April 2019
Vol. 42, No. 4

ASSOCIATION OF OLD CROWS

JED

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The Journal of Electronic Defense

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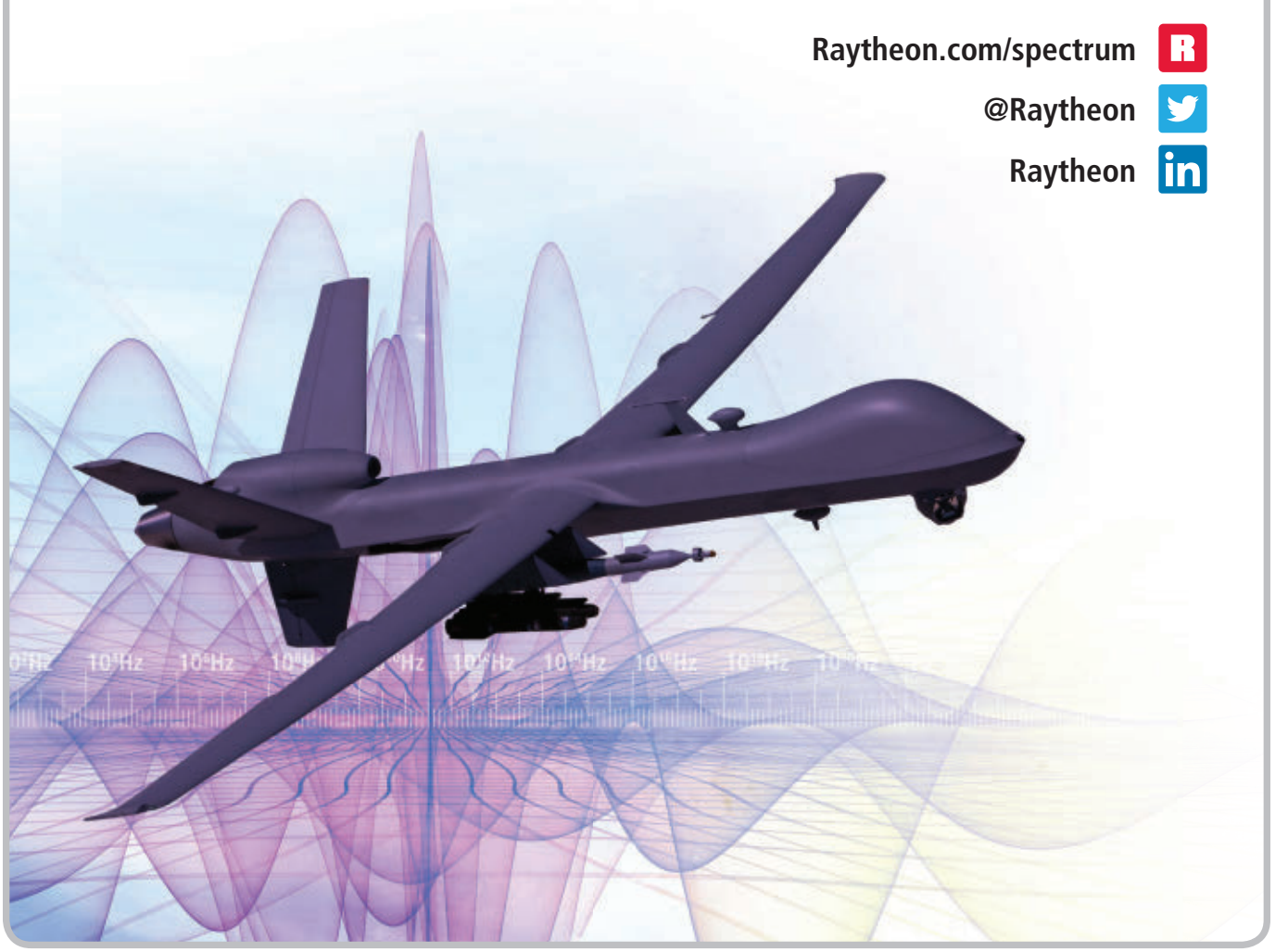

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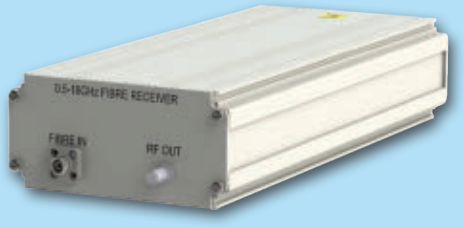

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F-35C Lightning II aircraft of the Argonauts of Strike Fighter Squadron (VFA) 147 at Naval Air Station Lemoore. The F-35C achieved initial operating capability (IOC) last month. US NAVY

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So far in 2019, the discussion about the Electromagnetic Domain has continued to ripple through the DOD. I confess that it's not what I anticipated. About this time last year, I expected the EW Executive Committee (EXCOM) to recognize the EM Domain and then to proceed in some deliberate way to begin linking together the DOD's Balkanized EW and spectrum management organizations that make up its EMS enterprise. That recognition didn't happen, and the EW EXCOM didn't provide a rationale for its decision. In the vacuum that has followed, the Services seem to be taking their own approaches to the EM Domain issue. The Navy was the first to weigh in, when it issued a rather indirect statement (a memorandum with an even more informative cover letter) stating that the EMS is a maneuver space *like* the other warfighting domains, and that it must be managed under an enterprise model. The Air Force, through the Electromagnetic Defense Task Force, has also started to address the EM Domain issue. The EW EXCOM continues to study the issue, as well.

To use an EW metaphor, it's become a somewhat noisy signal environment. There is more DOD-wide interest in an EM Domain than ever before. However, there is less clarity about what an EM Domain means or how an enterprise approach to the EM Domain will be fleshed out. One group is suggesting that key EW organizations should be moved under Cyber Command. Another group has suggested recognizing the EMS as a domain but placing EMS planning and funding under the Space Force.

These types of proposals show that the US EW community has a lot more educating to do across the DOD with regard to the EM Domain discussion. The good news is that DOD leaders are beginning to recognize that the EM Domain is strategically important to future operations. But their solutions, which are focused on finding a home for the EMS Enterprise – somewhere, anywhere – are not viable. Cyberspace and the Space Domain represent a very small portion of the operational responsibilities in the EM Domain. This would be like asking the Navy to manage the Air Force because some planes fly from aircraft carriers. Air power is far more complex than this, just as operational responsibilities within the EMS extend far beyond Space and Cyberspace.

In the midst of all these proposals, few leaders are recognizing that the best place for EW to flourish over the long term is to build its own home within an EMS Enterprise anchored within an EM Domain. This will enable the EW Community to continue meeting all of the DOD's EMS requirements no matter which weapons platform must be protected, which datalink must remain viable, or which enemy ballistic missile must be defeated. Instead of trying to wedge EW into a narrow lane where it will only be funded to meet the needs of space or cyber customers, how about creating a place where EW can serve every warfighter who needs it. – *J. Knowles*

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JED
The Journal of Electronic Defense

APRIL 2019 • VOL. 42, NO. 4

The Journal of Electronic Defense is published for the AOC by
NAYLOR ASSOCIATION SOLUTIONS
5950 NW 1st Place
Gainesville, FL 32607
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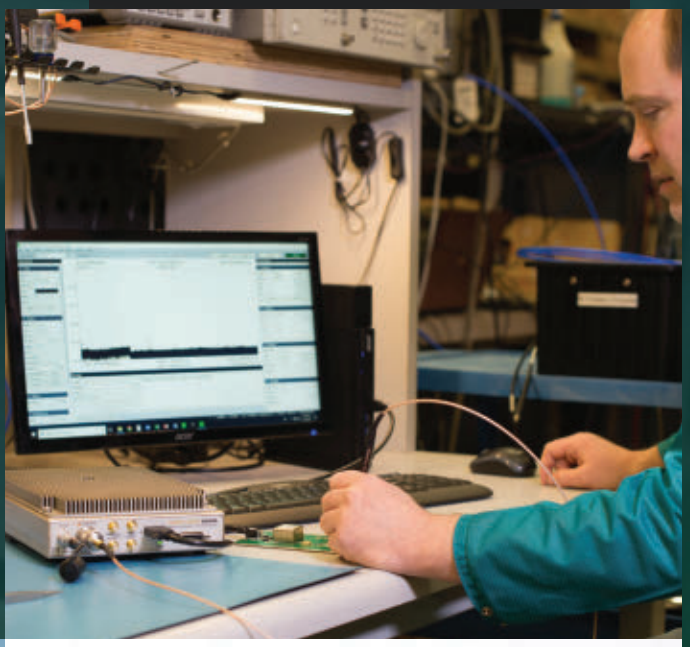

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USMC SIGINT Day
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Washington, DC
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Air University Electromagnetic Defense Task Force (EDTF) Summit
April 29-May 1
Maxwell AFB, AL
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MAY

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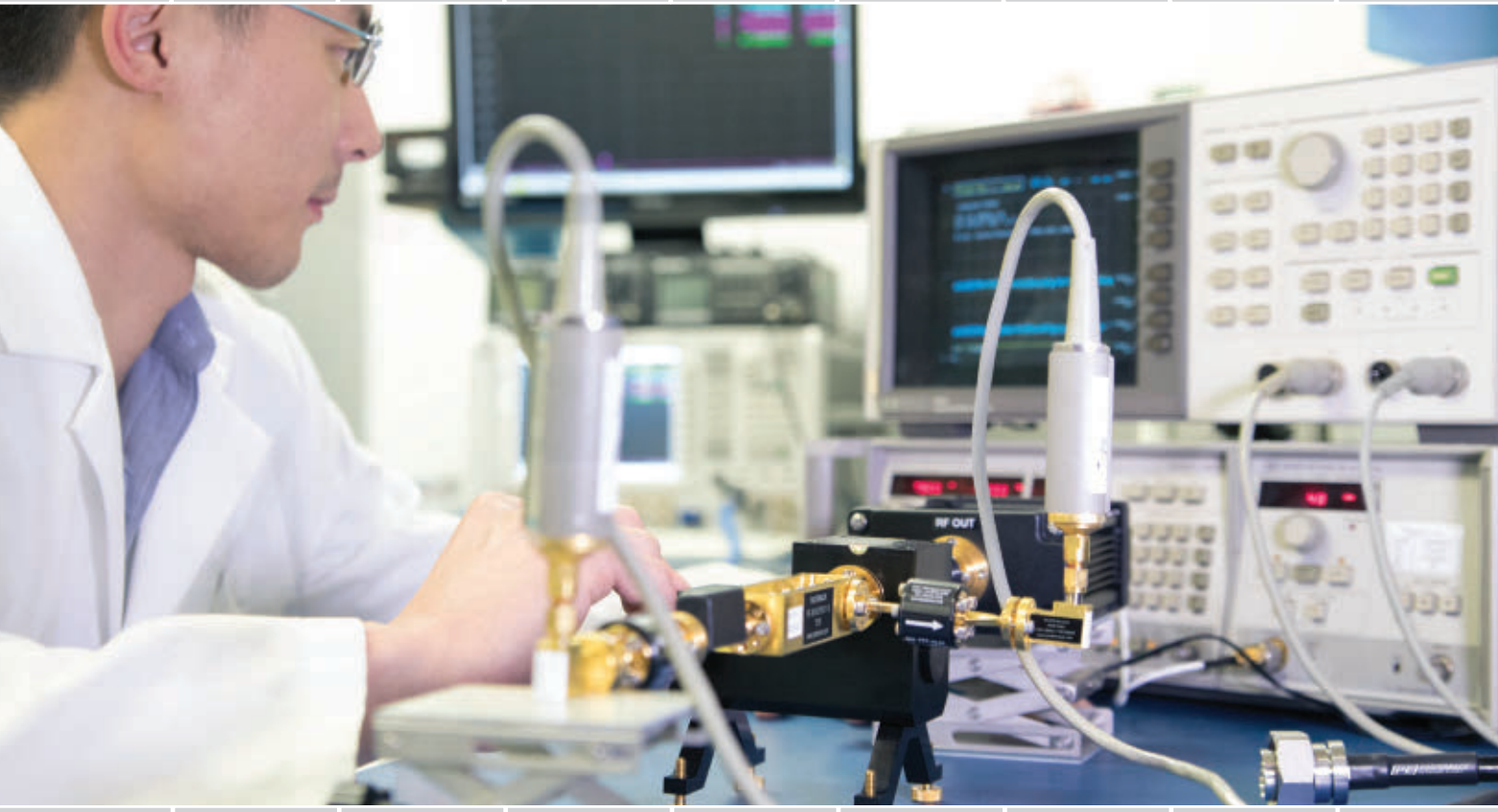

