEMAlite Virtual Summit
September 29
www.crows.org

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

OCTOBER

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

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

Precision Strike Symposium
October 20-22
Laurel, MD
www.precisionstrike.org

EURONAVAL
October 20-23
Paris, France
www.euronaval.fr

MILIPOL Qatar 2020
October 26-28
Doha, Qatar
https://en.milipolqatar.com

NOVEMBER

EW Europe
November 16-18
Liverpool, UK
www.eweurope.com

Bahrain International Airshow 2020
November 18-20
Sakhir Air Base, Bahrain
www.bahraininternationalairshow.com

I/ITSEC
November 30 – December 4
Orlando, FL
www.iitsec.org

DECEMBER

57th Annual AOC International Symposium and Convention
December 8-10
Washington, DC
www.crows.org

JANUARY

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

European Microwave Week
January 12-14
Utrecht, Netherlands
www.eumweek.com

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

9TH ANNUAL INFORMATION OPERATIONS & ELECTRONIC WARFARE SYMPOSIUM

All Domain Operations from Competition into Conflict

The contributions of IO and EW to Joint all-domain warfighting challenges, and to achieving a Free and Open Indo-Pacific during competition.

Now 19-23 OCTOBER 2020 delivered online and VTC

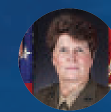
This event will be delivered online and via secure video teleconference in response to the current restrictions on travel to Hawaii following the global COVID-19 pandemic.

The symposium will now start on Monday, October 19 with three days of UNCLASSIFIED presentations, panels, and speakers delivered via the Federal Business Council (FBC) Online Events platform. Classified presentations follow on October 22 and 23 and will be delivered via DOD secure Video-Teleconference. Detailed instructions for DOD and invited Ally and partner militaries for SECRET REL discussions will be published via official message from HQ U.S. Indo-Pacific Command Director of Operations, J3.

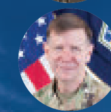
Individual registration is required to participate in any of the online presentations of the Symposium. Registered participants can then choose the plenary sessions and separate presentations they wish to attend. Registered symposium participants will need to register for each of the three plenary sessions, and for individual presentations and panels conducted outside of the plenary sessions that will run from 1100-1400 Hawaii Standard Time. For the classified sessions, participating military commands, DOD PME institutions, academia, Industry, and Allies and partners will coordinate with the symposium chair for instructions on how to be connected to the Towers Conference Room for October 22 and 23 over DOD networks.

Please contact the Symposium Chair Dr. Arthur Tulak, COL USA, Ret., via e-mail at Arthur.N.Tulak.ctr@pacom.mil for more information.

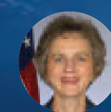
FEATURED SPEAKERS



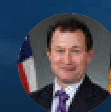
LTGen Loretta E. Reynolds
Deputy Commandant for Information



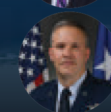
LTG Stephen G. Fogarty
Commanding General of Army Cyber Command *(Invited)*



Ambassador Jennifer Zimdahl Galt
Foreign Policy Advisor, J005, United States Indo-Pacific Command



Mr. Dave Tremper (SES)
Director, Electronic Warfare at Office of the Secretary of Defense



Brig Gen Dave Abba
Director of the F-35 Integration Office, United States Air Force

Brig Gen Mike Manion
Director, HAF/A5L Spectrum Superiority Directorate

Mr. Ken Dworkin
Roundtable Moderator
Executive Advisor, Booz Allen
Former National Security Agency EW Executive (NSA/EWX)

COL Andrew Whiskeyman, PhD,
Chief, Information Operations Division - U.S. Central Command (USCENTCOM)

Major General Tom Coppinger-Symes – CBE
Director Military Digitisation, UK Joint Force Command *(Invited)*

The revised agenda will be published at: FBCINC.COM/E/AOCPACIFIC

ASSOCIATION OF OLD CROWS
DIAMOND HEAD CHAPTER
HONOLULU HAWAII

Calendar *Courses & Seminars*

SEPTEMBER

AOC Virtual Series Webinar: Understanding Quantum Computing & Communications
September 3
1400-1500 EST
www.crows.org

AOC Live Professional Development Web Course: Machine Learning for Electronic Warfare
September 14-28
7 sessions, 1300-1600 EST
www.crows.org

Advanced Radar Signals Collection and Analysis (ARSCA)
September 22-24
Atlanta, GA
www.pe.gatech.edu

Radar Warning Receiver System Design and Analysis
September 22-24
Shalimar, FL
www.pe.gatech.edu

AOC Virtual Series Webinar: Convergence of TDOA/AOA in Operational Environments
September 24
1400-1500 EST
www.crows.org

Electro-Optic and Infrared Systems
September 28 – October 2
Swindon, UK
www.cranfield.ac.uk

Due to the disruptions caused by COVID-19, some event organizers have chosen to change the dates and/or venues of their event. Please contact the event 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

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

Airborne EW System Integration
October 20-22
Atlanta, GA
www.pe.gatech.edu

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

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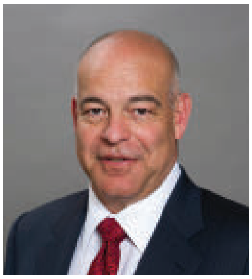


LESSONS LEARNED

EW runs in cycles: when we are at war, EW is vital to success; when we're not at war, EW atrophies, and we pay the price in capacity and sometimes in the next conflict. What lessons have we learned?

1986: Operation El Dorado Canyon involved air strikes by the United States against Libya on 15 April supported by EA-6Bs and EF-111s launching Shrikes, HARMs and other assets, including in-depth mission analysis conducted by the Joint Electronic Warfare Center (JEWC) in San Antonio, TX. EW was important, fully integrated and synchronized. The US lost one F-111.

1991: Operation Desert Storm began on 17 January. EW supremacy was a main contributor to the stunning success of the allied coalition's air campaign against Iraqi Forces. The coalition utilized EA-6Bs, EF-111s, F4G Wild Weasels, EC-130 Compass Calls, RAF GR1 Tornados, HARM and ALARM missiles, ALQ-184 aircraft self-protection jammers and for the first time, F-117A stealth aircraft. General Myers, Tactical Air Command's deputy chief of staff for Requirements, emphasized that the Air Force will continue to "need ECM systems that are effective, timely, and affordable." Otherwise, he warned, the impressive record racked up in Desert Storm electronic warfare may not be duplicated the next time around.

1994: I was a student at the Naval War College, and we had a briefing from Chief of Staff of the Air Force Gen Merrill McPeak. In his commentary, he referred to the Air Force no longer needing EW, as it was investing in stealth technology. By the end of the 1990s, the EF-111 was retired without a replacement, the F-4G Wild Weasel was retired and replaced by the "interim" F-16CJ, and US Air Force EW expertise was rapidly diminishing.

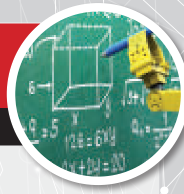
1993-1999: Operation Deny Flight and Operation Allied Force over the former Yugoslavia was supported by EA-6Bs, Compass Call aircraft, F-16 CJs, ECR Tornados, and F-117As as part of a NATO coalition that flew over 38,000 combat missions. During OAF, it was apparent that US Air Force EW had atrophied since Desert Storm.

2001-2011: The decade following the 9/11 attacks against the US saw major operations in Afghanistan and Iraq. With the exception of the initial 2003 air campaign in Iraq, tactical air operations were conducted in permissive environments. However, the US Army was learning other EW lessons against IR-guided MANPADS and RCIEDS.

2012-present: The rise of near-peer competitors, such as China, and the resurgence of Russia's military power have focused Western military forces on a new set of maneuver challenges in the EM Environment. At the same time, our EMSO community is trying to break the cycle of "temporary resourcing" in war followed by post-conflict atrophy that I described at the beginning of this message. Meaningful progress is shaped by the degree to which we evolve our doctrine, create new organizations and elevate leadership. We are succeeding in these areas, but we must not allow ourselves (or our military leaders) to relax. We must continue to build and strengthen our EMS enterprise, or we will repeat our mistakes. – *Muddy Watters*

FEATURED LIVE COURSES

Machine Learning for EW



Kyle Davidson

Mondays, Wednesdays, & Fridays

13:00 – 16:00 EDT | September 14 – 30, 2020

This course introduces students to the fundamentals of machine learning and its application to modern Electronic Warfare (EW) and cyber solutions.

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.

Intermediate Electronic Warfare

EW EUROPE 2020

Dr. Clayton Stewart

Thursday & Friday | **08:00 – 17:00 BST**

November 19 – 20, 2020 | Liverpool, UK

We will begin with a historical perspective and introduce use of radar, integrated air defense system, early EA functions and conclude with an overview of modern EA, ES, and EP.

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.

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.

= Web Course, no travel required!

WASHINGTON D.C. 57TH AOC INTERNATIONAL SYMPOSIUM & CONVENTION

RF Theory for ES Operations

Dr. Patrick Ford

Sunday & Monday

09:00 – 17:00 EST | December 6 – 7, 2020

Advanced EW – Concepts and Developments

Kyle Davidson

Friday & Saturday

09:00 – 17:00 EST | Dec 11 – 12, 2020

Hands-on Introduction to Radar and EW

Dr. Warren Du Plessis

Sunday & Monday

09:00 – 17:00 EST | December 6 – 7, 2020

Tactical Battlefield Communications

Dave Adamy

Friday & Saturday

09:00 – 17:00 EST | Dec 11 - 12, 2020

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

AUSTRALIA SIGNS ON FOR NGJ-LB COOPERATION

Australia is deepening its cooperative partnership with the US Navy on the Next Generation Jammer (NGJ) program by extending the scope of the arrangement to include the Next Generation Jammer Low Band (NGJ-LB) variant.

Signed on 13 July, the expanded project arrangement is intended to ensure commonality on future airborne electronic attack (AEA) payloads for the EA-18G Growler aircraft operated by the US Navy and the Royal Australian Air Force (RAAF). Australia is already a partner on the AN/ALQ-249(V)1 Next Generation Jammer-Mid Band (NGJ-MB).

Managed by the Airborne Electronic Attack Systems Program Office (PMA-234) in the US Naval Air Systems Command (NAVAIR), the NGJ program is intended to augment, and ultimately replace, the legacy ALQ-99 tactical jamming system (TJS). The NGJ capability is being delivered in three phased increments, each covering a different portion of the frequency spectrum, beginning with the NGJ-MB variant currently under development by Raytheon.

Due to enter service in 2022, the NGJ-MB system represents a step change from ALQ-99 in terms of its software-based digital architecture, and use of high power active electronically scanned arrays based on Gallium Nitride technology. The NGJ-MB program expects to complete Milestone C later this year, with a Low Rate Initial Production contract award to follow.

The RAAF has acquired 12 EA-18G Growler aircraft under Project Air 5349 Phase 3. The aircraft, which achieved initial operating capability in February 2019, have entered service with the same AN/ALQ-99 TJS that currently equips the US Navy's EA-18G Growlers.

Under Project Air 5349 Phase 6 Advanced Growler, Australia has established a co-operative agreement with USN to further develop its AEA capability, and acquire additional anti-radiation weapons. Within the scope of this effort, the Commonwealth in November 2017 signed a project agreement to join the NGJ-MB program: the two countries in May this year signed a second agreement to enter production, sustainment, and follow-on development of the AN/ALQ-249(V)1 NGJ-MB.

The NGJ-LB program is currently in the materiel solutions analysis phase, with L3Harris and Northrop Grumman completing parallel Demonstration of Existing Technologies (DET) contracts. According to NAVAIR, the downselection of a single prime contractor to develop the NGJ-LB Capability Block 1 tactical jamming operational prototypes is anticipated later in 2020.

The NGJ-LB will utilize the latest digital and software-based technologies that will address advanced and emerging threats in the lower frequency bands of the electromagnetic spectrum. The DET contract has seen joint government/industry teams work to assess the technical maturity of the respective technical solutions developed by L3Harris and Northrop Grumman. Both companies have now completed a number of test events, including a joint government/contractor test period during which a prototype Technology Demonstration Unit from each company was tested at Naval Air Station Patuxent River (Patuxent River, MD) in a representative environment. – *R. Scott*

EMSO AND SIGINT HIGHLIGHTED IN HOUSE DEFENSE POLICY BILL

The US House of Representatives passed its version of the National Defense Authorization Act (NDAA) on July 21 in a bipartisan vote. The policy bill authorizes $635.5 billion for the DOD's base budget and another $69 billion for Overseas Contingency Operations. The House Armed Services Committee (HASC) report accompanying the NDAA (H.R. 6395) includes several Electromagnetic Spectrum Operations (EMSO)- and Signals Intelligence (SIGINT)-related "Items of Special Interest."

Helicopter ASE

One area where the HASC focused its attention was helicopter aircraft survivability equipment (ASE). The committee called for a report on sensor payloads for the Army's Future Vertical Lift (FVL) program. "The committee notes that the Army has yet to define the acquisition strategy for FVL mission equipment payloads and sensors, despite an accelerated platform development schedule," the report states. "The committee understands that fielding mission equipment that is as advanced and capable as the platforms themselves will require investment and development in the coming years. The committee is concerned that without a well-defined acquisition strategy and risk reduction effort for mission equipment payloads and sensors, industry will be unable to make the investments necessary to deliver advanced capabilities on time for FVL programs."