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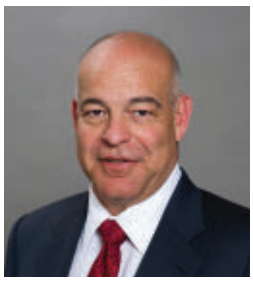

OUR COMMITTMENT

There was a time when the United States was the undisputed leader in electronic warfare (EW). We grew accustomed to relying on our EW superiority as part of our "kick-the-door-down" strategy, or even in the more subtle strategy of stabilizing our Indications and Warning tasks. However we entered a 20-year period of resting on our laurels, benign neglect, and paralysis through analysis. We've had way too many studies and not enough action in the Joint and DOD-wide EW portfolio. Lack of investment, lack of an appreciation of the value of EW, a sophisticated global response to our capabilities, and CONOPS by competitors fielding equal or even better systems. We are struggling to catch up, hold our position, and lagging in fielding the quantities and capabilities to counter a growing and evolving threat. You don't fight wars with R&D projects in the lab and continuous studying and analysis of the problem.

The Chairman of the JCS characterizes the threat as 4 + 1 (China, Russia, N. Korea and Iran plus others). Let's assess where the 4 + 1 major adversaries stand on EW:

1. **China:** China continues to make development and deployment of advanced EW systems a priority. China is extremely predatory and acquires EW jammers from any willing seller – from Ukraine to Russia to Iran to countries with advanced telecommunications technologies. China reportedly has the ability to jam common satellite communication bands and GPS signals at will. They can match our EW/EMS capability frequency by frequency.
2. **Russia:** Assessing Russia's invasion of Ukraine is an example of their capability. They used six different jamming and radio monitoring platforms in Ukraine, as well as HPM systems, and they are still morphing their advanced capabilities. Russia is using advanced EW/EMS capabilities in Syria, as well.
3. **North Korea:** North Korea has acquired and is actively using EW against US space systems today. They will continue to buy EW/EMS capabilities on the open market.
4. **Iran:** Iran has publicly acknowledged its ability to spoof GPS signals, and is well known for downing the US RQ-170 unmanned aerial system in 2011. Iran also imports EW systems from Russia.
5. **Other (The Plus 1):** Non-state actors continue to utilize and weaponize commercial technology (e.g., drones) in key conflict areas, such as Syria.

In summary, there is a growing global appreciation of the military value of controlling and dominating the Electromagnetic Spectrum. We have taken our EW/EMS capabilities for granted for too many years, and this has created unintended EW vulnerabilities and attendant EMSO consequences. We must now deal with an anti-access/area-denial situation that negates many of our former technology advantages embedded in our fourth- and fifth-generation systems. We can and must do better – immediately.

The AOC stands ready to support the US and its allies in reversing this situation and re-establishing the warfighting advantage that we need in order to decisively win anytime and anywhere. – *Muddy Watters*

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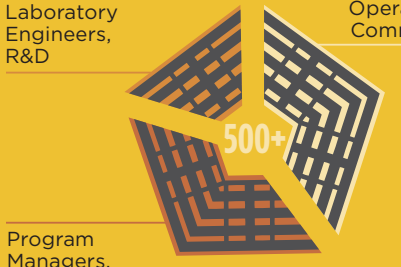

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DARPA TO DEVELOP SPECIALIZED HARDWARE FOR MACHINE LEARNING

The Defense Advanced Research Projects Agency (DARPA) is seeking submissions of innovative basic or applied research concepts under its Artificial Intelligence Exploration (AIE) program. Noting limitations on the DOD's access to low-latency artificial intelligence for analytics and real-time tactical response, DARPA's Photonic Edge AI Compact Hardware (PEACH) opportunity looks to development of specialized hardware for provision of real-time and low-latency predictive AI capabilities to platforms constrained by size, weight and power (SWAP) considerations.

PEACH seeks novel AI processing architectures with innovative optoelectronic hardware that can enable breakthrough AI functionalities with significant reductions in hardware complexity. The goal of PEACH is to explore how to scale AI complexity by at least 1,000 times, leading to at least 100 times combined improvement in processing latency and power consumption, targeting new AI engines that provide cluster-scale capability in a chip scale for DOD systems.

Citing recent improvements in temporal-based reservoir computing, which show the possibility to simplify the complexity of recurrent neural networks, and new photonic techniques that leverage multi-dimensional signal diversity to simplify AI processing and hardware, DARPA suggests that challenges associated with current state of the arm machine learning hardware can be overcome by use of a photonic or optoelectronic reservoir approach.

The program anticipates two phases, a feasibility study followed by a proof of concept option. Phase 1 efforts will cover architecture, algorithm, dataset and application development, including development of the machine learning architecture, reservoir algorithm, dataset and simulation to show the initial feasibility of the proposed application. The first phase also includes the hardware design study to develop a high level programmable hardware design to estimate the potential benefits of custom hardware, including an exploration of how the DOD could use the resulting PEACH hardware at the tactical edge for a DARPA-relevant mission. The total contract value is $1 million, and the planned cycle for the program is 18 months. – *E. Richardson*

DARPA SEEKS TO LEVERAGE QUANTUM SOLUTIONS FOR COMPLEX PROBLEMS

Last month, the Defense Advanced Research Projects Agency (DARPA) Defense Sciences Office (DSO) held a proposers day to outline the objectives for a coming Broad Agency Announcement (BAA) for the Optimization with Noisy Intermediate-Scale Quantum devices (ONISQ) program.

The main objective for the ONISQ program is to demonstrate the quantitative advantage of Quantum Information Processing (QIP) over the best classical methods for solving combinatorial optimization problems using Noisy Intermediate-Scale Quantum (NISQ) devices. In addition, the program seeks to identify families of problem instances in combinatorial optimization where QIP is likely to have the biggest impact.

Universal quantum computers with millions of quantum bits, or qubits – which can represent a one, a zero, or a coherent linear combination of one and zero – have the ability to revolutionize information processing for commercial and military applications. However, with that reality still years away, performance and reliability of quantum devices depend on the length of time the underlying quantum states can remain coherent, and the short coherence time makes it difficult to perform any meaningful computations.

To exploit quantum information processing before fully fault-tolerant quantum computers exist, the ONISQ program will pursue a hybrid concept that combines intermediate-sized quantum devices with classical systems to solve a particularly challenging set of problems. Solving combinatorial optimization problems, given the number of potential combinations, is of significant interest for military applications, including supply chain and logistics, though DARPA notes that ONISQ could also provide advancements for machine-learning, coding theory and electronic fabrication, among other areas.

A proposers day was held in March. The BAA was due out after press time. The point of contact is Dr. Tatjana Curcic, Program Manager, ONISQ@darpa.mil. – *E. Richardson*

USAF F-16 EW SUITE UPGRADE ADVANCES

Air Force Materiel Command (Rome, NY) has issued a project announcement as step two of a two part solicitation of project proposals for the US Air Force F-16 Electronic Warfare Suite Program Prototype. The program, renamed the USAF F-16 Detect Analyze Neutralize Threat Emission (DANTE) Viper Internal Electronic Warfare (VIEW) Program Prototype.

The USAF F-16 DANTE's VIEW Program Prototype aims to design, develop, test and produce a mature EW Suite system

prototype, internal to the F-16, with long-term growth capability to support future upgrades. The four-phase project calls for rapid development, demonstration and testing of multiple prototypes in a competitive environment.

The government plans to award two DANTE View Program Prototype Firm Fixed Price Project-level Agreements with an estimated face value of $25 million. Participation in the request for project proposals requires membership in the System of Systems Consortium (SOSSEC). The solicitation number is RIK-OTA-19-R-F16EW. The primary point of contact is Linda Sasser, lsasser@sossecinc.com, (603) 458-5529. The secondary point of contact is Mark Southcott, mark.southcott@us.af.mil, (315) 330-4590. Responses are due April 8. *– E. Richardson*

US AIR FORCE SEEKS NEXT-GENERATION AERIAL TARGETS

The US Air Force has issued a Request for Information (RFI) for new aerial targets that will be used to test future Air Force weapons systems. The RFI was issued by the Aerial Targets Program Office (AFLCMC/EBYA), which falls under the Air Force Program Executive Office for Weapons (AFPEO/WP) at Eglin AFB, FL.

The Next-Generation Aerial Targets Program aims to develop a suite of solutions that can replicate threat aircraft systems that emulate performance, signatures and countermeasures of enemy aircraft. The aim of the RFI is to "... determine the existence of sources that have the capability to design, integrate, build, test and manufacture an affordable suite of aerial target solutions and payloads (radio frequency or RF emitters, electronic attack or Electronic Attack (EA) capabilities and expendables such as chaff and flares) capable of providing adequate fidelity presentations of advanced adversary aircraft (Su-57, J-20 and FC-31) for specific test scenarios. The suite may comprise either clean-sheet designs, modifications to previously-developed capabilities or both. The suite may also comprise destructible and reusable aerial assets as well as manned and unmanned assets."

The RFI further states, "The 5th generation representative target suite should be able to provide – as a single target or as a combination of target presentations – a remotely-controlled, destructible asset with threat representative RF Emissions, EA Emissions, Radar Cross Section (RCS) signature, Infrared (IR) signature, and internally carried expendables. Destructible target solutions are expected to have a minimum service life of 10 flights, with a 30 flight hour lifetime average before being destroyed. Remotely-controlled targets must be capable of autonomous operation, either under remote control by a human operator, autonomously by onboard computers, or any combination of the two methods."

The program's goal is to develop an affordable suite of targets with a development cost of less than $300 million and a unit cost of less than $10 million. Among the desired capabilities are:

- A destructible target capable of carrying an internal 500-lb payload and external under-wing pods weighing up to 250 lb per wing;

- At least one target type that is capable of flying at altitudes from 500 ft to 50,000 ft; and
- At least one target type that travels at high-subsonic speed (up to 0.95 Mach).

The technical point of contact is Capt William Lowder, Program Manager, (850) 883-1328. The contracting point of contact is Arnette Robinson, (850) 883-3376, arnette.robinson.3@us.af.mil. – *J. Knowles*

DARPA SEEKS LESS ONEROUS M&S FOR CROSS-DOMAIN WARGAMING

The Defense Advanced Research Projects Agency (DARPA) has issued a Request for Information (RFI) to solicit industry input in support of its new Modeling and Simulation Integrated Environment (MSIE) Program.

The goal of the MSIE Program, which is being managed by the Agency's recently formed Adaptive Capabilities Office (ACO), is to "advance the state of the art in warfare M&S," according to the RFI. In describing the shortcomings of current M&S technology, it stated, "Modern warfare is becoming increasingly dependent on complex combinations of capabilities resident in all domains in order to achieve combined effects not possible from individual platforms or service domains. Developing adaptable systems to support these highly inter- related, cross-domain war fighting architectures requires much more capable M&S environments than currently exist."