The committee directed the Secretary of the Army to submit a report on FVL mission equipment, payloads and sensors to the House and Senate Armed Services Committees by December 1, 2020. This report should include "1) the acquisition strategy for FVL mission equipment payloads and sensors, including radar, electronic warfare, 360 degree distributed aperture, missile warning, and advanced electro-optical infrared; 2) planned risk reduction activities for the sensor payloads; and 3) an estimate of the cost and schedule for the development and production of required sensor payloads."

In another section of the committee report, the HASC focused on "Aviation Survivability of Marine Corps, Navy, and Air Force Rotary Wing Aircraft." Here, it recognized "...the importance of the Distributed Aperture Infrared Countermeasure (DAIRCM) system and the Department of Defense's efforts to integrate an aircraft protection system to protect small to medium rotary wing aircraft from increased threats." Noting that the Air Force has already deployed the system, the Committee stated that it, "... recognizes there is a future gap in this aircraft survivability capability for both the Air Force and Marine Corps in the coming fiscal years and supports the efforts by these services to rapidly transition to a production capability. This transition will ensure all Marine Expeditionary Units and forward deployed Air Force rotary wing aircraft are properly equipped to meet this threat." The Committee directed the Secretary of the Navy and the Commandant of the Marine Corps to provide a briefing by March 1, 2021, "... on the effective integration of DAIRCM into additional light and medium rotary wing aircraft and the long-term strategy for aircraft survivability of the Marine Corps and Air Force rotary wing fleet."

Directed Energy

The HASC also took note of directed energy weapons (DEW) programs. The committee report stated, "The committee is concerned with the ongoing development of the Navy's Long-Range Ocular Interrupter (LROI) Program. The committee understands that the LROI is intended to provide the Navy with the capability to deliver a bright light producing a dazzling or glare effect on a closing target to warn and/or suppress potential threats through increasing levels of visual degradation... The committee agrees with the military utility of this capability, and the need for the Navy to move forward to field a materiel solution. However, the committee is troubled by the continued schedule slippage of LROI in the Engineering and Manufacturing Development (EMD) acquisition phase. For example, the committee is concerned that the Navy is continuing to develop the LROI system when existing commercial-off-the-shelf capabilities are already being fielded by other military services. The committee is further concerned that there are ongoing disputes over the intellectual property of the LROI system." The committee directed the Secretary of the Navy to provide a report on LROI acquisition plans by February 1, 2021.

The Committee also addressed the Surface Navy Laser Weapon System (SNLWS) program. According to the report, "The Committee commends the Department of the Navy's recent success with the Laser Weapons System Demonstrator (LWSD) from an LPD. In addition, the Committee is encouraged that SNLWS Increment 1, the High Energy Laser with Integrated Optical-Dazzler and Surveillance (HELIOS) is on schedule to begin integration and land-based testing later this year. In addition, the Committee recognizes that both the Navy and industry have invested in this technology and understand the need to take incremental steps since there is no one-size fits all solution. However, the Committee is concerned with both the fragility of the supply base and that the protracted time between development, test and installation for an at-sea trial will cause the Navy to reprogram outyear funding to other needs. Therefore, the committee directs the Secretary of the Navy to brief the committee no later than October 1, 2020 on an updated acquisition timeline that illustrates its path forward on SNLWS Increment 1 and allows for an efficient fielding of SNLWS Increment 2."

SIGINT

Elsewhere in the report, the HASC addressed next-generation SIGINT for the Navy's surface combatants. "The committee notes that the Spectral program is an incremental acquisition, Government Off-The-Shelf/Commercial Off-The-Shelf program that provides cryptologic signals exploitation capabilities designed to meet the requirements for shipboard cryptologic operations within the Ship's Signal Exploitation Equipment (SSEE) aboard a variety of ship classes and shore facilities. The Spectral system is programmed to provide a mobile, passive capability to detect, classify, track, and determine the intent of enemy units through exploitation of their command and control emissions... The committee believes that the Secretary of the Navy should expedite the development of this critical capability and supports decoupling the hardware from the software so that capability enhancements are delivered by software as soon as they are developed. To achieve maximum competition and to solicit the most cur- rent technologies, the committee further believes that the Secretary should continue to prioritize an open architecture approach so that the new system can readily integrate emerging third-party capabilities." In this regard, the HASC directs the Secretary of the Navy to provide a Spectral program briefing by January 30, 2021.

The Senate passed its version of the NDAA in late July, as well. When the House and Senate reconvene this month, both are expected to meet in conference to begin working out the differences in their respective NDAA bills. – *J. Knowles*

FINCANTIERI GROUP WILL PROVIDE ITALIAN MOD A PROGRAMMABLE EO/IR SEEKER EMULATOR

The Naval Armaments General Directorate (NAVARM) of the Italian Ministry of Defence's (MoD's) Secretariat General of Defence/National Armament Directorate has awarded Fincantieri Group's INSIS (Ingegneria dei Sistemi Speciali) business an undisclosed value contract for the design and supply of a programmable EO/IR (electro-optical/infrared) seeker emulator to evaluate the effectiveness of EO/IR countermeasures systems in the naval and airborne domains.

The contract, announced by Fincantieri on August 5, was awarded under a restricted international procedure, issued by the Italian MoD NAVARM's 3rd department (Combat Systems), 8th Division - Surface Systems and Weapons, and involves the design and development of a support system for the verification and validation of IR decoys and DIRCM countermeasures techniques to defend Italian Navy ships and aircraft against electro-optical/infrared (EO/IR)-guided missiles.

The system's main purpose will be to test the effectiveness of flare launch sequences and DIRCM jamming techniques, according to the documentation released by the same NAVARM office, to the creation of effective EW libraries usable on board ships. The system must also be set up to assist in the verification and validation of missile-defeating techniques generated by the defensive aid subsystems (DASS) of airborne platforms.

The system will comprise a multi-sensor gyro-stabilized hardware unit that can be transported aboard naval platforms or deployable in firing ranges. The system will be integrated with a software component developed for simulation of engagement and tracking techniques typical of various types of missile seekers (imaging and non-imaging), and it will enable users to assess the threat and countermeasures response (intended as a combined use of flare, DIRCM and platform evasive maneuvers). It will estimate the miss-distance of the deployed soft-kill techniques, and therefore the effectiveness or the improvements to these countermeasures.

According to the NAVARM office, the system architecture will have to ensure, consistently with the rest of the EW verification and validation equipment employed by the service, scalability and upgradeability for future developments, including its integration into wider test scenarios, such as multi-threat or dual-guided RF/IR threat scenarios.

The awarded contract will have an overall duration of about 30 months and will end with the performance of field test campaigns carried out in collaboration with the Italian Navy's Naval Experimentation and Support Centre (CSSN-ITE) based in Livorno. – *L. Peruzzi*

IN BRIEF

The **Air Force Research Laboratory, Sensors Directorate (AFRL/RYW)** (Wright-Patterson AFB) issued a solicitation for the first call under the Multi-Spectrum Defensive Electronic Warfare (MSDEW) program. Titled Threat Assessment & Aircraft Protection Defensive Electronic Warfare (TAAP-DEW), the objective of call 01 is to "design expendable (ordinance) and directed-energy (signal) countermeasure concepts, in electro-optical (EO) and multi-spectrum electro-optical/radio-frequency (EO/RF) domains." Specific tasks include threat exploitation and assessment; modeling, simulation and analysis; hardware testing and experimentation; and countermeasure technique and technology design. The MSDEW program, with a five-year $396.6 million budget, aims to "develop sensors and systems supplies to meet the need for the national defense for improved joint lethality in contested environments" by advancing Air Force electronic warfare (EW) capabilities. The total value for the TAAP-DEW call is estimated at $68.6 million, likely to be awarded under a single contract. Proposals were due August 14, with contracts to be awarded December 2020. The contracting point of contacts are Dawn Dalhamer, 937-713-9968 or dawn.dalhamer@us.af.mil, and Donald Grein, 937-713-9822 or donald.grein@us.af.mil.

BAE Systems (Nashua, NH) has won a $179 million contract for the first two production lots of the Limited Interim Missile Warning System (LIMWS) for US Army helicopters. The LIMWS program, which is an upgrade to the AAR-57 Common Missile Warning System, is based on the company's 2-Color Advanced Warning System (2CAWS), which the company says includes "an open system processor, two-color infrared sensors for increased range, and a fiber optic A-kit for faster data transmission." Under earlier contracts, the LIMWS system has been fielded on Army Special Operations Command helicopters as part of a quick reaction program. The recent contract, which funds 200 LIMWS systems, marks the first production units for US Army helicopters. Leonardo DRS is supporting the program with sensor technology. Previously, the US Army has said it expects to upgrade approximately 400 CMWS systems to the LIMWS configuration.

The **Hudson Institute** (Washington, DC) has established a Center for Defense Concepts and Technology chaired by Senior Fellow Bryan Clark and supported by Fellow Timothy A. Walton. The center will explore evolving fields of military competition and the implications of emerging technologies for defense strategy, military operations, capability development, and acquisition. For several years, Clark was a senior fellow at the Center for Strategic and Budgetary Assessments (CSBA), where he focused on EMSO-related topics.

Textron Systems (Hunt Valley, MD) won a $4.4 million contract from the US Air Force to supply a Radio Frequency Threat Simulator for the Air Force Test Center's Electronic Warfare Lab at Eglin AFB, FL. The contract runs through March 2021.

The US Army's **Product Lead Electronic Attack (PdL EA)** (Aberdeen Proving Ground, MD) has issued a Request for Information (RFI) to solicit industry input for its Next Generation Counter Radio-Controlled Improvised Explosive Device (RCIED) Electronic Warfare (CREW) System. According to the RFI, PdL EA seeks to "...identify parties that have invested Internal Research and Development (IR&D) dollars to design a Command Control Communications Computers Cyber Intelligence Surveillance Reconnaissance (C5ISR)/Electronic Warfare (EW) Modular Open Suite of Standards (CMOSS) and Modular Open Radio Frequency (RF) Architecture (MORA) compliant mounted CREW system or have the ability to integrate mature subsystems into a partial MORA/CMOSS compliant CREW system." The RFI also states, "The prototype capability (CMOSS and MORA compliant Card) described in this RFI will be integrated into the CMFF prototype platform with additional CMOSS complaint cards with various functionality." The RFI indicates that program officials are contemplating an 18- to 24-month development effort with two major demonstrations occurring at 12 months and 18 months from the contract award date. The contractor would produce two demonstration units and eight additional systems at the end of the contract. Responses are due September 3. The technical point of contact is Dr. Leslie Litten, e-mail leslie.a.litten.civ@mail.mil, and the contracting point of contact is Eric Pyles, e-mail eric.c.pyles.civ@mail.mil. The RFI solicitation number is W56KGY-20-R-E004.

US Air Force EMS Strategy Impleme

By John Haystead

It's not clear when the US Air Force reached its low point in electronic warfare (EW) or exactly what caused it. Some would say it began after the 1991 Gulf War with the reorganization of Strategic Air Command and Tactical Air Command into Air Combat Command. Others would point to the retirement of the F-4G Wild Weasel and EF-111 Raven in the 1990s as a low point. The specifics aren't very clear, and they don't really matter. What is undeniable is that the Air Force allowed its EW resources – its personnel, organizations, leadership, materiel, training, etc. – to atrophy over the past 30 years. This decline occurred in not just in terms of numbers of people or aircraft, but also in terms of the way EW was organized across the Air Force – in a scattered, disconnected way. There was no enterprise concept for EW. It was spread so thin that it was "everywhere," and yet it was buried so deep within the organizations that no one could find it.

This situation began to change a few years ago when the Air Force began to take an enterprise approach to the Electromagnetic Spectrum. Air Force leaders began to think in terms of EMS Superiority and EMS Dominance, and they set in motion a plan to achieve those ambitious goals. The result has been the beginning of what many hope is a new era for Air Force, underpinned by a new approach based on EMS Operations (EMSO).

THE AIR FORCE'S PATH TO EMS DOMINANCE

To properly understand the direction, goals, and progress of the Air Force's initiatives toward achieving EMS dominance, it's necessary to have a general understanding of the Service's organizational structure, the delineation of responsibilities and missions, and its overall relationships within the Joint Force and DOD. While it may initially appear that there are a lot of disparate or disconnected EMSO activities going on with no real overall coordination, a closer look reveals that there is indeed a master plan, and one that is, in fact, already beginning to come to fruition.

The FY2019 National Defense Authorization Act (NDAA) mandated the Air Force create a dedicated team to develop an electronic warfare strategy, including assessments of vulnerabilities and capability gaps, leading to an acquisition plan.

In a discussion of the Air Force's EMSO initiatives, the chain-of-command generally centers around the USAF Chief of Staff (AF/CC), currently Gen David L. Goldfein. Within Goldfein's Air Staff, there are a number of Deputy Departments, one of which is the Deputy Chief of Staff for Strategy, Integration and Requirements (AF/A5). The AF/A5 was created in October 2018 to ensure the Air Force remained aligned to the US National Defense Strategy. Lt Gen Samuel C. Hinote is the current AF/A5 Deputy Chief of Staff, as well as being dual-hatted as the Director of the Air Force Warfighting Integration Capability (AFWIC) organization (AF/A5A).

General Goldfein, together with the Secretary of the Air Force at the time, Dr. Heather Wilson, created the AFWIC in October 2017 "to explore and wargame innovative solutions, develop an integrated family of concepts, and direct capability development efforts across the Air Force." The organization was also to develop a single, multi-domain strategy that will identify, guide, and prioritize future force development. According to its mission statement, "Through a process of innovative exploration, concept development and enterprise-wide integration across core functions, AFWIC produces future force design and capability development guidance to synchronize acquisition, planning, and programming. AFWIC bridges the gap between Strategy and Planning by providing a future force design relevant to the threat, strategy, and need to develop new ways of operating as a joint force."

EMS SUPERIORITY ECCT DIGS INTO THE PROBLEMS

Meanwhile, in January of 2018, the Air Force officially announced the formation of an Enterprise Capability Collaboration Team (ECCT) aimed at ensuring electromagnetic spectrum superiority. Gen Stephen Wilson, Air Force Vice Chief of Staff under General Goldfein, actually first broke the news to spontaneous applause during his keynote address to the 2017 AOC International Symposium and Convention. The ECCT team was to be led by Brig Gen David Gaedecke, then director, Cyberspace Operations and Warfighter Communications, Office of the Air Force Headquarters Deputy Chief of Staff for Intelligence, Surveillance, Reconnaissance and Cyber Effects Operations (HAF/A2/6). As only the third AF ECCT to be stood up at the time, General Wilson, stated that, "As we look around the globe we see that our adversaries have studied us over the last 26 years that we've been in conflict, and they've been looking at areas that they think they can exploit. One of those areas is electronic warfare – to be able to dominate the spectrum."

U.S. AIR FORCE PHOTO BY TECH. SGT. BRIAN KIMBALL

Superiority ntation Heating Up

Basically one year later, the results were in. In January 2019, during a special meeting at the Combat Air Forces (CAF) Weapons and Tactics Conference (WEPTAC) of 2019, at Nellis Air Force Base, NV, General Gaedecke officially announced the results of the ECCT and noted, "In order to execute the Air Force's five core missions, the Air Force should deliberately refocus efforts on electronic warfare and the EMS as a whole." He identified three enterprise-wide recommendations and initiatives:

"Unifying and organizing corporate governance of the EMS enterprise by establishing an EMS Superiority Directorate in the Headquarters Air Force, led by a general officer, to oversee and manage enterprise-wide EMS priorities and investments which will be subsumed and managed as a single portfolio."

"Combining and consolidating EMS services, software programming infrastructure and expertise into a multi-domain organization focused on achieving real-time effects and enabling evolution to machine-to-machine adaptive and cognitive spectrum control. In order to win and control the EMS, the Air Force will employ distributed systems and capabilities coordinated to defeat a sophisticated adversary of complex systems aligned to deny Joint Force capabilities."

And, "developing and instilling an EMS Warrior ethos by building enterprise-wide education and training programs to lead, innovate, integrate, train and build EMS awareness in Airmen at all levels. Air Force operational concepts, tactics and doctrine, and institutional expertise as a whole, will progressively advance with renewed focus of a near peer in the EMS domain."

DOCTRINAL CHANGES

As expected, the results of the ECCT led to key changes to the Air Force's EW Doctrine Document (Annex 3-51 – Electromagnetic Warfare and Electromagnetic Spectrum Operations), most notably the change in terms from "electronic warfare" to "*electromagnetic* warfare." Released in July 2019, the revised doctrine also addressed EW structure, which was rewritten to describe EW as a subset and specialized form of EMS operations (EMSO), essentially combining and consolidating information in equivalent joint publications (JPs) 3-13.1, Electronic Warfare, and 6-01, Joint Electromagnetic Spectrum Management Operations.

The updated doctrine also included "enhanced information on EW in space and cyberspace, with additional material discussing the integration of EMSO across all domains, including air, land, and maritime." And, it also added new material on organizing, planning for, executing and assessing EMSO, which was not previously included in the doctrine. Importantly, as noted in its introduction, the document is intended to serve toward the 2019 NDA mandate of "cementing the base of joint EMS capability with a dedication to the education and training of the whole force and the staffing of a dedicated professional force fluent in EMS operations."

As described by Col Lisle "Sack" Babcock, Vice Commander, LeMay Center for Doctrine Development and Education, there is customarily a two-year review cycle at the LeMay Center for reviewing and updating doctrine documents. This is usually about a 9-month process to get all the players involved reviewing proposed changes and providing feedback. However, in the event of a significant development coming in from the field, or a Major Command (MAJCOM) indicating that a current doctrine is inadequate, this can be moved up and a short-notice working group convened.

This is what happened with 3-51. The ECCT revealed that the existing doctrine contained a large amount of out-of-date or antiquated information leading Colonel Babcock to immediately put together an electromagnetic spectrum working group of 40-45 experts from across the Air Force. "Right away," says Babcock, "we decided we were not going to call it electronic warfare anymore, it would be electromagnetic warfare and electromagnetic spectrum operations. And, the focus would not be just on air operations, which is pretty well written but not very inclusive, it would also include cyber and space."

According to Babcock, "One of the biggest things was really talking about how to integrate EMS fires as part of a larger non-kinetic operations capability, merged with cyber and space to provide the counterpart to the kinetic options. Although the Air Force does very well at EW training and preparedness at the micro-tactical level and in a very scripted way, where we know what and where most of the threats are and how we will address them, we don't know how to do this very well at the operational level, which is the level at which the LeMay Center doctrine is written – the operational level."

The doctrine team also realized early on that the Joint Force Air Component Commander (JFACC) staff did not take non-kinetic capabilities seriously for the most part across the Geographic Combat Commanders (GCCs), not because

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ENSURING THE BEST AESA PERFORMANCE

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Test challenges for AESA TRMs in development and production

Breakthrough technological advancements, such as direct digital synthesis, phased arrays and gallium nitride (GaN) components, have spawned a new breed of radar – multifunctional active electronically scanned array (AESA) radar. The AESA radar performance strongly depends on the quality of transmit/receive module (TRM), and due to their complexity, the TRMs require a lot of verification and testing during their development, which has a big time and cost impact.

Flexibility and efficiency are the most important parameters taken into consideration when developing and testing TRMs. The testing setup has to be both radar and customer specific, but also scalable and efficient in order to ensure the required performance in each phase of development and production. It is a complex demand for the test equipment involved, and Rohde & Schwarz holds the right solution.

The Rohde & Schwarz scalable solutions for multiple tests in a single setup

The characterization of TRMs requires flexible test and measurement equipment capable of handling arrays of different measurements. Due to this, TRM test and measurement setups are complex in configuration, calibration and measurement, but also error-prone - if one device is not working properly, the whole configuration fails.

All typical TRM test cases can be covered with a single network analyzer, such as the R&S®ZNA. If higher performance, for example pulsed noise figure, is required from a spectrum analyzer, the R&S®FSW signal and spectrum analyzer is added to the setup. The R&S®TS6 TRM test library, based on the the R&S®TSrun test sequencer software, adds flexible test automation with powerful evaluation features in a simpler setup with fewer cables. In a combination with a signal conditioning unit, the R&S®ZVAX-TRM extension unit, all tests, including multiplexing, can be carried out without any reconnection.

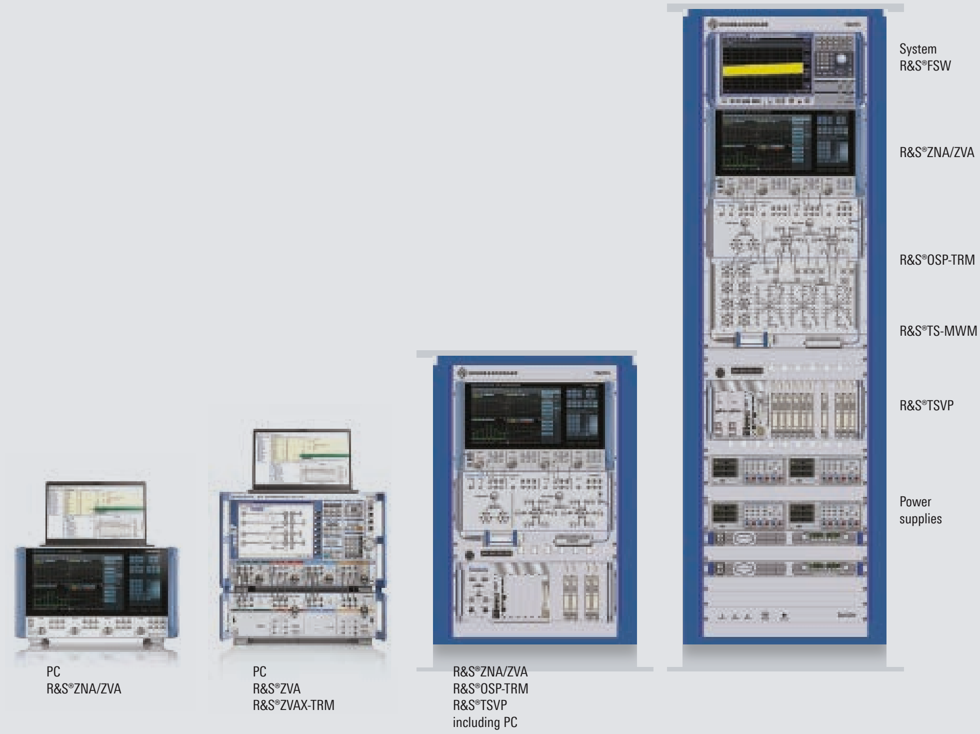
A special feature is the calibration routine in the the R&S®TS6 TRM test library. It collects all the calibration requirements from the test and runs an optimized calibration without any compromises in accuracy. The support of multiport calibration units enables the efficient calibration of devices under test (DUTs) with many ports. This combination of a simplified test setup with a high degree of automation ensures reliable and reproducible measurements by a scalable solution that always adapts to your requirements: from the manual testing of components, over complete module characterization in development to automated production testing.

Ideal for increasing your test throughput

Each AESA radar consists of a large number of TRMs. Each of them has to be tested and, depending on the application, individually calibrated over a large number of DUT states and frequencies. Here, time is of the essence, and Rohde & Schwarz offers testing of parallelly running systems during production. The R&S®TS6 TRM test library together with the R&S®TS6710 TRM radar test system are ideal solutions for this. Years of experience in TRM testing have helped us deliver the fastest possible speeds for TRM testing, as expected from test equipment from Rohde & Schwarz, in combination with a fast handover between measurement and device programming.

As an example, thanks to the fast frequency sweeps and the possibility of multiple measurements within one pulse, the number of required TRM state changes is reduced and the overall test time is minimized. With the R&S®ZVAX-TRM signal conditioning unit, all tests run automatically without interaction, including port multiplexing. A typical test time for a complete TRM characterization can be reduced from hours, required by the legacy TRM test systems, to only a few minutes.

Figure 1: Rohde & Schwarz solutions as a single setup for TRM testing



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Confidentiality and flexibility ensured with an open DUT interface

The parameters of TRM designs are radar specific and are considered confidential. Each TRM must be controlled by a specific interface, protocol and trigger for testing. The R&S®TS6 TRM test library has an open software interface for TRM control. The plugin can be programmed locally and can interface with any Rohde & Schwarz hardware. In combination with the wide range of test parameters, the whole test configuration can be carried out locally. This also allows faster on-site adaptations and optimizations. An efficient option for TRM control is the R&S®CompactTSVP test system versatile platform with flexible and fast control interfaces, plus digital and analog measurements. In this configuration, shorter test times are achieved in many setups without any field-programmable gate array (FPGA) programming.

Rohde & Schwarz offers:

- Scalable solution for TRM testing from development to production
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- Very short test times
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Follow our series of articles and webinars on latest test solutions for radar and EW testing. In November, in our next edition, we will be talking about radar design debugging. For more information, visit: **https://www.rohde-schwarz.com/aerospace-defense/AESA** they didn't think it was important, but because, over the last 25 years, the fight had been in CENTCOM, and EW was largely relegated to RCIED detection and insurgent suppression. It was clear that the revised doctrine needed to address big-picture topics such as the Air Force's reprogramming efforts as highlighted by the ECCT. Says Babcock, "It was clear that people just didn't understand it, and the current doctrine didn't explain it. We needed people to understand that when you're talking about the EMS Enterprise, you've got to be focused on the programming/and reprogramming of all of the systems."

"When we found ourselves now looking at a near-peer threat as per the new NDS directive," recalls Babcock, "it was clear that our focus on EW capabilities in the EMS were woefully inadequate across the DOD. We no longer had capabilities like Wild Weasels, the F-117, or backseat EWOs, as part of the fires in the Air Force. The pool of expertise was really only Compass Call, Rivet Joint, or machines on airplanes." To address this, Babcock says their first task was to get the Air Force to understand why the EMS is important – "to understand that our peer adversaries are heavily invested in these areas, and if we don't address this, we will be crushed."

Babcock recalls things came to fruition after the Combat Air Forces (CAF) Weapons and Tactics Conference (WEPTAC) of 2019, when as the ECCT lead, General Gaedecke briefed General Goldfein. As Babcock recalled, Gaedecke pointed to 15-20 years of studies showing that we were behind the power curve in the EMS, and he detailed how we will have to go after it in our planning, organizing, training and equipping. Here's how we need to do it, said Gaedecke, if we're going to be able to program and reprogram; to actually teach EMS theory and doctrine to our airmen from the youngest age, and execute all of these things.