Currently, modeling, simulation and analysis systems mostly rely on script-based programming to create scenarios, execute simulations and perform analysis. This requires a high level of knowledge and experience, and it is very time consuming. DARPA officials want to replace this process with M&S capabilities "…that will allow modelers to rapidly configure new scenarios, environments, situationally-adaptable kill webs, and variable fidelity composable models through novel, intuitive interface designs (such as drag- and-drop)." The RFI goes on to state, "The goal is to create an all-domain M&S environment that will run large-scale scenarios faster than real time and must allow modelers to rapidly and easily configure new scenarios, environments, architectures, communication structures that incorporate or decompose blue and red threat system models for all domains of interest, and will utilize a common interface that will allow ease of integration for models native to other architectures. The environment must be able to readily configure and conduct a wide range of analysis, including financial, survivability, lethality, and logistical analysis. Additionally, the environment will need a model repository, which will be an authoritative source of verified and validated models for use across the DoD, IC and defense contractor M&S communities. This model repository will drive the development of standardized blue and red model architectures with the intent that these architectures will be adopted for future use by DoD, IC, and defense contractor M&S communities."

A significant portion of the MSIE program will focus on M&S related to electromagnetic systems and effects,

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Vice Admiral Timothy "T.J." White - Commander, U.S. Fleet Cyber Command / U.S. TENTH Fleet *(invited)*

Mr. Michael Carlan, NRO

Mr. Kevin Coggins, BAH

Mr. Michael Ducharme, NRO

Dr. Ilya Lipkin, AFLCMC/ EN/SOSA

Mr. Daniel Lough, NRO

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network effects and cyber effects. The RFI states, "There are several existing M&S systems and environments that provide some, but not all of the capabilities of the desired environment. In the interest of speed and efficiency, the environment shall leverage aspects of the Joint Simulation Environment (JSE), Next Generation Threat System (NGTS), Advanced Framework for Simulation, Integration, and Modeling (AFSIM), One Semi-Automated Forces (OneSAF), and Integrated Threat Analysis Simulation Environment (ITASE). This list is not all inclusive and the desired environment shall have the capability of including additional simulation environments."

MSIE program officials are seeking RFI responses by March 29. Information can be e-mailed to Rich Tempalski, DARPA ACO, at DARPA-SN-19-42@darpa.mil. – *J. Knowles*

IN BRIEF

Northrop Grumman Innovation Systems (Northridge, CA) has received a $322.5 million, cost cost-plus-incentive-fee, sole-source contract from the Naval Air Systems Command (Patuxent River, MD) for the engineering and manufacturing development (EMD) of the AGM-88G, Advanced Anti-Radiation Guided Missile – Extended Range (AARGM-ER). The EMD effort includes the design, integration and test of a new solid rocket motor for the AARGM-ER for use on the F/A-18E/F, EA-18G and F-35A/C aircraft platforms. Work is expected to be complete in December 2023.

Raytheon (El Segundo, CA) has been awarded a $12.19 million cost-plus-fixed-fee, indefinite-delivery/indefinite-quantity contract from the Naval Air Warfare Center Weapons Division (Point Mugu, CA) for engineering and test support services for the ALQ-249 Next Generation Jammer (NGJ) Low-Band systems, currently in development for US Navy EA-18G aircraft. Work is expected to be complete in March 2024.

The Naval Surface Warfare Center (Crane, IN) has awarded **Irvin GQ** (Bridgend, UK) a $386,500 contract for spares, repairs, and engineering services in support of the MK 59 Mod 0 passive offboard decoy and launching system. The contract includes engineering services in support of recertifying 30 decoys. The MK 59 is the US Navy designation for the Outfit DLF 3b decoy system previously supplied by Irvin GQ to the UK Royal Navy. The Mk 59 system has been fitted on a number of US Navy warships since 2013 under a Chief of Naval Operations Speed-to-Fleet initiative.

EWA Government Systems (Herndon, VA) is receiving a $4.87 million cost-plus-fixed-fee, firm-fixed-price, cost-only contract from Naval Sea Systems Command (Washington, DC) for development and production of the Battle Force Electronic Warfare Trainer (BEWT)/Surface Electronic Warfare Team Trainer hardware and associated engineering services. If all options are exercised, the total value of the contract could increase to $33.67 million. Work is expected to be completed by February 2024.

Air Force Materiel Command (Robins AFB, GA) announced plans to award a sole source contract to General Microwave (Farmingdale, NY) for purchase of additional digitally tuned oscillators (DTOs) used on the ALQ-131 electronic countermeasures pod and the ALR-56 series (specifically the ALR-56C and the ALR-56M) radar warning receivers for F-16 and A-10 aircraft.

Leidos (Reston, VA) has received an $11.56 million cost-plus-fixed-fee contract from Naval Air Systems Command (Patuxent River, MD) for procurement of non-recurring engineering efforts to analyze, define and document system and subsystem requirements for capability enhancements to integrate the adaptive radar countermeasures program on the F/A-18. The project is expected to be complete by June 2020.

world report

IN FOCUS: AUSTRALIA

As the Government of Australia continues to push forward with modernization efforts, here is a summary of recent developments in the country's push to improve its defensive capabilities:

Last month, the government received approval for the purchase of AIM-120C-7 Advanced Medium-Range Air-to-Air Missiles (AMRAAM) and related equipment from the US via Foreign Military Sales (FMS) channels. The purchase, from Raytheon Missile Systems (Tucson, AZ) as the prime contractor, comes with an estimated cost of US$240.5 million and includes up to 108 AIM-120C-7 Advanced Medium-Range Air-to-Air Missiles (AMRAAM); six AIM-120C-7 AMRAAM Air Vehicles Instrumented; and six spare AIM-120C-7 AMRAAM guidance sections. The agreement also includes containers, weapon system support equipment, support and test equipment, spares and other support.

The AMRAAM upgrade supports Australia's acquisition of the National Advanced Surface to Air Missile System (NASAMS). Designed for homeland defense of critical assets, NASAMS is a distributed, networked mid-range defense solution used by the US, Norway, Finland, Spain, The Netherlands, Oman, Lithuania and Indonesia.

In late February, The Royal Australian Air Force (RAAF) unveiled a new large unmanned system platform that it had secretly developed with Boeing in Brisbane. The prototype UAV, which was nearly the size of a jet airplane, was designed for electronic warfare and reconnaissance missions, and could eventually be used to carry armaments. The system is the first to be designed and developed in Australia in more than 50 years, and it could, according to reports, be in production by the middle part of the next decade. In the meantime, as announced late last year, Australia will field the MQ-9 Reaper as its first armed, remote piloted aircraft system.

The RAAF's Hawk Mk.127 trainers have been upgraded to train pilots for fifth-gen fighters.

PHOTOSLEUTH

Meanwhile, last month, the country took a step closer in preparation of its pilots to take on F-35 aircraft. The Hawk Mk.127 aircraft completed upgrades via the Lead-In Fighter Capability Assurance Program (LIFCAP). The program, via BAE Systems Australia, in partnership with various units and industry partners, including CAE And Cubic Defense Applications, allows the Hawk to remain as a fighter trainer for new fast-jet pilots graduating from the RAAF's new training program in preparation for operational conversion to a fifth generation aircraft platform, i.e., the F-35A. The upgrade, which is similar to the Hawk T.2 currently in service with the Royal Air Force, includes simulated radar and EW systems, digital mapping, enhanced ground proximity warning and other improvements. The RAAF LIFCAP Hawks retain the original aircraft ability to deploy live weapons. – *E. Richardson*

IN BRIEF

- **Harris Corp.** (Clifton, NJ) has received a $43.27 million modification to a previously awarded firm-fixed-price FMS contract from Naval Air Systems Command (Patuxent River, MD) for Lot 16 Integrated Defensive Electronic Countermeasures (IDECM) AN/ALQ-214 A(V)4/5 Onboard Jammer systems for the F/A-18 E/F aircraft for the government of Kuwait. The modification allows for procurement of additional full rate production IDECM systems for the 22 F/A-18E and six F/A-18F Super Hornets being built by Boeing, which received more than $2.5 billion in contracts to produce and provide services in support of the Royal Kuwaiti Air Force.

continued on page 23

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Work is expected to be complete by August 2022.

- **Rockwell Collins** (Fort Worth, TX) has received a $22.14 million firm-fixed-price contract from the Naval Air Warfare Center Aircraft Division (Patuxent River, MD) for production of 132 Joint Helmet Mounted Cueing System (JHMCS), Night Vision Cueing and Display Systems (NVCD). The contract includes purchases for the US Navy (56), government of Australia (55) and government of Switzerland (21). Work is expected to be complete in February 2021.
- **Lockheed Martin Missile and Fire Control** (Grand Prairie, TX) was awarded an $8.47 million modification to an FMS contract for Phased Array Tracking Radar to Intercept on Target Advanced Capability-3 Missile Support Center Field Missile Activities. The contract from the US Army Contracting Command (Redstone Arsenal, AL) covers work for Japan, Saudi Arabia, Republic of Korea, Kuwait, Qatar, Taiwan, United Arab Emirates, Germany and The Netherlands and is expected to be complete by the end of May 2020.
- **Collins Aerospace**, a division of Goodrich (Westford, MA), has been awarded a $47.61 million modification to a previously awarded Foreign Military Sales (FMS) contract involving support to Jordan, Qatar and Bahrain for the DB-110 Tactical Reconnaissance Pod program. The contract, via the Air Force Life Cycle Management Center (Wright-Patterson AFB, OH), includes procurement of DB-110 reconnaissance pods, plus program infrastructure, airborne data link terminals, surface terminal equipment, mobile, fixed and transportable ground stations. The modification brings the contract ceiling to $183.1 million, and work is expected to be complete by mid-November 2023.
- **Boeing** (Seattle, WA) has received a $428.9 million advance acquisition contract modification to a previously awarded firm-fixed-price contract for long-lead materials and activities in support of 16 P-8A Poseidon Multi-Mission Maritime lot 11 aircraft. The contract, via Naval Air Systems Command (Patuxent River, MD) combines purchases for the US Navy (six aircraft) with FMS sales to the Republic of Korea (six aircraft) and the government of New Zealand (four aircraft). Aircraft deliveries are expected to be completed by June 2020.

"EW LIVE" RETURNS TO ESTONIA

The "EW Live" electronic warfare (EW) exhibition and conference will be returning to Estonia in 2019. Sponsored by the Republic of Estonia Ministry of Defence and Estonian Defence Industry Association, and organized by Tangent Link (Slough, UK), the EW Live event is a unique venue in that it includes live demonstrations of equipment and systems in an actual field environment. Last held in 2017, this year's event will take place April 9-11 in Tartu, Estonia, and will comprise three days of classroom and live-field demonstrations from over 20 companies at Tartu Airport "showcasing a cycle of EW operating technologies designated for the NATO Air, Land and Sea communities."