AN EMS SUPERIORITY DIRECTORATE AND THE CFT FOR EMS DOMINANCE

The electromagnetic warfare doctrinal changes were followed in August of that year with the official formation of an Air Force Cross Functional Team (CFT) aimed at Electromagnetic Spectrum (EMS) Dominance. The groundwork for the EMS Dominance CFT had been lain during the CORONA South summit at MacDill AFB, FL, where top Air Force leaders, including General Goldfein, convened to discuss strategy and policy.

The EMS Dominance CFT was one of eleven CFTs established by the Air Force's AFWIC group and set up along the lines of the Army Futures Command's CFTs. The EMS Dominance CFT was tasked with "pursuing a holistic multi-domain approach to electronic warfare and EMS dominance, including a family of systems approach, to ensure access through the spectrum and deny that access to competitors."

Most importantly, however, also in August, the Air Force formally announced the creation of the Air Force Electromagnetic Spectrum Superiority Directorate (HAF/A5L) within the Air Force Headquarters Deputy Chief of Staff for Strategy, Integration and Requirements. As called for in the ECCT findings, the new Directorate would be responsible for gaining and maintaining EMS and electromagnetic warfare superiority, orchestrating enterprise-wide actions and unity of effort in developing and synchronizing multi-domain EMS operations doctrine, strategy, policy, requirements, capability development and Planning, Programming, Budgeting & Execution across all Air Force core functions. Coming full circle, in addition, the EMS Superiority Director would also be dual-hatted to lead the new EMS Dominance CFT in partnership with the Air Force Warfighting Integration Capability (AFWIC) office. General Gaedecke initially served in this role, but as of this June has handed the reins to Brig Gen Michael Manion.

Lt Col Jeff "Seed" Kassebaum is a Division Chief within A5L and also serves as Deputy Director of the EMS Dominance CFT. AFWIC is now within AF/CC under newly appointed Deputy Chief of Staff for Strategy, Integration and Requirements (AF/A5), Lt Gen Clinton Hinote. Newly reorganized and provisionally established as A57, the EMS Dominance CFT is directly headed by General Hinote. It includes three centers with the CFTs belonging to Center 2 (Capabilities). However, A57 is unique in that it is run by General Manion, who in addition as A5L Director also reports directly to General Hinote.

If this seems a bit confusing, well, it is. The Air Force now has an EMS Dominance CFT and an EMS Superiority Directorate. Both of them are led by the same people (General Hinote and General Manion), and staffed by some of the same personnel (such as Lieutenant Colonel Kassebaum). Both organizations share many of the same responsibilities and goals (EMS dominance/superiority). The good news is that the Air Force is in the process of bringing these two organizations together into one office.

As Kassebaum describes it, the entire roster of the EMS Dominance CFT includes about 70 people, however this number includes MAJCOM representatives who are not officially tasked as part of the CFT's work. Most of its efforts are conducted by a core team of about a dozen participants from the National Capital Region (NCR), as well as an AFRL member, that meet more frequently.

From his perspective Kassebaum doesn't believe the AFWIC sees the EMS Dominance CFT as ultimately compiling a formal all-encompassing report, but rather as a group continually focused on future force design and development planning, with targeted reports to help influence planning choices, budget decisions, and future design inside and outside of the Future Years Defense Plan (FYDP). "My personal view is that strategy documents and guidances should be a relatively small number of pages, and not spend a lot of pages just talking about what the Spectrum is," Kassebaum explains. "It should be concise and provide clear priorities focusing on the Air Force's problems-to-solve." He went on to say, "There really hasn't been a strategy out there, and we want to get that information and strategy out as we move from EW toward EMSO and realignment of force design. We want to focus on a coherent strategy that is useable."

With regard to the creation of the A5L organization, Kassebaum says, "It's a tremendous win to have a general-officer led Directorate focused on EMS Superiority. The role of Air Force HQ is to provide a strategic framework where the major commands can fit in their capability development strategies based on their requirements and gaps. Air Force HQ's job is to provide left and right bounds, provide prioritization, define lines of effort, and drive the effort forward with everyone all pulling in the same direction. Where major commands have conflicting requirements, we need to resolve those or align similar capabilities. We will be derivative from the DOD strategy, or at least not in conflict."

One area where Kassebaum expects the A5L to have significant impact is in helping the Air Force move away from hardware-centric and platform-dependent solutions and moving toward solutions that are software-defined and platform agnostic. "As we do more studies, we'll find out that if we can proliferate software-defined capabilities, we will be inherently more flexible and scaleable and will have many more options going forward," he says. "What we don't want to do is to only have a capability strategy that's dependent on 'matter' acquisition. The strategy must encompass both matter and energy, so if we can't buy enough missiles, we have to come up with some other creative solutions, and energy weapons help us do that. We will absolutely need more energy weapons, and this is where EA, and EM-delivered cyber come in. This has been an area of focus in our first year of stand-up."

Kassebaum notes that A5L did have an opportunity to comment on the DOD's upcoming EMS Superiority Strategy written by the EMSO CFT. "Primarily," he says, "we wanted to make sure there was an emphasis on EM attack. Older versions didn't talk about attacking in the spectrum, as opposed to just being able to use the spectrum. So, we put in more from the attack side."

A SPECTRUM WARFARE WING

Col William "Dollar" Young, former commander of the US Air Force's 53d EW Group (Eglin AFB, FL), is well known to the AOC and EW community at large. The 53d EW Group is part of the 53d Wing, and is responsible for providing operational, technical and maintenance electronic warfare expertise for the CAF and for systems engineering, testing, evaluation, tactics development, employment, capability and technology assessment. This includes the wartime responsibility for emergency reprogramming and dissemination of EW system mission data software for CAF aircraft. The group manages the COMBAT SHIELD Electronic Warfare Assessment Program for CAF aircraft EW systems. COMBAT SHIELD provides operational units a system-specific capability assessment for their radar warning receivers, electronic attack pods and integrated EW systems.

After transferring command of the 53d EWG to Col David Perez in July 2019, Colonel Young was tasked to plan for, develop, and implement the stand-up of a new Air Force Wing – The Spectrum Warfare Wing. As he describes it, "When ACC [Air Combat Command (ACC)] commander Gen James M. 'Mike' Holmes made the decision to pursue standing up a Spectrum Warfare Wing to satisfy the ECCT requirement, I was the guy that

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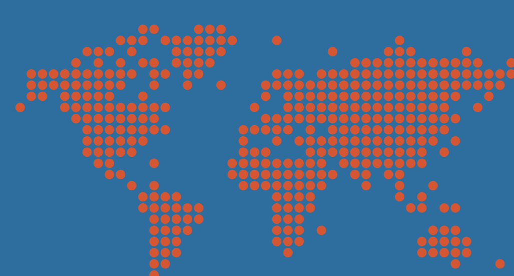

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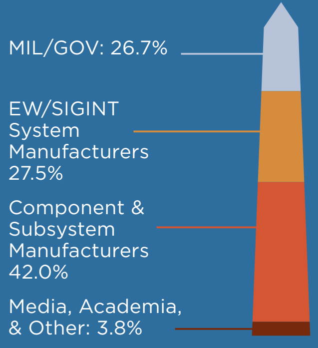
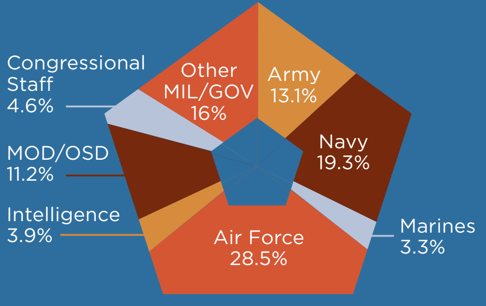
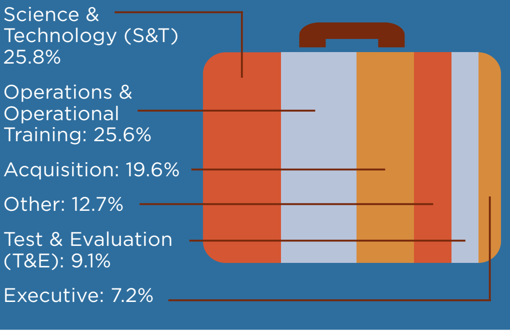


MIL/GOV Breakdown by Employer



MIL/GOV Breakdown by Job Function



ters for Disease Control and Prevention (CDC) and the World Health Organization (WHO). We are actively working precautionary measures to further reduce health risks at our events. The health and safety of our attendees, got tapped to figure out how to do it." Now, serving as the Special Assistant for Spectrum Warfare, Young describes his role as "project lead for pulling all of this together." The initial working group was very small, including only Young, ACC Deputy Director of Operations Ted Uchida, and General Gaedecke. "Over time, we've expanded the team from an exploratory group, bringing in people from the [Air] Warfare Center, from the bigger staff at ACC, other MAJCOMs, and the 53d Wing."

Colonel Young emphasizes that they didn't just launch into the task, but began with a strategic design. As has been made clear in the ECCT and subsequent work by A5L and the LeMay Center, programming and reprogramming are seen as a critical element of achieving and maintaining EMS dominance, and as observed by Young, "Given a tasking of consolidating and modernizing the EW programming enterprise, the strategic design was really an exploration of the problem space, and what that really meant. Once we had approval on that, we used it in the same way that an architect uses a blueprint to actually do the building that is going on now. What was really powerful about this is that one of the things that the Chief of Staff had talked about as one of his priorities was improving the ability of airmen to operate in a Joint environment. The strategic design then is actually a Joint Publication (JP) 5-0, Joint Planning doctrine, which lays out operational design of our problem planning environment. We focused not on organizational charts, we started with a deep dive into Air Force-wide reprogramming activities and into the broader task of achieving, gaining and maintaining EMS dominance. We focused on identifying and creating a sustainable competitive advantage and then how to scale that."

Although it may seem likely that the 53d EW Group will be incorporated in some fashion within the Spectrum Warfare Wing, no specific organizational arrangement and structure for the new Wing has yet been officially announced publicly. In fact, a decision to stand-up of the Wing, itself, has not been announced publicly either to date, although there has certainly been some unofficial public discussion of this possibly taking place with an Initial Operating Capability (IOC) sometime next Spring.

Colonel Young says there will "absolutely be a relationship between the new Wing, the A5L, LeMay Center, and AFWIC, as well as many other Air Force organizations. If you look at the capabilities that AFWIC is developing and envisioning for the future force design, a key portion of all of that will rely on the EMS. If you go back and take a look at the Chief's (Goldfein's) presentation at AFA last year, he presented a vignette of multi-domain operations as he was conceptualizing it at the time, and I like to point out that all the lightning bolts on his presentation slides and connecting all of those capabilities from ships to aircraft to satellites, were in fact the EMS. The organization that will make those lightning bolts real is the Spectrum Warfare Wing."

The ability to perform rapid reprogramming is crucial to achieving EMS superiority. As described by Young, "If we envision a world where everything is a software-defined radio (SDR) or a reprogrammable multi-function array, and then ask, 'where is the advantage there?' You immediately find that the advantage lies in the ability to produce the equivalent of applications (apps) that tie together all these different capabilities, because in order to be able to do this at mission-relevant timelines, you aren't going to be able to produce new hardware and you won't be able to change an operational flight program (OFP) for all these individual components. What you can do, however, is to introduce, or modify, what we call 'mission-ware' which for simplification sake can be thought of as apps for embedded systems. The mission-ware, or apps, being developed jointly with EW experts at the Air Force Research Laboratory (AFRL) and the Air Force Life Cycle Management Center (AFLMC), allow you to pose a challenge to your adversary based not on how an individual system and its capabilities currently exist, but by being to combine different capabilities from all of the different platforms – aircraft, ships, satellites, etc. – any way we choose via the EMS. The advantage is the ability to rapidly change and vary our approach by providing a wide array of apps and continuously updating those apps and combining them in different ways."

Young also points to the current situation where reprogramming centers are largely concentrating on data. "But," he says, "what we're talking about now and for the future with SDR is not just data. The data will still be important, but the ability to actually write software (mission-ware) that is somewhere in between this notion of apps to get new capabilities without changing the operating system or the hardware itself will be even more powerful. The functionality is still limited by the limitations of the hardware and the operating system, but there is still a whole bunch of things you can do to change different things with a new app, or changing the data on a new app. You can change that a lot faster than it takes to write a new operating system or build new hardware."

A BIG PICTURE VIEW

As observed by Colonel Young, one need only look at the number of new announcements coming out on a regular basis to see that the Air Force has put a significant emphasis on EMSO Dominance, and particularly on the promise of the Spectrum Warfare Wing. "Putting it in perspective, at a time when we have so many priorities, for our leadership to say, not only are we going to double down on our investment in the EMS, but add to that the power in the fact that the Air Force is not standing up an EW Wing, but a Spectrum Warfare Wing. Our leaders were very deliberate about sending that message. We're standing up a new organizational type that is fitted in its design from its very inception to compete and win in the 21st Century warfighting environment. It is inherently suited for multi-domain operations, because that's what it was born to do. It's totally different than taking a 20th Century organizational type and trying to update it. It's a particularly powerful message and goes to the faith that our senior leaders have in our ability to compete and win in this domain. It also speaks to their belief in our ability to generate an advantage in the EMS and then convert that advantage into competitive advantages across all the other domains."

TECHNOLOGY SURVEY

A SAMPLING OF EW AND SIGINT TUNERS

By Barry Manz

EW and SIGINT tuners are some of the most complex subsystems to design, and the challenge grows more daunting every year, driven by several factors. First, these subsystems must not only detect signals in the incredibly dense spectral environment from HF through 6 GHz but increasingly up to 50 or 60 GHz, as well. In addition, finding a target signal in this spectral soup has become daunting for SIGINT and EW systems, especially in airborne environments, where every nanosecond of additional response time can increase exposure to threats. Tuners must do this while achieving extremely high sensitivity, high spurious-free dynamic range, fast tuning speed and high performance in other critical metrics.

The DOD would ideally like to field EW and SIGINT systems that feature the fewest components and lowest power consumption, and that are packaged in the smallest footprint. Fortunately, tuner manufacturers are rising to this challenge. But the fact remains that covering 50 GHz of spectrum requires multiple tuners that cannot be accommodated in a tiny enclosure – at least not yet. The good news comes, as usual these days, in the form of digital technology that can replace and often eliminate functions traditionally performed in the analog domain.

In fact, as digital devices replace or eliminate analog functions in a receiver, the tuner has almost disappeared within the confines of the receiver in some designs, thanks in large measure to two major technological advances. The first to help this transformation was direct digital synthesis (DDS), whose benefits include fast switching between frequencies, fine frequency resolution and operation over a broad range of frequencies. DDS achieves this, ideally, without discontinuities, phase shifts and other artifacts, with its overall performance relying on its spur-free dynamic range, phase noise and jitter, as well as the performance of its converters. While DDS once required a considerable number of components, today it can be achieved in a small device that consumes little power.

Another, more recent, development is direct RF sampling, which also simplifies receiver design by dramatically reducing the number of analog components, which in turn results in a smaller footprint and higher efficiency. Its simplified architecture also removes potential sources of noise, images and other errors, such as LO leakage and quadrature impairments. For example, with the venerable heterodyne receiver architecture, the incoming signal is downconverted to a lower intermediate frequency where it is then digitized, filtered and demodulated. This typically requires an RF front end consisting of a bandpass filter, low-noise amplifier (LNA), mixer and local oscillator (LO).

In contrast, a direct RF sampling receiver consists of only the low-noise amplifier, filters and an analog-to-digital converter (ADC). There is no need for mixers and LOs as the ADC digitizes the analog RF signal directly off the air, after which the data stream is sent to an FPGA for processing. It's also possible to employ digital rather than analog filters, except for those required for anti-aliasing and reconstruction. In short, analog frequency conversion is not required, so the design is simpler, smaller and potentially less expensive.

Along with these benefits, however, come design challenges. Foremost among them is the fact that directly ingesting higher frequencies requires ADCs with higher sampling rates, so the performance of the entire tuner (or receiver) relies in large measure on advances in this single device. For example, the instantaneous bandwidth of the ADC is dictated by Nyquist sampling, in which the sampling rate is twice that of the highest frequency of the input signal. If that frequency is, say, 40 GHz, the sampling rate would need to be at least 80 Gsamples/sec, a formidable achievement.

The answer to whether this is currently achievable is available only for those with "a need to know," as such devices are either designed and fabricated by test equipment manufacturers for exclusive use in their own products or are available only to the DOD. However, it's safe to assume that the top-tier of ADCs have performance well beyond what is available on the Web.

Overall performance can also be realized by time-interleaving multiple (and identical) ADCs, which makes it possible to sample data at a higher rate than the sample rate of each converter. It can also be achieved by interleaving the two channels of a single ADC in which each channel has, for example, a sampling rate of 5.2 Gsamples/sec that would result in 10.4 Gsamples/sec per channel and an instantaneous bandwidth of 5.2 GHz.

Interleaving multiple ADCs can produce remarkable results, hints of which are sometimes revealed, perhaps inadvertently, such as instantaneous bandwidths of 100 GHz. That said, interleaving is difficult and poses significant design challenges, but when these are adequately addressed, the results can be spectacular.

Although DDS and direct RF sampling are essential technologies required to advance the tuner state-of-the-art, there are others as well, and collectively they will ensure that there will be no shortage of good problems for designers in the years to come.

EW & SIGINT TUNERS

MODEL	OPERATING FREQ	IF CENTER OUTPUT FREQ.	IF BANDWIDTH	NUMBER OF CONVERSION STAGES	TUNING TIME AND STEP SIZE	RF TO IF GAIN
Annapolis Micro Systems; Annapolis, MD, USA; +1 410-841-2514; www.AnnapMicro.com						
WWGM61 / WWGM62 / WWGM63	10 MHz - 6 GHz	10 MHz - 10 GHz	6 GHz	*	*	*
Atlanta Micro, Inc.; Peachtree Corners, GA, USA; +1 470-253-7640; www.atlantamicro.com						
AM9012	2 MHz - 6 GHz	60 MHz	80 MHz	3	100 µsec / 5 MHz (analog)	3 dB
AM9017	100 MHz - 18 GHz	1 GHz	500 MHz	2	100 µsec / 5 MHz (analog)	8 dB
Collins Aerospace; Richardson, TX, USA; +1 972-705-1438; www.rockwellcollins.com/ewsigint						
RC-8800 Microwave Tuner	0.5-20 GHz	*	*	*	*	*
CommsAudit; Cheltenham, UK; +44 (0)1242 253131; www.commsaudit.com						
CA7814	9 kHz - 32 MHz	Digital	Full-band (31.991 MHz)	*	1 msec typ. 1 Hz	Configurable
CA7852	20 MHz - 6 GHz	Digital	2x 100 MHz	*	1.5 msec typ. 1 Hz	Configurable
CA7878	6 - 40 GHz (43 GHz option in development)	Analog IF configurable	1.5 GHz	*	1.5 msec nom. (within 10 kHz) 2.5 Hz	*
CyberRadio Solutions; Mt. Airy, MD, USA; www.cyberradiosolutions.com						
NDR364 Wideband Digital Tuner	20 MHz - 6 GHz	Digital	125 MHz BW	2	100/1Hz	25 dB
NDR584 3U VPX Tuner	20 MHz - 18 GHz	1 GHz	500 MHz BW	2	50 msec/1MHz	25 dB
NDR378 6U VPX Tuner	2 MHz - 6 GHz	Digital	80 MHz BW	2	100/1Hz	25 DB
Digital Receiver Technology, Inc.; Germantown, MD, USA, +1 301-916-5554; www.drti.com						
RFT3A-40	20-3000 MHz	120 MHz	40 MHz	*	*	*
RFT4	20 MHz - 6.5 GHz	120 MHz	40 MHz	*	*	*
diminuSys; Irvine, CA, USA, +1 800-809-4230; www.diminusys.com						
P518B500	0.5-18 GHz	1000 or 1200 MHz	500 MHz	*	100 µsec, 1 Hz	-20 to +40 dB
P540B500	0.5-40 GHz	1000 or 1200 MHz	500 MHz	*	100 µsec, 1 Hz	-20 to +40 dB
Epiq Solutions; Rolling Meadows, IL, USA; +1 847-598-0218; www.epiqsolutions.com						
Sidekiq X4 VPX Blade	1 MHz - 6 GHz	Digital, I/Q output	Up to 400 MHz	1	*	0
Sidekiq X4 PCIe Blade	1 MHz - 6 GHz	Digital, I/Q output	Up to 400 MHz	1	*	0

DYNAMIC RANGE	NOISE FIGURE	BUS STRUCTURE	RECEIVER CHANNELS	POWER (W)	SIZE (HxWxL inches/cm)	FEATURES
52 dB	*	*	2 / 8 / 4	35.9W (typ); 60W (max)	3.98 x 3.22 x .46 in.	Integrated heatsink and EMI / crosstalk shields; commercial and industrial temperatures available.
80 dB	12 dB	SPI	1	4W	0.26 x 1.44 x 2.33 in. / 0.66 x 3.65 x 5.92 cm	PC mount mini-module.
75 dB	15 dB	SPI	1	3.7W	0.26 x 1.38 x 2.69 in. / 0.67 x 3.51 x 6.82 cm	PC mount mini-module.
*	*	*	4	*	6U, single slot	*
3rd order IIP +4dBm; 2nd order IIP +40dBm	10 dB max.	Control: 1 GbE; data: 10 GbE	1	40 W max.	4 x 15 x 26 cm	250 MSPS, 16 bit I/Q output in VITA 49 format; ultra low phase noise; high dynamic range.
3rd order IIP +15dBm; 2nd order IIP +40dBm	7-10 dB typ.	Control: 1 GbE; data: 10 GbE	2	70 W typ.	4 x 17 x 27 cm	Multiple tuners can be connected as phase coherent for DF applications; precision timestamps for TDOA applications
*	14-16 dB nom.	Control: 1 GbE	1	18.5 W	8 x 12 x 24 cm	When combined with a CA7852, the down-converter can provide 100 MHz of digital IBW with streaming I/Q data.
80 dB	14 dB	*	4	38W +11 to 15 VDC	5.7 (W) x 8.4 (D) x 1.6 (H) in.	Up to 512 DDC's/built-in GPS receiver.
72 dB	15 dB	*	4	40W, (10W per channel)	3U	Independent and phase coherent.
83 dB	15 dB	*	8	+12 VDC (P0) Power Input - 110	6U	Supports all 7 modes of operation.
85 dB	*	CPCI	2	30W max.	4 x 0.8 x 6.5 in.	Dual-channel, fast-tuning digital tuner covering 0.5-3000 MHz.
85 dB	*	CPCI	2	34W max.	4 x 0.8 x 6.5 in.	Dual-channel, fast-tuning digital tuner covering 0.5-6500 MHz.
87 dB, 1 MHz BW	14 dB	USB, Ethernet, Serial	1	85W	1.7 x 11.8 x 19 in., 1U	Synchronous auxiliary outputs at 900, 160 and 21.4 MHz; field replaceable input connectors.
82 dB, 1 MHz BW	17 dB	USB, Ethernet, Serial	1	98W	1.7 x 11.8 x 19 in., 1U	Synchronous auxiliary outputs at 900, 160 and 21.4 MHz; cooling inlets and outlets on back panel.
75-80 dB SFDR typical	8 dB typical noise figure	VPX, Ethernet	4	*	3U OpenVPX Compliant, 1 in. VITA 48.2, 6.3 x 4 x 1 in.	Multi-card sync to support channel coherency across cards; Kintex UltraScale XCKU115 FPGA; Zynq UltraScale+ ZU7EV MPSoC.
75-80 dB SFDR typical	8 dB typical noise figure	PCIe	4	*	Half length PCIe, 6.6 x 4.25 in.	Kintex UltraScale XCKU060 or XCKU115 FPGA.

EW & SIGINT TUNERS

MODEL	OPERATING FREQ	IF CENTER OUTPUT FREQ.	IF BANDWIDTH	NUMBER OF CONVERSION STAGES	TUNING TIME AND STEP SIZE	RF TO IF GAIN
Epiq Solutions; Rolling Meadows, IL, USA; +1 847-598-0218; www.epiqsolutions.com *cont'd.*						
Sidekiq Stretch	45 MHz - 6 GHz	Digital, I/Q output	Up to 56 MHz	1	*	0
FEI-Elcom Tech, Inc.; Northvale, NJ, USA; +1 201-767-8030 ext 271; www.fei-elcomtech.com						
SIR-4000 digital receiver	0.5-18, 0.5-26.6, 0.5-40 GHz	1, 1.85 GHz, 160, 140, 70 MHz, tunable	1 GHz, 500, 200, 100, 50, 5, 1 MHz, 100, 50, 20, 10 KHz	2	< 1 msec	30 dB RF, 90 dB digital
DCMCHNL-6500	.5-18, 6-18, 0.5-26, 6-40 GHz	1, 1.85 GHz, 160, 140, 70 MHz, tunable	1 GHz, 500, 200, 100, 50, 5, 1 MHz	2	< 50 micro second	30 dB
VPXST-6500	2-18, 6-18, 2-26, 6-40 GHz	1, 1.85, 2.8 GHz, other optional	1, 2 GHz	2	< 1 micro second	30 dB
GEW Technologies (Hensoldt South Africa); Silverton, South Africa; +27 421-6200, www.gew.co.za						
GEW® GRX6000 WB HF Receiver	8.3 kHz - 30 MHz	Digital	2.5, 5, 10, 30 MHz	Direct	1 Hz	-40 to +35 dB
GEW® GRX7 Compact HF/VHF/UHF/SHF Receiver	8.3 kHz - 6 GHz	Digital	1, 2, 5, 10, 20 MHz	*	570 us, 1 Hz	-30 to +20 dB
GEW® MRR8001C WB HF/VHF/UHF Receiver	500 kHz - 3.6 GHz	153.6 MHz	1, 2, 5, 10, 20, 40, 80 MHz	2	150 us, 1 Hz	-30 to +40 dB
iRF Solutions Inc.; Sparks, MD, USA; +1 443-595-8500; www.irf-solutions.com						
iWR-6800	0.5-26.5 GHz	1 GHz, 160 MHz	500 MHz, 100 MHz	Multiple	< 300 μsec, 1 kHz	+20 dB ± 1dB
iWR-6500	0.5-44 GHz	1 GHz, 160 MHz	500 MHz, 100 MHz	Multiple	< 300 μsec, 1 kHz	+20 dB ± 1dB
iCC-1000 (BLND)	3.4-24.2 GHz	950-1950 MHz	1 GHz	Single	Block down converter	10 dB nom.
Leonardo DRS; Germantown, MD, USA; +1 301-948-7550; www.leonardodrs.com						
Polaris VHF/UHF Multichannel Wideband Tuner	2 MHz - 6.2 GHz	70 MHz	40 MHz analog, 85 MHz digital	*	300 μsec, 1 MHz	16 dB min., 26 dB max.
Harrier Fullband Multichannel HF Digital Tuner	500 kHz - 30 MHz	Digital	30 MHz, DDCs 10 Hz - 10 MHz	*	100 μsec, 1 Hz	*
Talon VHFUHF 4 channel tuner	20 MHz - 6 GHz with 2-20 MHz bypass	Digital	40, 25, 10 & 3 MHz	*	50 usec, 1 MHz	24 dB
Mercury Systems; Andover, MA, USA; www.mrcy.com; +1 978-967-1401						
RFM3202	2-18 GHz	4.5 GHz	2 GHz	Dual conversion superhet	25 μsec typi. (to within 10 kHz)	25 dB
RFM3111	6-18 GHz	1.875 GHz	1 GHz	Dual conversion superhet	25 μsec typ. (to within 10 kHz)	25 dB