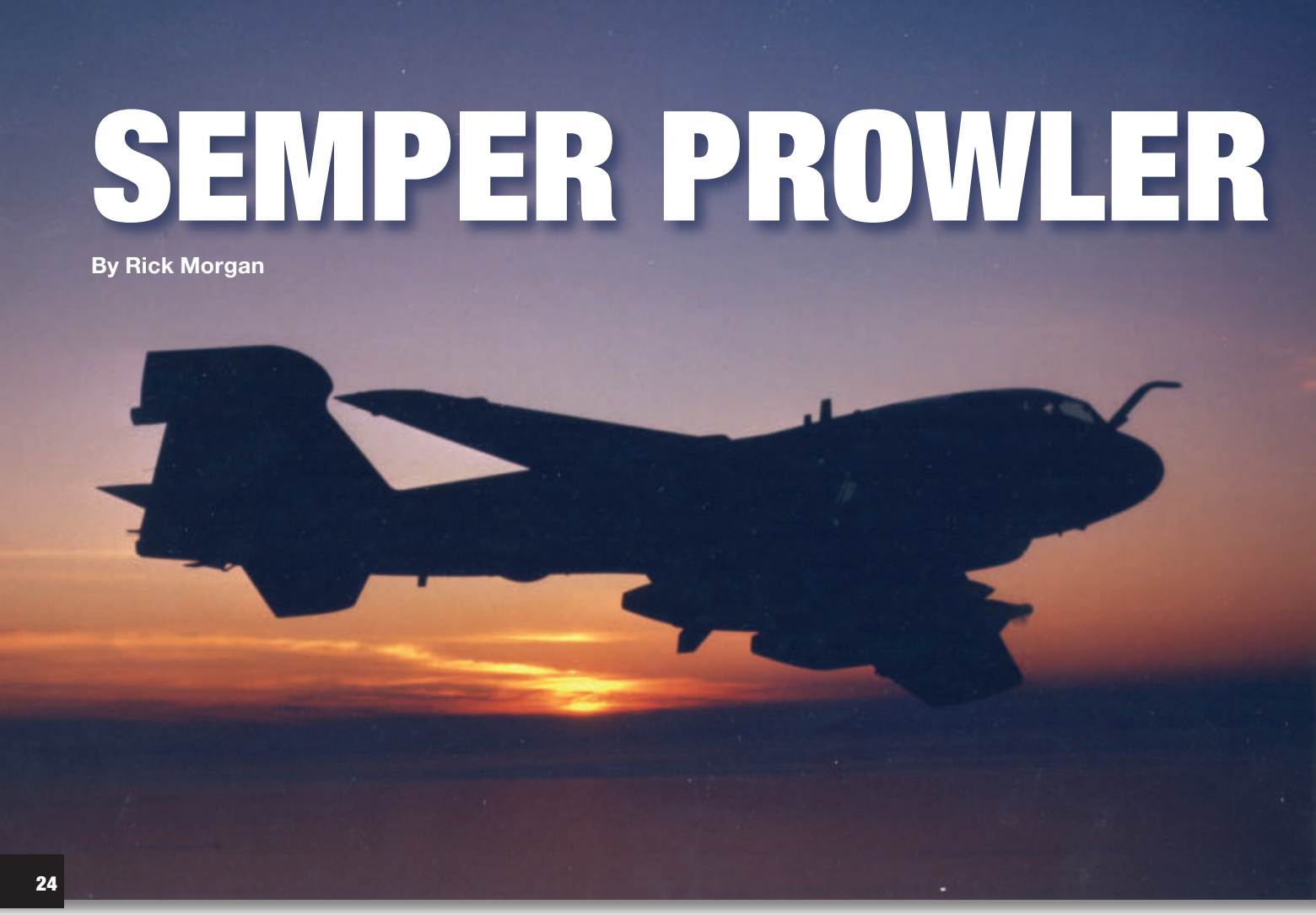
With the theme, "Delivering Knowledge Through Demonstration," the 2019 EW Live event will feature "a live COMINT and ELINT threat spectrum setting presenting the threat context to current and new types of EW operational equipment, as well as a 'counter-drone zone' featuring live drone scenarios."

J. HAYSTEAD

Also held in Tartu, the 2017 EW Live attracted 243 attendees from 29 countries, primarily from Central and Eastern Europe, the Middle East, and the Nordic region. According to Tangent Link, the attendee breakdown was 47% military, 31% industry, 12% Research Organizations and 10% government civilian. Not surprisingly, EW Live has also caught the attention of the AOC, with multiple board members attending, and JED is the official media partner for the event.

SEMPER PROWLER

By Rick Morgan



On Friday, 8 March, 2019, the United States Marines deactivated Marine Tactical Electronic Warfare Squadron-TWO (VMAQ-2) at Marine Corps Air Station (MCAS) Cherry Point, NC. This ceremony marked several distinct milestones, including 68 years of service for the squadron and its predecessors, as well as the final retirement for the Grumman EA-6B Prowler after 48 years of duty. This event comes four years after the Navy ended its long association with the Prowler, having replaced the classic airframe with the Boeing EA-18G Growler.

For the Marines, it's a bittersweet point in history, as the Corps has always been at the forefront of what we now call Airborne Electronic Attack (AEA), having conducted the business with panache since the Korean War.

For VMAQ-2, the oldest of the four Marine Prowler units, it secures its colors after seeing combat in Vietnam and over Iraq, the former Yugoslavia, Afghanistan, Syria and off Libya. The squadron's simple motto, "Can Do" (or, as commonly seen, "Can Do Easy") said it all, and became ample evidence of what Marine airborne EW has accomplished over many decades. As is often said, "It's not boasting if it's true."

BEGINNINGS

While the Marines certainly experimented with what was called "Radio Countermeasures" during World War II, it was during the Korean War that specialized units were formed to emphasize the use of electronics and expanding technology to support the Marine Rifleman on the ground.

Up to late 1951, the Marines had assigned small numbers of night-attack and ECM-capable Douglas Skyraiders, and a limited number of Grumman TBM-3Q Avengers to headquarters and maintenance units. The rapidly growing need for these capabilities led to the Corps activating three new Marine Composite Squadrons (VMC) in 1951 and 1952.

The initial roles for these squadrons was night attack and airborne early warning, with a variety of specialized Douglas AD Skyraiders assigned. Through the early to mid-1950s, these units continued to experiment on improving their capability by acquiring existing jamming equipment and mounting it in their aircraft.

Their work continued through 1955, when the decision was made to merge the VMC units with Marine Photo Reconnaissance Squadrons (VMJ) to form what were now titled Marine Composite Reconnaissance Squadrons (VMCJ). VMC-2 and VMJ-2 were merged on 1 December, 1955 to form VMCJ-2 at Cherry Point. VMC-3 and VMJ-3, now at El Toro, CA, did the same on the same date. It took a little longer for the 1st Marine Air Wing to follow suit, with VMC-1 and VMJ-1 joining on 31 July 1958.

Changes were coming for the new VMCJ squadrons as, during the same period, the Marines had recognized the need to have a full-time jet-powered electronic warfare aircraft. This requirement preceded the other Services, as the Navy retained propeller-driven AD Sky-

raiders for the mission (as AD-5Qs), and the Air Force's Tactical Air Command held only a few, outdated Douglas B-26s for the role.

The Marines decided to use the Douglas F3D-2 Skyknight as a dedicated EW platform, with 35 eventually being modified to carry receiver systems and jammers. By the end of the 1950s, all three VMCJ squadrons had settled on two types of aircraft, F3D-2Qs for the EW mission and new Vought F8U-1Ps conducting photo-recon. Both would see duty around Cuba during the 1962 missile crisis; the photo birds conducting low-altitude missions and "Willy the Whale," as the F3Ds were frequently called, recording valuable ELINT data for other agencies.

SERVICE IN VIETNAM

In 1962, a service-wide re-designation effort led to both aircraft becoming the EF-10B and RF-8A, and that's what they started with in Vietnam as VMCJ-1 left its Iwakuni, Japan home to take residence in Da Nang for the duration of the war.

By the start of the Vietnam War, the trio of VMCJ squadrons had stabilized with a mix of Skyknights and Photo-Crusaders. The Marines soon found their EF-10Bs in high demand to provide jamming support for strikes deep in North Vietnam, particularly as Soviet-supplied SA-2 Surface-to-Air Missiles (SAMs) began impacting US strike operations.

The "Drut," as the Skyknight was also called, was flown heroically day and night, facing both MiG and SAM threats in support of Marine, Navy and Air Force strikes. To put it succinctly, only the Marines would fly a corpulent, non-ejection seat, straight-winged, sub-sonic jet that burned AVGAS against SA-2s. And, in the finest traditions of the Corps, they made it work. There was a cost, of course; five EF-10Bs being lost during the war due to both combat and operational causes.

Help was on the way, however, as in the early 1960s, the Marines were working with Grumman to develop a replacement for the Skyknight. This aircraft, derived from the A2F (A-6) Intruder, would first fly in April 1963 as the EA-6A. The "Electric Intruder," as it was eventually called, retained the strike aircraft's two-seat design but also featured new, podded jammers and an excellent receiver system.

The Marines pioneered the use of jet aircraft as tactical jamming platforms through introduction of the Douglas F3D-2Q (EF-10B) Skyknight in the late 1950s. Here, a division from VMCJ-3 fly in echelon. The EF-10B would serve with distinction in Vietnam, not being retired until 1970.

US MARINE CORPS PHOTO

Twenty-seven EA-6As would be either modified from bombers or built new and delivered to the three VMCJ squadrons to completely replace the EF-10B by the end of 1969. The new aircraft entered combat in Vietnam with VMCJ-1 in October 1966 and quickly proved itself to be the most capable jamming aircraft used in the war, with an excellent blend of frequency range and jamming power, as well as airframe endurance, speed and survivability.

VMCJ-1 continued to fly combat out of Da Nang through 1970, when it returned to Japan. Meanwhile, VMCJ-2 and -3 continued training in CONUS and supporting "CJ-1." The "Playboys" of VMCJ-2 also made two deployments in aircraft carriers with the 6th Fleet in 1971, marking the first time the EA-6A was part of a Navy Carrier Air Wing (CVW).

The Grumman EA-6A Intruder replaced the EF-10B as the Marines' tactical jamming platform from 1966 and also saw widespread service in Vietnam. Charlie Yankee 00, shown here, is the legendary "Methuselah," the second Intruder built and first modified to the electronic attack version. It's shown about 1977 in full VMAQ-2 "Playboy" markings. The airframe is now on display at MCAS Cherry Point, NC.

US MARINE CORPS PHOTO

The invasion of South Vietnam by the North in April 1972 led to VMCJ-1 returning to war with its Intruders, now flying missions out of Cubi Point, Philippines. They were joined by a detachment from VMCJ-2, adding their significant weight of wattage to the electronic attack effort in Operations Linebacker and Linebacker II. Two EA-6As would be lost during the 1972 effort, one in combat, the other to a complete hydraulic failure.

THE PROWLER ARRIVES

The end of the Vietnam War in 1973 quickly led to "Ops Normal" for all three VMCJ squadrons. VMCJ-1 soon picked up additional duties covering the EW and photo-recon roles for the USS Midway (CVA-41) and Carrier Air Wing-FIVE (CVW-5) out of Japan. VMCJ-3 continued flying out of sunny Southern California, while Cherry Point-based VMCJ-2 worked with the 2nd MAW, as well as continuing periodic operations monitoring Cuba.

In 1975, the Marines elected to completely change the organization of the composite units, as they decided to split the two missions into separate squadrons. On 1 July 1975, VMCJ-2 was re-designated Marine Tactical Electronic Warfare Squadron-TWO (VMAQ-2), now having sole custody of all EA-6As in the DOD inventory. The same day, VMCJ-3 became VMFP-3, gaining all of the Corps' RF-4B Phantom IIs. VMCJ-1, in Japan, was deactivated, their place being covered by detachments from the two "new" squadrons, who were now deploying under the recently instituted Unit Deployment Plan (UDP).

The "Playboys" of VMAQ-2 now covered Marine electronic attack assignments world-wide with their black-tailed Intruders seen from Norway to Japan, continuing their tradition of excellence in the EW field. The EA-6A itself was overdue for replacement, and in 1977, the Marines took possession of their first Grumman EA-6B Prowler.

The Prowler, a four-seat EW derivative of the Intruder, had been introduced by the Navy directly into combat in 1972. While the initial "Standard" version of the EA-6B didn't have the frequency coverage of the EA-6A's EW suite, rapid improvements to the type quickly

outstripped the capability of the A-model, with the Marines starting with the "Improved Capability" (ICAP) model of the Prowler. As part of a unique set of requirements for the Marines, they also installed the AN/ASQ-90A Tactical Electronic Reconnaissance Processing and Evaluation System (TERPES) digital recording device in their Prowlers. TERPES would remain unique to the Marines, as the Navy believed its VQ electronic reconnaissance community carried out the same basic function. For the purposes of deployment, VMAQ-2 organized three standing detachments (X, Y and Z) and launched its first det overseas with the type, to Japan, in December 1978.