DYNAMIC RANGE	NOISE FIGURE	BUS STRUCTURE	RECEIVER CHANNELS	POWER (W)	SIZE (HxWxL inches/cm)	FEATURES
60 dB SFDR typical	< 8 dB typical noise figure	PCIe	1	*	22 x 80 x 4.5 mm, compatible to NVMe® SSD host socket	PCIe M.2 2280 key B or M socket (commonly used for NVMe® SSD). Pre-select receive filtering.
91 dB, 1 MHz BW	14 dB typical	*	1	150W	19 in. rack mount 2U	Low cost; low SWAP to operate in harsh environments.
93 dB,1 MHz BW	14 dB typical	*	4	100W	19 in. rack mount 1U	Supports both independent and phase coherent operation and conduction cooled environments.
93 dB, 1 MHz BW	14 dB typical	*	4	< 40W	6U VPX	500 MHz digitized BW over 10GbE, FPGA DSP resources.
≥ 80 dB	≤ 9 dB typ	1 x 1 GbE, 1 x 10 GbE Optical	Up to 4 independent full HF channels	90W (model dependent)	19 in. 2U x 450 mm depth	Streaming capability of entire HF band (30 MHz).
≥ 70 dB	≤ 12 dB typ	1 x GbE, 1 x USB2.0, 1 x USB3.0	Single channel HF/VHF/UHF/SHF	25W	107 x 40 x 198 mm	Compact and lightweight up to 6 GHz performance.
≥ 75 dB	≤ 10 dB typ	3 x 1 GbE, 1 x 10 GbE Optical	Up to 32 DDC channels	250W max.	19 in. 2U x 450 mm depth	Instantaneous bandwidth up to 80 MHz with up to 32 digital demodulators (system dependent).
Single Tone SFDR: > 55 dB	13 dB typ	VPX	1	< 30W	3U VPX, 1 in. Pitch	*
Single Tone SFDR: > 55 dB	13 dB typ	Brick	1	< 50W	1.6 (H) x 5.5 (W) x 10 (D) in.	Optional integrated ADC w/ user FPGA.
Internally Generated Spurious < -80 dBm	≤ 19 dB	Modules	2	< 10W	3.2 (H) x 5.5 (W) x 10 (D) in. enclosure	IF Outputs: Analog & RF over fiber, RF over fiber: +5dBm, 1310 nm, LC/APC.
SFDR = 74 dB with two tones @ -35 dBm input	13 dB; 6 dB with LNA on	RS-232, USB 2.0, 10/100 Base T, 10 Gig E SFP+	1-5	5W per analog channel	3 x 2.5 x 5 in.	Supports flexible digital down-converters with a range of bandwidths.
Instantaneous Dynamic Range > 130 dB at 1 KHz BW; SFDR > 105 dB @ -20 dBm two-tone input	< 12 dB at max. gain	Control: 1 Gb RJ-45 Ethernet; data out: 10 Gb SFP+ Ethernet	2 or 4 channels with up to 64 DDCs	< 100W	1U half rack; 1.75 x 8.5 x 22 in.	Exceptionally high dynamic range, very low phase noise, phase coherent; compact and low power.
SFDR = 82 dB with two tones at -31 dBm input	12 dB typical	VRT encoded over 10 Gigibit Ethernet	2-4 plus 8 DDC channels	100W	1U half rack; 1.75 x 8.5 x 22 in.	Four independent or phase coherent RF channels, selectable IF BW and ultra-low phase noise.
90 dB (with 1 MHz BW)	15 dB (Rx typical)/ 25 dB (Tx typical)	SOSA-aligned	2Rx/2Tx	120-140W	3U OpenVPX	2GHz instantaneous bandwidth; wideband design with excellent phase noise and high-dynamic range.
91 dB (with 1 MHz BW)	14dB (Rx typical)/24dB (Tx typical)	SOSA-aligned	1Rx/1Tx	44-55W	3U OpenVPX	1 GHz IBW to maximize spectral density; rugged, compact, and open-systems compliant.

EW & SIGINT TUNERS

MODEL	OPERATING FREQ	IF CENTER OUTPUT FREQ.	IF BANDWIDTH	NUMBER OF CONVERSION STAGES	TUNING TIME AND STEP SIZE	RF TO IF GAIN
Mercury Systems; Andover, MA, USA; www.mrcy.com; +1 978-967-1401 ***cont'd.***						
TAC-3290	0.5-26.5, 0.5-44 GHz	Tunable, 0.5-4.5 GHz	Selectable; 500, 1000 & 2000 MHz	Superhet	200 µsec, typ.	30 dB
Midwest Microwave Solutions Inc.; Hiawatha, Iowa, USA; +1 319-393-4055; www.mms-rf.com						
UWBT-218G-D	2-18 GHz	3 GHz	1.5 GHz	2	300 µsec typ	40 dB
WRX-626G-D	6-26 GHz	Digital	500 MHz	2	300 µsec typ	60 dB
TN-26GLX-D	30 MHz - 26 GHz	140/150 MHz	Selectable 20-80 MHz	2	200 µsec typ	60 dB
Norden Millimeter Inc.; Placerville, CA, USA; +1 530-719-4704; www.NordenGroup.com						
NUDC2-18_1.3-2.3	2-18 GHz	1.8 GHz	1 GHz	2	20 µsec/ 100 MHz	40 dB
NDC0218I0203N10	2-18 GHz	1.875 GHz	1 GHz	2	External LO	25 dB
NDCR518I01N14	0.5-18 GHz	1 GHz	500 MHz	2	External LO	10 dB
NuWaves Engineering; Middletown, OH, USA; +1 513-360-0800; www.nuwaves.com						
HiPerTuner	200 MHz - 2.5 GHz	200 MHz - 2.5 GHz	4-8%	*	50 msec, 1-MHz step size	200-500 MHz, 28 dB min.; 1800-2500 MHz, 21 dB min.
PLATH GmbH; Hamburg, Germany; +49-(0)-40-23-73-40; www.plath.de						
SIR 5110	0.5-30 MHz	*	Coherent 12.288 MHz (digital in 16 subbands)	Direct sampling of entire range	*	*
SIR 5115	0.5-30 MHz	*	Coherent 29.5 MHz (digital in 40 subbands)	Direct sampling of entire range	*	*
SIR 2115	9 kHz - 6000 MHz	*	80 MHz (V/UHF) 30 MHz (HF)	2 - superhet (V/UHF), direct sampling (HF)	≥ 800 µsec	*
R. A. Wood Associates; Frankfort, NY, USA; +1 315-735-4217; www.rawood.com						
RCT0017 WB Tuner/ Quad Converter	2-18 GHz	745 MHz (x4)	555-935 MHz (x4)	*	< 3 µsec, 375 MHz	10 dB typ.
RCT0040 Four-Channel Tuner Module	1-18 GHz	160 MHz (x4)	80 MHz (x4)	*	< 1 µsec, 1-MHz step size	15 dB
Rohde & Schwarz GmbH & Co.KG; Munich, Bavaria, Germany; +49-89-4129-0; www.rohde-schwarz.com						
R&S®EM200	8 kHz - 8 GHz	Digital	40 MHz	3	≤ 1 ms, 1 Hz	*

DYNAMIC RANGE	NOISE FIGURE	BUS STRUCTURE	RECEIVER CHANNELS	POWER (W)	SIZE (HxWxL inches/cm)	FEATURES
> 80 dB (1 MHz BW)	14 dB, typ	Ethernet, Serial	1 Rx, 2 Rx	~35W (dual channel version)	10 x 7 x 1.5 in.	Single- or dual-channel in SFF chassis; multiple, selectable BWs; tunable IF.
> 90 dB, 1 MHz	14 dB	10/100 Ethernet RS-422 Option	2	20W	5.5 x 4.5 x 1.2 in.	Multi-channel options available; ultra-miniature package, VPX versions.
> 90 dB, 1 MHz	14 dB	1Gige control 40Gb Data	2	36W	6.9 x 4.1 x 1.3 in.	500 MHz digitized BW per channel, DDC options.
> 90 dB, 1 MHz	14 dB	10/100 Ethernet RS-422 Option	2	16W	7 x 4.0 x 1.7 in.	Low SWAP, independent/coherent.
90 dB	6 dB	Serial	1	30W	3U VPX, 1 in. pitch	Available in dual down converter configurations. Multiple units can be configured for independent or coherent operation.
90 dB	10 dB	Serial	1	18W	.69 x 4.26 x 6.03 in.	Hermetic case. Operating Temp -40 to +85 °C.
85 dB	14 dB	Parallel	1	13W	.7 x 5.5 x 5.7 in.	Receivers can be matched in phase and amplitude.
*	5-7 dB typ.	RS-232	1	1.8W	0.75 x 4 x 6.5 in.	45 dB of gain control in 1 dB steps; sleep mode, processor control with clock dithering.
105 dB	≤ 12 dB	*	Up to 120 DDC channels	≤ 150 VA	1U x 19 in.	7 high- and 7 low-pass preselection filters (sub-octave), multiclient ready,
105 dB	≤ 12 dB	*	120 DDC channel (BB) optional: 600 DDC	≤ 400 VA	3U x 19 in.	35 high- and 35 low-pass preselection filters (sub-octave), 120 virtual narrowband monitoring receivers.
80 dB (V/UHF) 90 dB (HF)	~6 dB (0.02-1 GHz); < 9 dB (3-6 GHz)	*	1	≤ 200 VA	1U x 19 in.	10 high- and 10 low-pass preselection filters (sub-octave), SNMP, 20 integrated DDC channels.
95 dB linear	< 24 dB	VME	4	62W	6U VME, 2 slots	Ultra low phase noise @ 20MHz offset, built-in test detectors, internal and external PLL references.
91 dB linear	25.5 dB	VME	4	< 70w	6U VME, 2 slots	Built-in-test and phase-lock detectors, voltage and temperature monitoring, high input dynamic range.
90 dB	≤ 10 dB, typ. 8 dB	1 GB Eth; 10 GB (SFP+)	1 RF channel	18-20W	247 × 55 × 401 mm	Digitized IF output (up to 40 MHz) over 10 GB interface; high scan speed of 47 GHz/s.

EW & SIGINT TUNERS

MODEL	OPERATING FREQ	IF CENTER OUTPUT FREQ.	IF BANDWIDTH	NUMBER OF CONVERSION STAGES	TUNING TIME AND STEP SIZE	RF TO IF GAIN
Rohde & Schwarz GmbH & Co.KG; Munich, Bavaria, Germany; +49-89-4129-0; www.rohde-schwarz.com ***cont'd.***						
R&S®ESME	8 kHz - 18 GHz (40 GHz opt.)	Digital	80 MHz	3	≤ 1 ms, 1 Hz	*
R&S®WPU2000	8 kHz - 18 GHz (40 GHz opt.)	Digital	2000 MHz	3	≤ 1 ms, 1 Hz	*
Saab Sensor Systems Germany GmbH; Nuremberg, Germany; +49 911 47725 001; www.saab.com/de/region/deutschland/						
MFT-200-9	9 kHz - 30 MHz	Digital IF via 10G Ethernet	Up to 30 MHz	*	< 1 ms, 1 Hz	-30 dB to +35 dB
MFT-400-5	20 MHz - 8 GHz	Digital IF via 10G Ethernet	Up to 80 MHz	2	< 1 ms, 1 Hz	-30 dB to +35 dB
cMFT-682-10	9 kHz - 6 GHz	Digital IF via 10G Ethernet	Up to 80 MHz	2	< 1 ms, 1 Hz	-30 dB to +35 dB
Silver Palm Technologies; Ijamsville, MD, USA; +1 301-874-0065; www.silverpalmtech.com						
SP-8318 V/UHF Tuner	2-8000 MHz	187.5 MHz; alternate w/ ThunderBolt 3 Digital IF	Selectable 100-MHz and 40-MHz filters	superhet converter	< 500 µsec, 1-MHz steps	25 dB
SP-8344 Quad VPX Tuner	20-6000 MHz	Digital I&Q	Up to 40 MHz	superhet converter	20 msec, 1-kHz steps; NCO tuning 1 Hz	25 dB nom. to ADC
SP-8444 Microwave Tuner	0.1-18 GHz	1 GHz	500 MHz	superhet converter	< 100 µsec	20 dB nom.
Spectranetix, Inc.; Santa Clara, CA, USA; +1 408-982-9057; www.spectranetix.com						
MX-101	70 MHz - 6 GHz	0 Hz I/Q output	Up to 56 MHz	*	< 5 mSec @ 1-Hz DDC step size	65-73 dB
SX-200	20 MHz - 6 GHz	128 MHz	40 MHz	*	0 settling time, due to dual tuning oscillators @ 1-Hz DDC step size	32 dB
Systems & Processes Engineering Corporation (SPEC); Austin, TX, USA; www.spec.com						
ADEP™ T9000 Series	100 MHz - 20 GHz	Digital	1 GHz	2	250 nS, 1 Hz steps	10-40 dB
TELEMUS Inc; Ottawa, Ontario, Canada; +1-613-592-2288; www.TelemusInc.com						
FASTR EAGLE 1U Tuner	375 MHz - 18 GHz	4 GHz, 1 GHz, 160 MHz	Analog Filters, 1000, 500, 250, 100 and 100, 50, 25, 10 MHz	2 Stages, 3 stages to 160 MHz	< 50 µsec, < 10 Hz	Through Path 4 dB, LNA Path 38 dB

DYNAMIC RANGE	NOISE FIGURE	BUS STRUCTURE	RECEIVER CHANNELS	POWER (W)	SIZE (HxWxL inches/cm)	FEATURES
120 dB	≤ 10 dB, typ. 7 dB	1 GB Eth; 10 GB (SFP+); 40 GB (QSFP+)	1 RF channel, up to 128 DDC channels	200-290W	426 x 176 x 450 mm (4HU, 19 in.)	Up to 128 integrated DDCs, digitized IF output (up to 80 MHz) over 10 GB / 40 GB interface, high scan speed of 110 GHz/s.
110 dB	≤ 12 dB	1 GB Eth, 40 GB (QSFP+)	1 RF channel, up to 8 DDC channels	250-400W	426 x 176 x 450 mm (4HU, 19 in.)	Superhet tuner, IF digitizer, digital channelizer and pulse analyzer in one device; upcoming bus structure: 100GB (QSFP28).
SFDR > 90 dB	< 10 dB typ.	S3G proprietary, TCP/IP and UDP based (Ethernet)	9 HF channels w/ up to 30 MHz BW each	300W	4U x 19 in. x 490 mm	Digital direct sampling receiver for SDR incl. digital IF output (full IF bandwidth for all channels).
SFDR > 75 dB	< 13 dB typ.	S3G proprietary, TCP/IP and UDP based (Ethernet)	5 VUSHF channels w/ up to 80 MHz BW each	490W	7U x 19 in. x 490 mm	All channels controlable independently (multifunctional), pre-selector per channel included.
SFDR > 75 dB	< 8 dB typ.	S3G proprietary, TCP/IP and UDP based (Ethernet)	2 HF channels w/ up to 30 MHz BW each and 8 VUSHF channels with up to 80 MHz BW each	390W	4U x 19 in. x 290 mm	Usable phase-coherent for full parallel DF.
80 dB	12-15 dB	RS-232 control, alternate w/ ThunderBolt 3	1	< 7W	3 x 4.5 x .6 in.	Phase coherent N channel synchronization, HF bypass for direct digitization of RF input.
80 dB	12-15 dB	Packetized VITA-49 standard over Aurora lanes, 10GBASE-KR or PCIe on VPX backplane (SOSA & MORA aligned)	4	< 45W	3U VPX - VITA 48.2 (6.3 x 4 x 1 in.)	Four highly integrated true Heterodyne tuners with a four channel IF digitizer. Kintex XC7K410T FPGA.
75 dB	15 dB	VPX 1Gig-E (SOSA & MORA aligned)	4	< 35W	3U VPX	High performance 4-channel microwave tuner with phase coherent or independent operation.
70 dB	< 8 dB	USB 3.0	2	2.8W	2.2 x 1.4 x 0.9 in.	Miniaturized SDR, with transceiver functions, deployable in manpacks, UAV's, embedded systems.
92 dB	< 7 dB	PXIe, VPX	1	10W	Dual 3U Slot	Conduction cooled, ruggedized construction for PXIe / VPX racks.
50 dB @ 1GHz BW	7.5 dB	VPX	Configurable	Depends on installed configuration	3U VPX, 3 slots per channel	Dynamic, intelligent, digital/RF configurability, rugged, low power, multi-mission control with adjustable IBW.
> 60 dB Instantaneous, > 90 dB Switched	LNA Path 5 dB, through path 13 dB	Ethernet; MLVDS, FAST BUS on VME backplane	1	55W	1.74 x 19.0 x 24.0 in. 1U 19 in. rack mount	Option 100 MHz-40 GHz; very low group delay variation, low phase noise, built-in IF DLVA with coax outpu.

EW & SIGINT TUNERS

MODEL	OPERATING FREQ	IF CENTER OUTPUT FREQ.	IF BANDWIDTH	NUMBER OF CONVERSION STAGES	TUNING TIME AND STEP SIZE	RF TO IF GAIN
TELEMUS Inc; Ottawa, Ontario, Canada; +1-613-592-2288; www.TelemusInc.com *cont'd.*						
FASTR EAGLE Quad Channel Tuner	375 MHz - 18 GHz	4 GHz, 1 GHz	Analog Filters, 1000, 500, 250, 100 MHz	2	< 50 µsec, < 10 Hz	Through Path 10 dB
thinkRF; Ottawa, ON, Canada; +1 613-369-5104 ext 2802; www.thinkrf.com						
D4000 RF Downconverter/Tuner	24-40 GHz	1.536 GHz	500 MHz	2	*	20 dB
R5550-427	9 kHz to 27 GHz	55 MHz or 1.2 GHz	Up to 160 MHz	3	< 3.5 ms; 100 MHz	Up to 30 dB
WiNRADiO Communications; Collingwood, Australia; +61 39417 3417; www.winradio.com						
WR-G528e "CHEETAH"	0.01-3000 MHz	70 MHz	22 MHz	2	5 ms typ. 1 MHz	30 dB typ.
WR-G536e "HUMMINGBIRD"	30-7200 MHz	70 MHz	16 MGz typ. 12 MHz min.	2	5 ms typ. 10 MHz	30 dB typ.

DYNAMIC RANGE	NOISE FIGURE	BUS STRUCTURE	RECEIVER CHANNELS	POWER (W)	SIZE (HxWxL inches/cm)	FEATURES
> 60 dB Instantaneous	13 dB max.	Ethernet; MLVDS, FAST BUS on VME backplane	4, with two selectable RF inputs per channel	86W	Five 6U single slot VME modules, 9.17 x 6.3 x 0.8 in. IEEE std. 1101.2	Option 100 MHz-40 GHz; airborne qualified, fits 5 slot 1/2 ATR VME, operates ambient -40 to +75° C.
115 dBc	< 12 dB typical	*	1	20W	7.6 x 7.6 x 1.6 in.; 193 x 193 x 41 mm	RF filter technology eliminates out-of-band signals and enables spurious mitigation; support for MATLAB and LabVIEW.
112 dBc	14 dB	*	1	20W	10.1 x 7.6 x 2.4 in.; 257 x 194 x 66 mm	Up to 160 MHz bandwidth; built-in preselect filtering; digital downconversion; digital or analog baseband output.
*	15 dB	USB	1	6W typ.	3.6 x 2.7 x 1.9 in.	Miniature wideband phase-coherent tuner front-end.
SFDR: 90 dB	Typ. better than 12 dB, 20 dB max. at 7200 MHz	USB	1	8.4W, 12VDC 700mA	92 (W) x 64 (L) x 19 (H) mm	Low phase noise -110dBc/Hz @ 10 kHz min @ 500 MHz. -100dBc/Hz @ 10 kHz max @ 6000 MHz.

SURVEY KEY – EW AND SIGINT TUNERS

MODEL
Product name or model number

OPERATING FREQUENCY
Indicated in MHz or GHz

IF CENTER OUTPUT FREQUENCY
Indicated in MHz or GHz

IF BANDWIDTH
Indicated in kHz or MHz
BW = bandwidth

CONVERSION STAGES
Superhet = superheterodyne

TUNING TIME AND STEP SIZE
Tuning time indicated in milliseconds, microseconds and nanoseconds; and step size indicated in kHz or MHz.

HENSOLDT PHOTO

RF TO IF GAIN
Indicated in dB or dBm

GAIN CONTROL
AGC = Automatic Gain Control
MGC = Manual Gain Control

DYNAMIC RANGE
Total dynamic range indicated in dB or dBm

NOISE FIGURE
Indicated in dB or dBm

BUS STRUCTURE
Indicates the type of bus structure (USB, VME, VPX, Ethernet, etc.) the tuner uses

RECEIVER CHANNELS
Number of receiver channels or RF paths per module

POWER
Power dissipated in Watts

SIZE
H x W x L in inches/cm

WEIGHT
Weight in lb/kg

FEATURES
Additional features
- BIT = Built-In Test
- COMINT = Communications Intelligence
- ELINT = Electronic Intelligence
- FPGA = Field Programmable Gate Array

OTHER ABBREVIATIONS USED
- opt = option/optional
- dep = dependent
- config = configuration
- wband = wideband
- nband = narrowband
- < = greater than
- > = less than
- min = minimum
- max = maximum
- deg = degree
- freq = frequency

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

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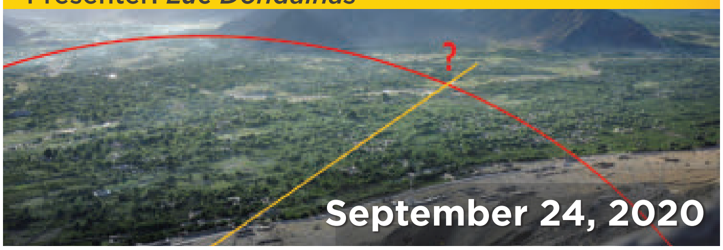
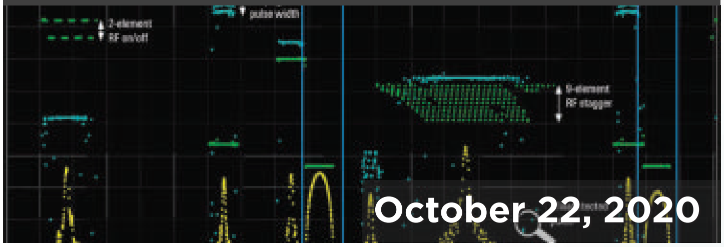


Specific Emitter Identification (SEI)
Presenter: Dr. Warren du Plessis

Introduction to Radar Pulse Deinterleaving
Presenter: Antonio Dias de Macedo Filho



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Presenter: John T. Tatum

An Overview of IADS (Integrated Air Defense Systems)
Presenter: *Dr. Clayton Stewart*

When Crows Break Codes
Presenter: Mr. John Kolm

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Presenter: Dr. Peter Pry

HF meets Big Data – Intercept in an era of HF Renaissance
Presenter: Dr. Ronald Meixner

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Space EW – Part 22

Down-Link Intercept

By Dave Adamy

This month, we will continue with part two of our discussion of the vulnerability of space links to intercepts by hostile ground-based receivers. We will significantly complicate this intercept problem by adding directional antennas, several more loss elements, signal modulation and receiver sensitivity. The math in this discussion gets a little involved, so this column will continue in next month's *JED*.

We will use the same satellite example we used last month: the vulnerable satellite is in a circular orbit 300 km above the Earth. Its sub-vehicle point is at 100° east longitude, and its latitude is 40° north. The satellite's ground control station is on the Earth at 103° east longitude, 44° north latitude. There is a hostile intercept site on the earth at 102° east longitude and 45° north latitude. The satellite down link has a 100-Watt transmitter at 2 GHz. Note that this is just a calculation number; it is not representative of any specific satellite or intercept site.

There are several diagrams in this discussion dealing with relative positions of the satellite and ground locations. Please be aware that the angles shown in these diagrams are not drawn to scale; they are spread out to allow labeling.We will give both the satellite down link and the hostile ground intercept station directional antennas. The transmitting antenna on the satellite is a 3-meter parabolic dish. The intercepting ground station has a 2-meter parabolic dish. First, we want to know the gain and 3-dB beamwidth of each of these antennas.

The antenna boresight gain of each antenna can be determined from the formula:

G = -42.2 + 20 log D + 20 log F

Where: *G* is the boresight gain in dBi,
D is the diameter of the antenna in meters, and
F is the operating frequency in MHz.

For the satellite antenna,
G = -42.2 + 20 log(3) + 20 log(2000)
G = -42.2 + 9.5 + 66 = 33.3 dB

For the ground antenna,
G = -42.2 + 20 log(2) + 20log(2000)
G = -42.2 + 6 + 66 = 29.8 dB

The 3-dB beamwidth of each antenna can be found from the formula:
α = Antilog [(86.8 – 20 log D – 20 log F) /20]

Where:
α is the 3 dB beam-width in degrees,
D is the diameter of the antenna in meters, and
F is the operating frequency in MHz.