Thus was set the operational routine for VMAQ-2 for over 15 years, with detachments rotating to Japan, typically for six months, after spending a year home in North Carolina. They also continued to cover the EW requirement for CVW-5 and *Midway*, finally being relieved by the permanent move of VAQ-136 from Whidbey Island in early 1980. While in Japan, the squadron's Prowlers typically covered exercises throughout the region while also keeping a wary eye on North Korea.

VMAQ-2 started receiving EA-6B Prowlers in 1977, replacing their two-seat EA-6As. This picture shows an ICAP-version in full "Playboy" markings in 1982.

US MARINE CORPS PHOTO

In 1982, the "Playboys" made their first extended carrier deployment to the Mediterranean with Prowlers, placing det Y aboard the USS *Nimitz* (CVN-68) as part of CVW-8. Two years later, det X joined CVW-17 and USS *Saratoga* (CV-60) for another Med deployment.

Most notable was the short-fused assignment of Detachment Y to USS *America* (CV-66) in January 1986. A crisis with Libya had led to *America* and CVW-1 losing their own Prowler squadron, VAQ-135, which had been moved to CVW-13 on USS *Coral Sea* (CV-43). The Marines were selected to fill the EW gap, quickly carrier qualified and headed to the Med. On 15 April, they supported Operation *El Dorado Canyon,* which involved strikes by Navy and US Air Force aircraft against targets in Libya. It would also be the first combat for Marine *Prowlers*. Later in 1986, VMAQ-2 started accepting their first Improved Capability II (ICAP-II) EA-6Bs, which also introduced the AGM-88 High Speed Anti-Radiation Missile (HARM) to their bag of tricks. Roughly four years later, in 1990, VMAQ-2 would answer the bell again as the Iraqi invasion of Kuwait quickly led to the largest deployment of US forces since the Vietnam War.

THE GULF WAR

When the word came to send Prowlers to Southwest Asia, the "Playboys'" det X was in Iwakuni Japan. They would be fated to remain in Japan for a year, as the remainder of the squadron was moved in August 1990 to a previously unknown base in southern Bahrain named Shaikh Isa. Their twelve Prowlers became the largest single-squadron de-

ployment for the type up to that point. They jumped right into Operation Desert Shield and prepared for what appeared to be the imminent liberation of Kuwait.

The start of the war on Iraq, now called Operation Desert Storm, started on the night of 17 January 1991, while practically the entire world watched on television as Allied missiles and aircraft attacked Baghdad in spectacular fashion. VMAQ-2 joined 29 Navy Prowlers, Air Force EF-111A Ravens, and EC-130H Compass Call aircraft to form an electronic warfare hammer that subdued and helped eventually destroy Iraq's air defense system.

RE-ORGANIZATION

Over the following six-week war, the "Playboys" performed heavy electronic bombardment throughout the war zone in support of strikes by Marine aircraft, as well as all of the other Allied Air Forces. From mid-February, they also launched HARMs on suitable targets. When all was said and done, and Kuwait was liberated, the squadron had flown over 1600 hours and in excess of 500 combat missions. Most of the squadron returned home triumphantly in early April, other than a det that had been quickly formed to stay in Bahrain for the immediate post-war period.

Meanwhile, Det X finally came back to North Carolina as well, in June, being relieved by an activated Reserve squadron, VMAQ-4. The "Seahawks" of VMAQ-4 had been formed in the Marine Reserves at NAS Whidbey Island, WA, in November 1981 with EA-6A Intruders as equipment. The squadron operated as part of the 4th Marine Air Wing for 19 years before being activated into the Regulars on 11 March 1991, with immediate transition to the EA-6B. Their hurry-up transition completed in June, they immediately moved to Iwakuni to take over the role as resident Prowler squadron in Japan. The Seahawks returned home to Whidbey in September and were de-mobilized to become the only Marine Reserve Prowler squadron. This status didn't last long, as on 1 October 1992, they were activated again into the Regulars and moved to Cherry Point as part of a massive re-organization of Marine Prowler assets.

The decision had been made to expand ("clone") each of VMAQ-2's detachments into full squadrons, which, when joined by VMAQ-4, would give the Corps four deployable EA-6B units. On 1 July 1992, Detachment Zulu was activated as VMAQ-3, taking the nickname "Moon Dogs." Det X-ray became VMAQ-1, the "Screamin' Banshees," and detachment Yankee remained as the core for VMAQ-2, which had changed its name to the

Marine Prowlers were no strangers to carrier operations. In 1986 VMAQ-2 det Y deployed in the USS America (CV-66) as a member of Carrier Air Wing-ONE. They would participate in Operation Eldorado Canyon, involving strikes on Libya, during the cruise. Playboy 605 is shown here taxiing onboard the ship with a VA-34 KA-6D tied down in the background. US NAVY PHOTO

"Panthers" after having been induced to lose the "Playboy" title after fall-out from the 1991 Tailhook Convention. By 1996, they would change their nickname again, now to "Death Jesters."

Each squadron was equipped with six Prowlers, making them larger than their Navy counterparts, which still typically deployed with four or five aircraft per squadron. Deployments initially remained to Japan under the UDP, although that would soon change. VMAQ-1 would be the first of the new squadrons to leave the nest, heading to Iwakuni soon after activation.

The mid-1990s were notable for the substantial reduction in forces the US military took as the Nation looked for an elusive "Peace Dividend" after the Cold War. While the Navy initially lost three Prowler squadrons during this period, the Marines retained all four of theirs, even while several Leatherneck fighter and attack units were deactivated.

As part of the drawdown, VMAQ-3 deployed to the Med in August 1995 as a member of Carrier Air Wing-ONE on the *America*. They replaced a Navy squadron for this one cruise and carried out a highly successful last-carrier deployment by a Marine Prowler unit. They also participated in growing operations over the former Yugoslavia as part of Operation Deliberate Force.

The Seahawks of VMAQ-4 started as a Marine Reserve squadron and drew their name from the Seattle NFL football team. They're shown here at Yuma in 2005 well after being made a Regular Marine unit. Marine Prowlers were familiar and critical participants in training events at Yuma conducted by Marine Aviation Weapons and Tactics Squadron-ONE (MAWTS-1). US MARINE CORPS PHOTO

The Balkan region itself had rapidly destabilized in the early 1990s, with both the United Nations and North Atlantic Treaty Organization (NATO) passing resolutions to bring peace to the area, through force, if necessary. In 1993, VMAQ-3 had made the first Marine deployment to Aviano, Italy, to cover Operation Deny Flight, which involved operations over Bosnia and Herzegovina, as well as Serbia.

Through this same period, the Air Force had made no secret that it wanted to retire its only tactical radar jamming platform, the EF-111A Raven. The Raven needed upgrades to keep up with the threat, and the Air Force was more inclined to develop "emerging technologies" (stealth being a major one) that it thought would be a better investment.

Several high-level studies later, the decision was made to make the Department of the Navy responsible for all tactical EW, with the Prowler being the surviving platform. The new, Joint concept, which began in 1997, made theater EW now more closely coordinated under the gaining Combatant Commander, such as PACOM, EUCOM or CENTCOM. The Navy would increase it useable EA-6B inventory to support four new "Expeditionary," or land-based squadrons to cover the new requirement, while the Marines were also now part of the Joint arrangement.

VMAQ-2 went through three different nicknames. By the time this picture was taken in March 2003, they were the "Death Jesters." Charlie Yankee 00 is shown departing Prince Sultan Airbase in Saudi Arabia for a mission during Operation Iraqi Freedom.

US AIR FORCE PHOTO; SSGT MATTHEW HANNEN

For the Marines, who would tell you they'd invented "Expeditionary EW," they continued to deploy around the world, but now not always under a Marine Aircraft Group or in direct support of Marines on the ground. Exotic locations, such as Prince Sultan Air Base in Saudi Arabia and Incirlik, Turkey, would now start showing up on their list of deployed locations, all in support of ongoing operations, including Operations Northern Watch and Southern Watch, where they helped monitor the "No-Fly" zones established over Iraq.

Meanwhile, the Balkans continued to boil, and in October 1998, Operation Allied Force kicked off, which involved combat operations in support of NATO air forces throughout Serbia and Kosovo. Eleven Marine Prowlers – from VMAQ-1, 2 and 4 – participated alongside four US Navy EA-6B squadrons throughout the 78-day effort. Although three Air Force jets were shot down by radar-directed missiles during the Operation, it was noted that none of them had the benefit of adequate EW support when they were lost. The value of standoff jamming was once again proven, even for the highly-touted new "stealth" platforms. With the end of operations in the Balkans, the VMAQ units stood-down for a short period and then went back to "routine" deployments to Japan, Saudi Arabia, Turkey and Italy. The terrorist attacks, on 11 September, 2001, quickly increased the tempo of operations yet again and began another 18 continuous years of direct combat by Marine *Prowlers*.

IRAQ AND AFGHANISTAN

The Allied invasion of Iraq in 2003, as part of Operation Iraqi Freedom (OIF), would be heavily supported by Marine EA-6Bs, initially flying from Saudi Arabia. Once again, Marine EA-6Bs carried out vital work – initially to suppress Saddam Hussein's integrated air defense network and then adapting to force protection missions, particularly as improvised explosive devices (IEDs) became the preferred weapon of the insurgency. VMAQ units started deploying inside Iraq, initially to Talil in the summer of 2004, and then to the former MiG base at Al Asad a year later. These counter-IED operations, in continued support of OIF, dominated Marine Prowler deployments from 2005 through 2010.

VMAQ operations in Afghanistan, as part of Operation Enduring Freedom, involved flying out of Bagram Air Base on multiple deployments from 2005 as they supported US and Allied troops on the ground, much of which was in what would have been previously considered "non-traditional" Electronic Warfare missions. As in Iraq, the presence of Prowler jamming quickly proved to be a lifesaver for troops on the ground. Vital

One of four Marine Prowler squadrons, VMAQ-1 made multiple deployments world-wide before becoming the replacement training squadron in 2013. This picture shows a "Screamin' Banshee" EA-6B as it taxis at Prince Sultan AB in Saudi Arabia on 18 Mar 2003 for another sortie as part of Operation Iraqi Freedom.

US AIR FORCE PHOTO; SSGT MATTHEW HANNEN

to this effort, and in another example of Marine innovation, was the rapid installation of the AN/AAQ-28 LITENING Electro-Optical pod for EA-6B use, a piece of kit the Navy never adopted.

The deployment of aircraft in country led to significant force protection concerns for US troops, with VMAQ-2 actually being involved in an attack on Bagram Airfield led by Taliban insurgents in May 2010. The heavily armed raiders tried to enter the base near the squadron's area and were quickly met by Leathernecks, who quickly reverted to their "Every Marine a Rifleman" training and repelled them with heavy Taliban losses. Two Marines were seriously wounded in the engagement.

Improved Capability III (ICAP III) EA-6Bs arrived from April 2010, with VMAQ-4 taking the first Marine examples to Afghanistan a year later. The ICAP III, which had been introduced into the Navy in 2005, featured a whole new "state-of-the-art" receiver system, the AN/ALQ-218, which was of the same basic design as what would go into the Growler. The ICAP III would prove to be the ultimate expression of the Prowler and a worthy final version of the aircraft.

THE END OF THE PROWLER ERA

By the start of the new century, it had become obvious that the EA-6B Prowler, no matter how successful it had been, would need replacement. The Navy-led study that followed decided to develop its F/A-18F Super Hornet into an EW variant, which eventually became the EA-18G Growler. Navy transition from the Prowler to the Growler started in June 2008 with the first delivery to Whidbey Island. The Navy would retire its last EA-6B in June 2015.