For the satellite antenna,
α = Antilog [(86.8 – 20 log(3) – 20 log(2000)) / 20]
α = Antilog [(86.8 – 9.5 – 66) / 20] = 3.7°

For the ground control station antenna,
α = Antilog [(86.8 – 6 – 66) / 20] = 5.4°

ANGLES RELATIVE TO THE GROUND CONTROL STATION

From here, we will determine the look angles from the satellite to its ground control station. **Figure 1** shows a spherical triangle formed by the North Pole, the sub-vehicle point and the satellite's ground control station. The dimensions of the triangle are:

- *Angle A* (the difference in longitude between the satellite and the ground station) = 3°

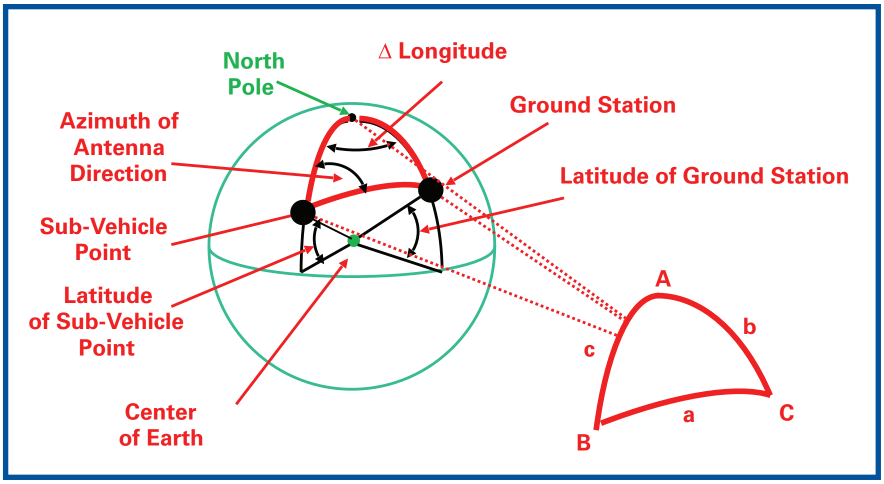

Fig 1: *The spherical triangle formed by the North pole, the sub-vehicle point and the ground station allows calculation of the satellite antenna azimuth to the ground station, and the geocentric angle between the satellite and the ground control station.*


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- *Angle B* is the azimuth from the satellite to the ground station
- *Side c* = 90° – the latitude of the sub-vehicle point = 50°
- *Side b* = 90° – the latitude of the ground station = 46°

The spherical law of cosines for sides can be written as:

Cos a = cos b x cos c + sin b x sin c x cos A

= cos(46°) x cos(50°) + sin(46°) x sin(50°) x cos(3°)

= (.695)(.643) + (.719)(.766)(.999)

= .997

Side a = arc cos(.997) = 4.44°

This is the geocentric angle between the sub-vehicle point and the ground station.

Note that the sine of this angle is .077.

The spherical law of cosines for sides can be reorganized to read:

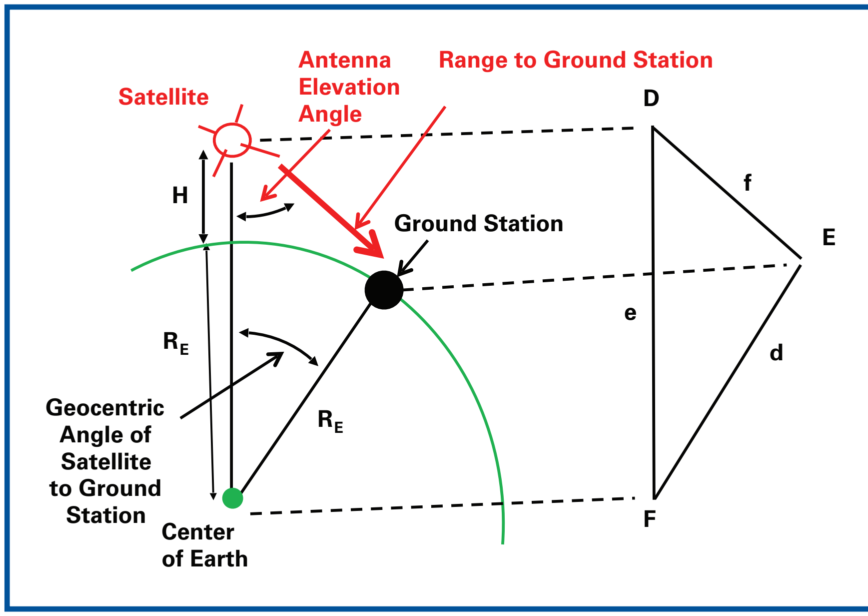

Fig 2: The elevation of the antenna (above nadir) and the range from the satellite to the ground station can be calculated from this plane triangle.

Cos B = (cos b – cos a x cos c) / (sin a x sin c)

= [(.695 – (.997)(.643)] / (.077)(.766) = .915

Angle B = arc cos(.915) = 23.79°

This is the azimuth to which the satellite antenna must be oriented to aim at the ground station.

Now we will determine the elevation of the ground control station from the satellite using **Figure 2**. This is a plane triangle with angles at the satellite, the ground control station and the center of the Earth.

- *Angle F* (the same as *angle a* in **Figure 1**) = 4.44°
- *Side e* (the radius of the Earth + the height of the satellite) = 6671 km
- *Side d* (the radius of the Earth) = 6371 km

The law of cosines for sides for plane triangles is:

Side $f^2 = e^2 + d^2$ – e d cos F

$= 6671^2 + 6371^2 - (6671)(6371)$ (cos 4.44°)

= 44,502,241 + 40,589,641 - 42,373,394

= 42,518,488 km^2

Side f (the square root of this number) = 6521 km. This is the link distance from the satellite to its ground control station.

Now we can use the law of sines for plane triangles to find *angle D*, the elevation of the ground station from the satellite. Remember that the elevation is the angle up from the center of the Earth.

Sin D = (d x sin F) / f

= [6371 km x sin(4.44°)] / 6521 km

= .0756

Angle D = arc sin(.0756) = 4.34°

This is the elevation of the ground station as seen from the satellite.

WHAT'S NEXT

Next month, we will finish the intercept discussion for a down link without any electronic protection measures. The following month, we will add important electronic protection measures. For your comments and suggestions, Dave Adamy can be reached at dave@lynxpub.com.

new
products

MMW AESA CAPABILITY

Cobham Advanced Electronic Solutions (CAES) has announced the development of a new millimeter-wave (mmW) active electronically scanned array (AESA) antenna system. Intended for electronic warfare (EW), radar, missile and unmanned aircraft systems (UAS) sensing, and comms applications, the AESA features a 256-element array (3.8 x 2.8 x 1-in.) comprising 64-element subarrays (1.9 x 1.3 in.) with 1W ERP per element. It operates within Ka-Band and W-Band frequencies at full- and half-power, offering solutions in frequency ranges atypical for AESA architectures. *Cobham Advanced Electronic Solutions (CAES); Arlington, VA, USA; +1 (703) 414-5300; www.cobhamaes.com.*

ANTI-JAMMING GNSS RECEIVER SYSTEM

Meteksan Defense has released its Anti-Jamming Global Navigation Satellite System (GNSS) receiver system for defense platforms, such as unmanned aerial vehicles (UAVs) and unmanned ground vehicles (UGVs). The GNSS receiver system includes a four-array CRPA antenna and a receiver subsystem that operates on GPS L1, GPS L2 and GLONASS L1 frequency bands. It is capable of resisting multiple jammer signals simultaneously and includes a built-in receiver, though it remains lightweight and compact for use on SWaP-limited unmanned systems. *Meteksan Defense Industry Inc.; Cankaya Bilkent-Ankara, Turkey; +90 312 266 15 20; www.meteksan.com.*

MULTI-CHANNEL SIGNAL GENERATOR

Berkeley Nucleonics has introduced the compact Model 855B Series Multi-Channel RF/Microwave Signal Generator, operating over two, four and eight channels depending on the specific model. With output power ranging from -80 dBm to 25 dBm and operating between 300 kHz and 40 GHz, the Model 855B Series is intended for radar simulation, quantum computing, EW systems and beamforming applications. *Berkeley Nucleonics Corporation; San Rafael, CA, USA; +1 (800) 234-7858; www.berkeleynucleonics.com.*

HAWAII AOC SAYS GOODBYE TO CHAPTER PRESIDENT

Chapter VP Dr. Arthur Tulak presents outgoing President Lt. Col. Jason Taylor with the AOC Achievement Award, recognizing his accomplishments as chapter president.

During a recent chapter meeting at the Sunset Lanai Camp Smith, the Diamond Head Chapter said goodbye to outgoing Chapter President Lt. Col. Jason Taylor. Taylor was recognized by both the Chapter and U.S. Indo-Pacific Command J39 for his leadership as the Hawaii AOC Diamond Head Chapter President and the Command Electronic Warfare Officer for USINDO-PACOM. Taylor served as chapter president from July 20, 2018 to July 3, 2020, and he was earned the AOC Achievement Award. Under his leadership, the Chapter successfully conducted the 2018 and 2019 Pacific Information Operations and Electronic Warfare Symposia. Each of these symposia broke past performance records in terms of ally and partner military participation, and the number of US military commands participating.

In addition, Lt. Col. Taylor ably led the chapter to play a major supporting role to the IO and EW communities in INDOPACOM. Since November 2019, Taylor led the planning for the 9th annual symposium, to be held October 20-23, 2020. During his tenure, the chapter's scholarship program continued to grow, and the presentation of scholarships is now a fixture of the annual symposium. In his professional duties, Lt. Col. Taylor led the first JEMSO Cell of any US Geographic Combatant Command, advancing the application of EW during great power competition. Throughout 2020, the Chapter has maintained a steady level of activity, even during the challenging times of the Corona Virus pandemic originating in Communist China.

During the meeting, the chapter also recognized members who have advanced the mission of professional education and development in the IO and EW fields. SGT Tony Serna was recognized for his paper, "Weaponizing History: The CCP's War of Words against Memory," presented at the 8th Annual IO & EW Symposium and published on the symposium webpage at www.fbcinc.com/e/aocpacific/agendarow2019.aspx. – *COL, Ret. Arthur N. Tulak, Ed.D.*

AOC PATRIOTS' ROOST CHAPTER AWARDS SCHOLARSHIP TO COMMUNITY COLLEGE OF THE AIR FORCE (CCAF) GRADUATE

Even during restrictions imposed during COVID-19, the Association of Old Crows continues to support its community. The Patriots' Roost Chapter, located in Burlington, MA, presented a scholarship to one of the graduates of the Community College of the Air Force (CCAF). TSgt Yaseni Benjamin was awarded a scholarship to help defray costs to continue her studies at the university level. TSgt Benjamin distinguished herself while working at the Hanscom Air Force Base Clinic during the peak of COVID-19. Chapter President Nino Amoroso and TSgt Benjamin followed appropriate safety procedures during the presentation. The CCAF Scholarship Program is one of the many scholarship and community programs of which the chapter is proud to support.

FORT WORTH AOC CHAPTER AWARDS 2020 STEM SCHOLARSHIPS TO GRADUATING SENIORS

The Fort Worth Chapter recently completed its 2020 STEM Scholarship campaign. The scholarship provides tuition funds for area graduating high school seniors who will be pursuing college degrees in STEM fields in the fall. This year, the Fort Worth and Abilene Chapters merged, expanding our region and enabling us to include Abilene school districts in the campaign. We had over 40 applicants, with 29 meeting all the requirements. The applicants were scored and ranked on academics, extra-curricular activities, community involvement, leadership roles and an essay.

The chapter was able to award a $1000 scholarship to each of the following five students for the fall 2020 semester at their school of choice.

- Jordan Chapin, Aledo High School – University of Nebraska, Mechanical Engineering
- London Kasper, Aledo High School – SMU, Computer Science
- Isabel Lopez, North Side High School – TCU, Mechanical Engineering
- Colin Means, Grapevine High School – Yale University, Bio-Medical Engineering
- Kaleb Reyna, Abilene TEMS High School – Abilene Christian University, Mechanical Engineering

The scholarship is funded by the proceeds raised during the annual Association of Old Crows Fort Worth Chapter Golf Scholarship Tournament. A virtual video award ceremony was held on July 24, 2020 with chapter officers, students and their families. Please join us in recognizing and congratulating these outstanding students.

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NGA - National Geospatial-Intelligence Agency
NLR - Royal Netherlands Aerospace Centre

GROUPS
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DRT, Inc.
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ELDES S.r.l.
Elettronica S.p.A
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EWS (EW Solutions Ltd)
Galleon Embedded Computing Norway
Georgia Tech Research Institute
GFB GmbH
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Intelligent RF Solutions
Interconnect Systems (a Molex company)
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ISPIN AG
ITA International, LLC
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Kihomac, Inc.
Kranze Technology Solutions, Inc. (KTS)
Kratos General Microwave Corporation
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Project Manager:
Tabitha Jenkins
Direct: +1 (352) 333-3468
tjenkins@naylor.com

Project Coordinator:
Amanda Glass
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Advertising Sales Representatives:
Shaun Greyling
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NAYLOR (Canada) Inc.
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