The Marines, which did not procure the Super Hornet, chose instead to continue flying the EA-6B for several more years. In order to insure a constant stream of trained aviators and maintainers, VMAQ-1 took over the replacement training ("RAG") function in 2013, being re-designated VMAQT-1. But even the Marines had to retire the Prowler at some point. The decision was finally made to start deactivating squadrons, one per year, from 2015, starting with VMAQT-1 in April 2016. The remaining three units continued deploying, now providing critical EW support for counter-ISIS operations in Iraq and, soon, in Syria. The Seahawks of VMAQ-4 were the second to go, deactivating in June 2017. Then it was the fabled Moon Dogs, who were put-down in May 2018.

This left the "Death Jesters," who made one more long deployment to Al Udeid, Qatar. It was a combat deployment, of course, and it included operations throughout the Central Command AOR. They came home to North Carolina in October 2018 and started the path toward deactivation.

It truly marked the end of an era; both for the Marines and their long, distinguished history as leaders in the EW business, but also for the Grumman EA-6B Prowler, which had become, arguably, the most significant EW aircraft in history over its many years of service.

The decision to retire the EA-6B without direct replacement was not without some controversy within the Corps. While the Navy was "all in" for the Boeing EA-18G Growler as an EA-6B follow-on, the Marines have pursued a different path. There remain more than a few voices that would tell you that the loss of the VMAQ community will leave a capability hole that cannot be easily filled. In particular, the talents and knowledge resident in the Electronic Countermeasure Officer (ECMO) specialty will be sorely missed both in the field, as well as on staffs and in schools.

3 Jan 2016 and the last time Prowlers from all four Marine VMAQ squadrons flew together as the first unit, VMAQT-1, would be deactivated the following April. They're shown here flying near their home of Havelock, North Carolina.

US MARINE PHOTO, CPL N.H. QUINONE

The men and women of VMAQ-2 stand before the squadron's six EA-6B Prowlers at Al Udied, Qatar during the unit's final deployment, on 16 August 2018. They would be replaced by Navy squadron VAQ-135, flying EA-18Gs.

US ARMY PHOTO, SPC JORGE DIAZ

Now dedicated manned EW support aircraft (like the Prowler) will be replaced by a rapidly evolving concept called Marine Air-Ground Task Force Electronic Warfare (MAGTF EW), which will combine specialized packages on a range of aircraft and drones that will be linked to a Radio Battalion on the ground to provide sensing and EW fires to support the Marine Rifleman.

The Marine Prowler legacy is a great one and will be a hard act to follow by whatever system, or systems, eventually arrive to replace it. More than the airframe, however, it was also the men and women who flew and fixed the aircraft that were truly, "In the Best Tradition of the Corps."

About the Author: *Rick Morgan, LCDR USN (Ret) is the historian for the Prowler Association with over 2000 hours in the EA-6B over 12 years of flying the aircraft. He currently lives outside St Louis, MO with his wife Julie and two cats. While not a Marine, he helped train a lot of young Marine ECMOs at VAQ-129, and his son Scott served five years in the Corps with two tours in Iraq. He served on the AOC National Board of Directors 2008 to 2010.*

For more information on Marine AEA history, the author highly recommends "Silent Heroes" by H. Wayne Whitten, COL USMC (Ret).

Prowler Association: www.ea6bprowler.org

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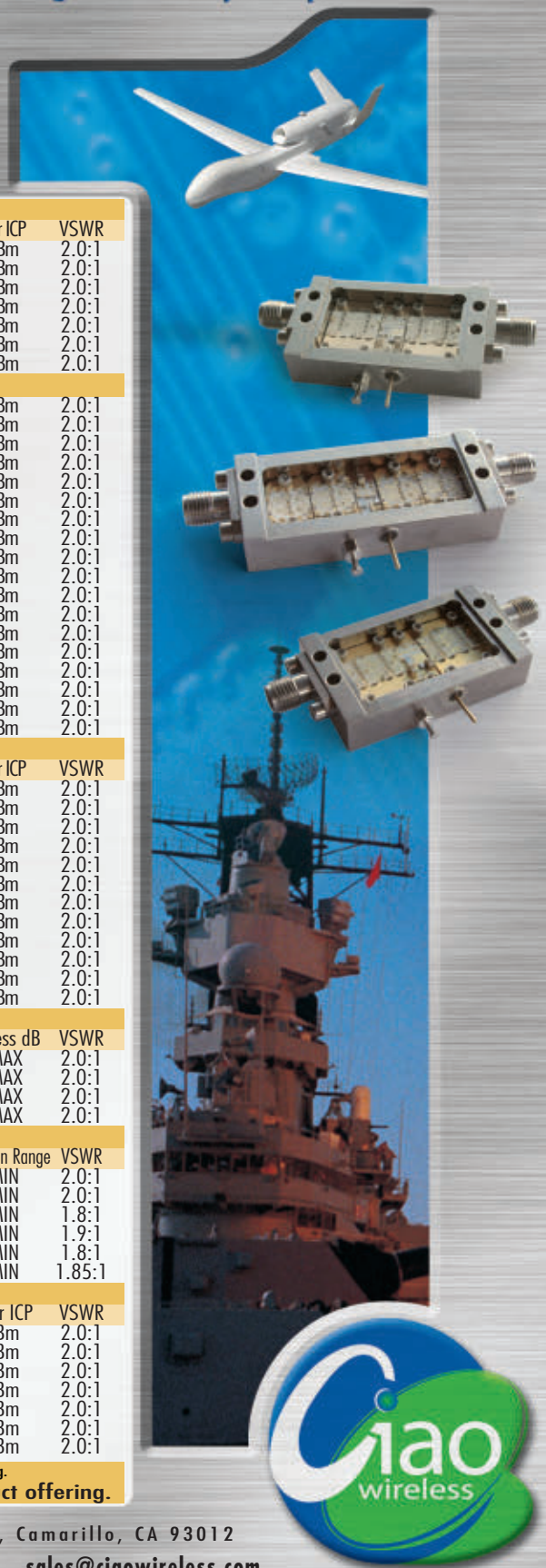

OCTAVE BAND LOW NOISE AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2110	0.5-1.0	28	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA12-2110	1.0-2.0	30	1.0 MAX, 0.7 TYP	+10 MIN	+20 dBm	2.0:1
CA24-2111	2.0-4.0	29	1.1 MAX, 0.95 TYP	+10 MIN	+20 dBm	2.0:1
CA48-2111	4.0-8.0	29	1.3 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA812-3111	8.0-12.0	27	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA1218-4111	12.0-18.0	25	1.9 MAX, 1.7 TYP	+10 MIN	+20 dBm	2.0:1
CA1826-2110	18.0-26.5	32	3.0 MAX, 2.5 TYP	+10 MIN	+20 dBm	2.0:1

NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA01-2111	0.4 - 0.5	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA01-2113	0.8 - 1.0	28	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3117	1.2 - 1.6	25	0.6 MAX, 0.4 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3111	2.2 - 2.4	30	0.6 MAX, 0.45 TYP	+10 MIN	+20 dBm	2.0:1
CA23-3116	2.7 - 2.9	29	0.7 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA34-2110	3.7 - 4.2	28	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA56-3110	5.4 - 5.9	40	1.0 MAX, 0.5 TYP	+10 MIN	+20 dBm	2.0:1
CA78-4110	7.25 - 7.75	32	1.2 MAX, 1.0 TYP	+10 MIN	+20 dBm	2.0:1
CA910-3110	9.0 - 10.6	25	1.4 MAX, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA1315-3110	13.75 - 15.4	25	1.6 MAX, 1.4 TYP	+10 MIN	+20 dBm	2.0:1
CA12-3114	1.35 - 1.85	30	4.0 MAX, 3.0 TYP	+33 MIN	+41 dBm	2.0:1
CA34-6116	3.1 - 3.5	40	4.5 MAX, 3.5 TYP	+35 MIN	+43 dBm	2.0:1
CA56-5114	5.9 - 6.4	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6115	8.0 - 12.0	30	4.5 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA812-6116	8.0 - 12.0	30	5.0 MAX, 4.0 TYP	+33 MIN	+41 dBm	2.0:1
CA1213-7110	12.2 - 13.25	28	6.0 MAX, 5.5 TYP	+33 MIN	+42 dBm	2.0:1
CA1415-7110	14.0 - 15.0	30	5.0 MAX, 4.0 TYP	+30 MIN	+40 dBm	2.0:1
CA1722-4110	17.0 - 22.0	25	3.5 MAX, 2.8 TYP	+21 MIN	+31 dBm	2.0:1

ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	3rd Order ICP	VSWR
CA0102-3111	0.1-2.0	28	1.6 Max, 1.2 TYP	+10 MIN	+20 dBm	2.0:1
CA0106-3111	0.1-6.0	28	1.9 Max, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-3110	0.1-8.0	26	2.2 Max, 1.8 TYP	+10 MIN	+20 dBm	2.0:1
CA0108-4112	0.1-8.0	32	3.0 MAX, 1.8 TYP	+22 MIN	+32 dBm	2.0:1
CA02-3112	0.5-2.0	36	4.5 MAX, 2.5 TYP	+30 MIN	+40 dBm	2.0:1
CA26-3110	2.0-6.0	26	2.0 MAX, 1.5 TYP	+10 MIN	+20 dBm	2.0:1
CA26-4114	2.0-6.0	22	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA618-4112	6.0-18.0	25	5.0 MAX, 3.5 TYP	+23 MIN	+33 dBm	2.0:1
CA618-6114	6.0-18.0	35	5.0 MAX, 3.5 TYP	+30 MIN	+40 dBm	2.0:1
CA218-4116	2.0-18.0	30	3.5 MAX, 2.8 TYP	+10 MIN	+20 dBm	2.0:1
CA218-4110	2.0-18.0	30	5.0 MAX, 3.5 TYP	+20 MIN	+30 dBm	2.0:1
CA218-4112	2.0-18.0	29	5.0 MAX, 3.5 TYP	+24 MIN	+34 dBm	2.0:1

LIMITING AMPLIFIERS

Model No.	Freq (GHz)	Input Dynamic Range	Output Power Range Psat	Power Flatness dB	VSWR
CLA24-4001	2.0 - 4.0	-28 to +10 dBm	+7 to +11 dBm	+/- 1.5 MAX	2.0:1
CLA26-8001	2.0 - 6.0	-50 to +20 dBm	+14 to +18 dBm	+/- 1.5 MAX	2.0:1
CLA712-5001	7.0 - 12.4	-21 to +10 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1
CLA618-1201	6.0 - 18.0	-50 to +20 dBm	+14 to +19 dBm	+/- 1.5 MAX	2.0:1

AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure (dB)	Power-out @ P1-dB	Gain Attenuation Range	VSWR
CA001-2511A	0.025-0.150	21	5.0 MAX, 3.5 TYP	+12 MIN	30 dB MIN	2.0:1
CA05-3110A	0.5-5.5	23	2.5 MAX, 1.5 TYP	+18 MIN	20 dB MIN	2.0:1
CA56-3110A	5.85-6.425	28	2.5 MAX, 1.5 TYP	+16 MIN	22 dB MIN	1.8:1
CA612-4110A	6.0-12.0	24	2.5 MAX, 1.5 TYP	+12 MIN	15 dB MIN	1.9:1
CA1315-4110A	13.75-15.4	25	2.2 MAX, 1.6 TYP	+16 MIN	20 dB MIN	1.8:1
CA1518-4110A	15.0-18.0	30	3.0 MAX, 2.0 TYP	+18 MIN	20 dB MIN	1.85:1

LOW FREQUENCY AMPLIFIERS

Model No.	Freq (GHz)	Gain (dB) MIN	Noise Figure dB	Power-out @ P1-dB	3rd Order ICP	VSWR
CA001-2110	0.01-0.10	18	4.0 MAX, 2.2 TYP	+10 MIN	+20 dBm	2.0:1
CA001-2211	0.04-0.15	24	3.5 MAX, 2.2 TYP	+13 MIN	+23 dBm	2.0:1
CA001-2215	0.04-0.15	23	4.0 MAX, 2.2 TYP	+23 MIN	+33 dBm	2.0:1
CA001-3113	0.01-1.0	28	4.0 MAX, 2.8 TYP	+17 MIN	+27 dBm	2.0:1
CA002-3114	0.01-2.0	27	4.0 MAX, 2.8 TYP	+20 MIN	+30 dBm	2.0:1
CA003-3116	0.01-3.0	18	4.0 MAX, 2.8 TYP	+25 MIN	+35 dBm	2.0:1
CA004-3112	0.01-4.0	32	4.0 MAX, 2.8 TYP	+15 MIN	+25 dBm	2.0:1

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US Air Force Reinvig

By John Haystead

For reasons of little relevance at this point in history, the Air Force's 479th Flying Training Group (FTG) Combat Systems Officer (CSO) School, is located at NAS Pensacola (Pensacola, FL). What is relevant, however, is that since 2009, the mission of the 479th FTG has been to provide USAF Undergraduate Combat Systems Officer Training (UCT) – providing rated aviators trained in the fundamentals of navigation (NAV), electronic warfare (EWO), Sensors (SO), Weapons Employment (WSO) and overall mission command.

Today, that mission continues, but with the implementation of a major change. The new "UCT Next" course program raises the level of expectation for graduates of the course, in particular those specializing in EW. The new course syllabus moves away from the previous approach, which involved broad, common training in all of the CSO mission areas followed by a final, short (21-day) "top-off" period of specialized training in the ultimately-assigned specialty area. Instead, with UCT Next, students begin extensive and comprehensive training in their specific mission area much earlier in the overall training program, and thus, upon graduation, will be further along in the education process and better prepared for their next-level of (on-the-job) training at their operational, or Formal Training Unit (FTU). The new training plan is intended to take advantage of advances in training simulation tools and includes input from experts at the 479th as well input from the FTU squadrons operating all of the different aircraft that CSOs serve in.

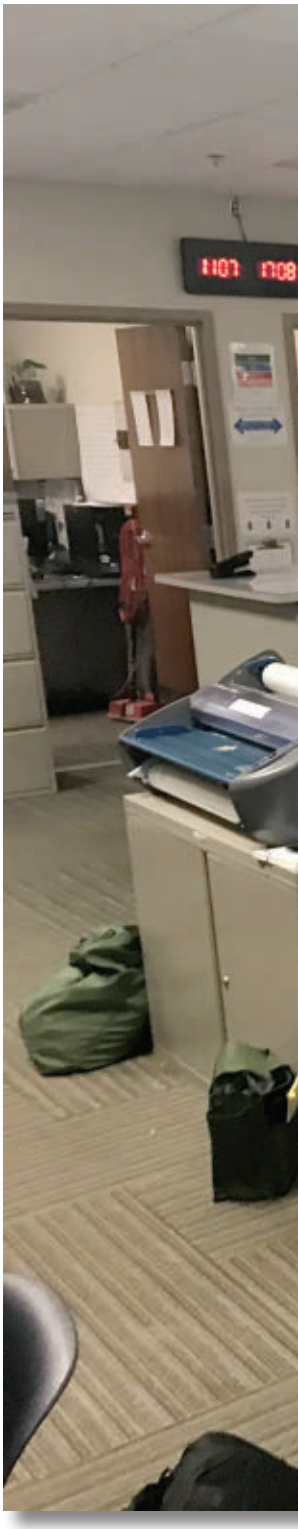
As described by Col Andy McElvaine, 479th FTG Commander, the curriculum change was driven by a pair of specific dynamics, the first being an increasing demand for graduates. Although the program was originally designed to support approximately 400 students/year, its instructors saw that, since they never had that many actually coming through the pipeline, there was a buffer capability that they could use to better optimize the training by adding on to the overall program. What wasn't recognized at the time, however, was that this approach was, by default, in turn reducing capacity, and the school could no longer support 400 students in the pipeline. "When the requirement grew, and we needed to get the number of graduating students up," says McElvaine, "we recognized that we needed to do things differently. To put things in perspective, two years ago, we graduated 250 students, while next year, we will graduate somewhere near 350 students with the same amount of resourcing."

McElvaine says the second reason was the desire to produce a better product across the board. "From the time the schoolhouse was first stood up, it had continuously evolved its curriculum based on the requirements and requests of its customers, and if you talked to each niche skill set that we produced graduates for – WSO, SO, EWO etc., they'd all say we could do better in each of their specific areas. And, in fact, we could, but what we couldn't do, was teach the entire class better across every one of those specific areas." The solution, says McElvaine, was to go back to a more specific syllabus, where they would teach different skill sets to different graduates. "This allows us to tailor the curriculum, to teach people faster, and to make them better for their eventual aircraft duties. My vision is that we will be able to produce up to 400 graduates per year, and that every one of our graduates, regardless of which platform they will go and fly, when they walk into the front doors on day one, they're a much better aviator for that mission."

McElvaine recognizes that the new approach necessarily includes tradeoffs, such as the fact that by specializing the training, the graduates coming out of the school will no longer be universally assignable. "Previously, with just a couple weeks of notice before graduation, we could take any one of our graduates and send them to any platform. We won't be able to do that anymore, but that is a conscious decision we've made, and the beauty of the new syllabus is that it's much easier now to change portions of it, because they're independent, and independently-tailorable, to best meet the needs of different customers."

IMPLEMENTING THE NEW SYLLABUS

Capt Tara Smith, Flight Commander, 479th Student Squadron (479 STUS/FC) is the lead on the UCT Next Military Training Route (MTR) EWO syllabus development project. She is working together with Capt Louis Bennett, Chief of Scheduling, to define all the syllabus guidances and products to be used by the initial cadre of EWO students to go through



orates EWO Training

Unclassified area of the 479th's CSO School EW training labs.

J. HAYSTEAD

the new program. Interestingly, both have B-52 EWO backgrounds.

As described by Captain Smith, the original concept of providing broad WSO training and giving everyone a taste of every kind of mission type was not necessarily a bad idea, but "what we found overall was that, in the Air Force, the jobs are still very specialized, and the graduates were showing up to their assigned units for follow-on training without this basic level of specialized training and below the knowledge level the units needed them to be at**.** Although, as Captain Smith points out, at the undergraduate level, the school can't function as a form of "mini FTU, specifically training to 17 different kinds of jets and tactics, at a more basic level, we can get them better prepared for the tracks they'll be going to."

As with the past program, students of all of the CSO skillsets will begin their training on simulators followed by flight training aboard T-6A Texan II aircraft, which as described by Captain Bennett is "basically, just learning to fly – co-pilots really, tuning instruments, basic navigation, flight-crew integration, etc." Now, however, EWO students will be selected out and go directly to their advanced syllabus and flight training on the T-1A Jayhawk aircraft at their 85th training day as opposed to the 195th day of common training. This was accomplished through the use of simulators to insert portions of formerly advanced phases of training into the primary phase. Captain Bennett says, "The part I like best about the new program is that the students get all their navigation, general airmanship, etc. stuff out of the way up front, and then go right into learning how to be an EWO. It's nothing but a solid building block approach, where all of their EWO training is all tacked together and they keep the learning going."

Reflecting on her own personal experience, Captain Smith can also relate to this point, observing that the approach should also provide a positive impact in terms of generating early "buy-in" from the UCT students themselves. "When I went through this program and had all of my EWO classes, I didn't yet know that I was going to be an EWO, so I was just trying to get through those tests the same as I was trying to get through all the other tests. Then, at the end, when I found out that I was actually going to be an EWO, I couldn't really remember much at all of what I had learned. Now, the EWO students will know early on, and throughout the program, that they really need to know and retain this information, because that is the job they're going into. Big picture, we're giving them a better baseline, so they can spend more time on the information that is most relevant to what they will be doing for the rest of their careers."

The 479th's fleet of T-1A Jayhawks are used to train EWOs.

Prior to flying back-seat in the T-1s, students are given simulator rides in Aircrew Training Devices (ATDs) which are exact mockups of the aircraft to get a hands-on feel for the platform, as well as a variety of EW equipment representative of a mix of different platforms. Says Captain Bennett, "Its real equipment, but kind of all packed together into one module. Remember, this is undergraduate training, and we're not training them for specific aircraft at this point, but for mission sets."

With the early transition to the advanced syllabus phase of their training, EWOs will now be able to focus on their primary tasks, such as threat-signal identification, electronic attack (EA) and self-protection EW. The program includes advanced "En-route," self-protection, and air-defense-simulation exercises. Says Captain Bennett, "It was important to include some kind of EWO

J. HAYSTEAD

scenario that really drives those points home. The approach we came to was a combination of self-protection and a type of recon mission (signal collection en-route and self-protection on the low level). Since there's no actual aircraft that does that mission, it's really just to give them an initial exposure to 'everything EWO.'"

Although there are no actual live emitters incorporated in the exercises, the on-board Air Combat Environment (ACE) system simulates real threat signals and other signals-of-interest being radiated toward the aircraft. As Captain Bennett describes, during the En-route exercise, students will be expected to monitor one or more different receivers onboard the aircraft and log each signal as it comes in as to what it is and where it is. Data is captured and evaluated in real time, although the system also has the capability to replay the entire mission at a later date, if desired.

For the self-defense portion of the exercise, students are given simulated self-protection jammers, chaff and flares, and they are also expected to conduct maneuvers representing defensive reactions. Says Captain Bennett, "Airmanship and crew coordination, including live, continuous verbal interaction between the pilot and the EWO is one of the primary emphasis points." Interaction with other potential airborne assets, such as AWACS or JSTARS aircraft, is also simulated. The instructor plays these roles as well as evaluating student responses, such as jamming effectiveness. Once this flight portion is completed, students continue their training on simulators. This work is all classified and, according to Captain Bennett, "is where the EWO portion of their training is really laid on thick."

More than 60% of the new EWO track syllabus will be taught in a classified environment. As emphasized by Captain Smith, EWO students will now also be introduced to the DOD's Secret Internet Protocol Router Network, or SIPRNet, as part of their training. SIPRNet "tokens" grant access to the network, and EWO students will be the only students in UCT to receive them. Says Captain Smith, "SIPRNet access allows them to do actual classified research, and the advanced EWO syllabus now culminates with a 'capstone' research and planning exercise to expose them to joint and inter-Service EW concepts." Having been through the school's earlier curriculum herself, Captain Smith feels "this is one of the most significant and exciting improvements to their training."

Generally, about 25% of the total students going through the CSO program will be EWOs with new classes beginning approximately every three weeks. With the UTC Next program, the total number of training days for EWOs (primary plus advanced) will now be about 177 days with the first cadre of students having already launched. According to Captain Smith, the primary syllabus has already gone live and there are already students in the pipeline. "These will be the first students to go through the new advanced syllabus, which is expected to be finalized and approved by April at the latest." If this schedule holds, the first UCT-Next-trained EWOs will be graduating in mid-August.

THE SKY AHEAD

Although Captain Smith doesn't expect the UCT Next program will be perfect out of the gate, she's confident it's headed in the right direction. "It will take a while before we start getting definitive feedback on, and from, the graduates of the new program syllabus, but I can say that since I went through the program, it's gone through many iterations, and the training has gotten better with each one. I expect the same will be the case here."

Colonel McElvaine agrees, adding that, although he doesn't expect the number of EWO billets in the operational Air Force to increase significantly over the next 5-10 years, he does "expect to see us better manning those billets. If you look right now, it's particularly evident at the staff level that we don't have adequate EWOs, NAVs or pilots to man our operational flying units. As a result, these billets have been filled with people taken from staffs, and that's not a viable long-term solution, since you're not doing yourself any favors by losing the advocacy for programs that should be resident at the staff level. What you'll see through our initiative here is more aviators being produced through the same kind of initiatives that have been ongoing at the pilot-training level, where production has really ramped up this year. It's a long-term problem, however. It took 5-10 years of under-producing for us to get ourselves in this position as an operational Air Force, and it will take some time to get back out of that hole."

In terms of future investment, the school expects to continue to improve its simulators, and UCT instructors continue to work closely with industry to design and develop more effective training tools, particularly using modified off-the-shelf equipment to provide more realistic training for its students. Ultimately, however, the goal is to equip its labs with virtual reality

capability. As Colonel McElvaine says, "For us, at the undergraduate level, if we had an extra pot of money, we'd put it toward additional training at the merge of the virtual environment and the physical environment. The Air Force is already doing this in a lot of mission areas, but if I could find a way to network a physical aircraft into a virtual environment where I could do a better job of threat replication and have a dynamic environment where the decisions made on an aircraft affected the synthetic environment that the operator was seeing in a more realistic manner, that is where I would put the investment. We do this very well in the simulation laboratories, but it's very difficult to replicate the physiological effects that happen to an aviator when they're in the air, and we're looking at ways to seamlessly join these environments. There are challenges there, but we're working towards that. That is the next evolution of our training, particularly for our EW professionals."

SPECTRA AND A

The 479th Flying Training Group (FTG) Combat Systems Officer (CSO) School, (NAS Pensacola, FL) isn't just about undergraduate CSO training. It's also the home of the 479th Operations Support Squadron (OSS) and its Special Courses and Training (SPECTRA) office whose mission is to "execute basic to advanced EW courses for the US and its partners and allies to ensure total force expertise in dominating the electromagnetic domain."

Lt Col William Tucker, Ph.D, OSS Assistant Director of Operations/ SPECTRA, emphasizes that "what we do here in Pensacola is non-CSO pipeline training. Our students are not undergraduate CSOs, but rather people that either have an interest in EW or are already EW professionals going out to air operations centers to work in an EW coordination cell for the Joint Force Air Component Commander (JFACC). We also have international students and generally get folks from 12-15 countries every year at various levels of experience."

SPECTRA has been in existence since the 1980s, but its first class as part of the 479th OSS in Pensacola passed through in October 2010, and it currently has five instructors processing about 250-300 students each year. Although, as Lt Col Tucker says, SPECTRA is not part of the CSO pipeline, its co-location with the UCT schoolhouse does provide synergy and allows qualified 479th UCT instructors to supplement its own cadre of instructors.

SPECTRA offers a number of course types and course-levels. Its most basic is an introduction to EW (IEW) course, which requires no prior EW knowledge or entry requirements other than a SECRET

DVANCED EWO/EMSO TRAINING

clearance, and is offered to anyone in the active DOD. Says Tucker, "It provides EW fundamentals, doctrine, history, and discussion on how we employ EW as a force. It doesn't make you an EW professional but more-or-less 'cocktail-party smart.'" The course is given eight times per year with about 15-20 students per class. SPECTRA also takes the IEW course on the road with mobile training teams, averaging about 4-6 of these excursions/year. As Lt Col Tucker points out, "It's a fantastic opportunity because we're not limited by the number of AETC (Air Education and Training Command) slots. We can teach as many people as they can bring in."

SPECTRA's EW Coordinators Course (EWCC) is specifically designed to enable mid-level company-grade officer (CGO) or senior NCOs to operate in an Air Operations or EW Cell (EWC) and for EW planning at an operational level. This class is at the top-secret-and-above level, and as described by Tucker is "where the rubber meets the road, with people that are going to go into theater and actually plan operations attending." In fact, the course is a deployment requirement for certain jobs in an EWC. Considered a graduate-level course by AETC, attendees are already EW professionals, and must have an EWO AFSC (service code), or have attended another introductory course such as IEW. Says Tucker, "It's a very unique class because a lot of outside agencies also send speakers, so we get a very real-time perspective on what is going on with R&D and operational capabilities." Upon graduation, attendees receive a special identifier beyond the basic EWO AFSC. The two-week long course is offered four times per year.

SPECTRA also offers international courses. The six-week long Multi-National EW International Officers (EWIOC) course, given at the unclassified level, and the NATO EWIOC course – provided at the SECRET/REL level – are designed to be taught across a breadth of experience levels although, according to Colonel Tucker, "it tends that the countries that send folks send people that already have an EW background." The majority of attendees are senior NCOs or O-5-level international officers. Says Tucker, "The EWIOC courses are almost more of an EW fellowship for six weeks, with core content and good discussion on how we can be more interoperable, and how different doctrines are designed and organized around EW." SPECTRA conducts an international or NATO course three times per year.

From his point of view, Colonel Tucker sees the Air Force re-emphasizing the importance of EW training – not just at the undergraduate level, but also at the graduate and senior-level. He also observes, however, that although "the aperture of EW or EMS training is opening as a whole, the more we open it, the more gaps we find. We do fairly well at training new and mid-level EWOs because that's their job, but at the senior level, there's been a gap in EW education over many years, because the senior leaders of today have spent their careers operating in areas where EW was almost an afterthought."

Given the prospect of what they would do with more resources, Colonel Tucker says, "We would be able to do more EW work at the foundational level that the Air Force needs, providing a critical foundational understanding of EW. It's not just airborne EWOs, or airspace or spectrum managers that need to know this. Every one of us is involved in the EMS in some fashion or other, and not understanding that is a huge limitation, especially in a warfighter." – *J. Haystead*

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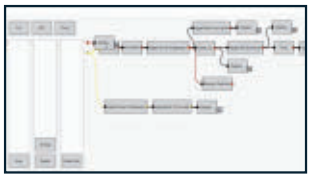
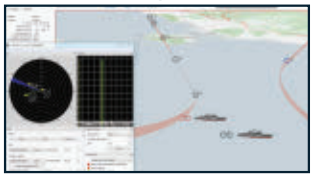
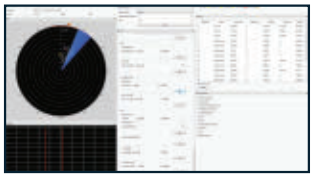


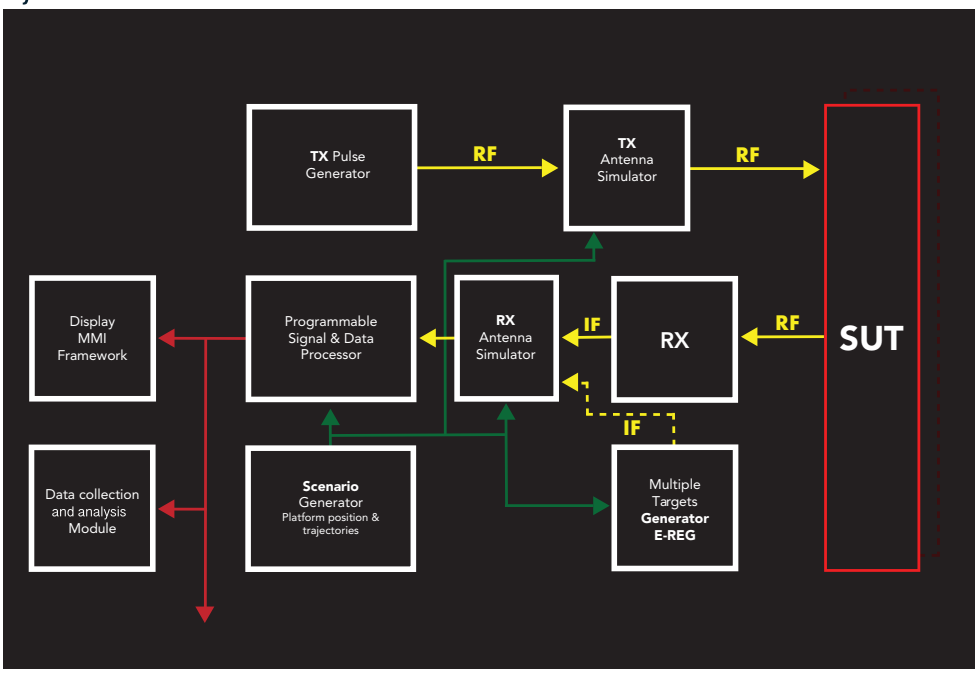
Scenario Configuration



Track Lost



System Architecture



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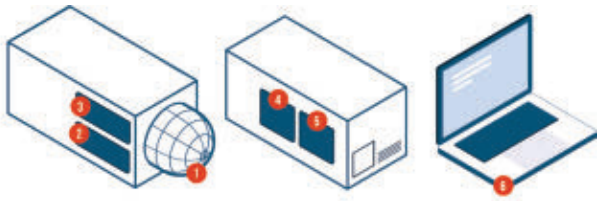

1 - Antenna
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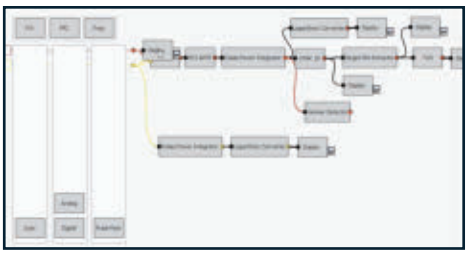
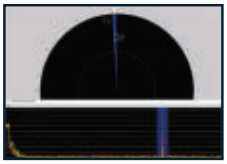
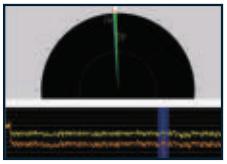


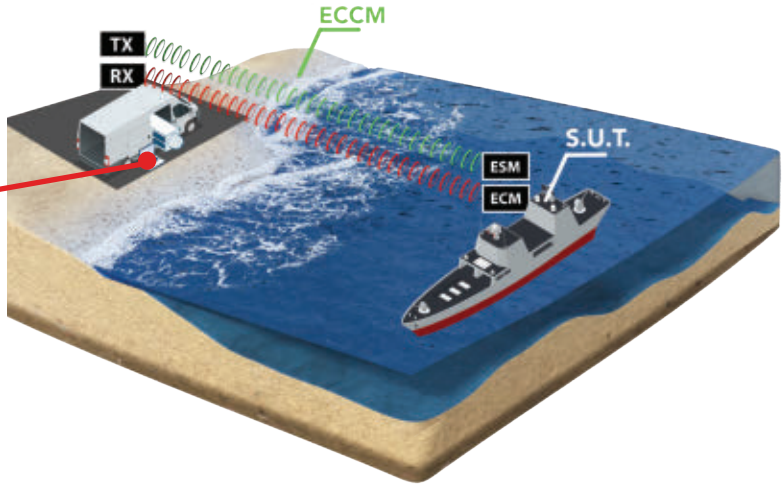
Seeker Model Configuration



Target Lock-ON



Ship ECM Effect



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RADAR SYSTEMS FOR METEOROLOGY AND DEFENCE

Defining the EM Domain

By John Knowles

This is the second installment in what will be a broad discussion of the Electromagnetic (EM) Domain. As we go forward, we will look at the EM Domain from several perspectives, including its historical evolution, relationships with other warfighting domains, policy and governance, and who holds operational responsibility for it. Along the way, we're going to address some "conventional wisdom" about the EM Domain, and we'll do some myth busting to get beyond some widely held misunderstandings about it. We hope that this approach provides you with a better understanding of what the EM Domain actually is and why we need to recognize it as a warfighting domain.

This month, we'll look at some aspects of what determines when a maneuver space needs to be recognized as a domain.

WHY DOMAIN?

In the US, warfighting domains have become very important over the past two decades because, once a maneuver space is recognized as a domain, it tends to signal to the wider government that military operations in that particular maneuver space are strategically important. Domain status helps to support consistent resourcing for doctrine, organization, training, materiel, leadership, personnel and facilities (DOTMLPF). In other words, domain status matters if you want to develop an enterprise approach to a particular maneuver space, such as air, land, sea, space, etc.

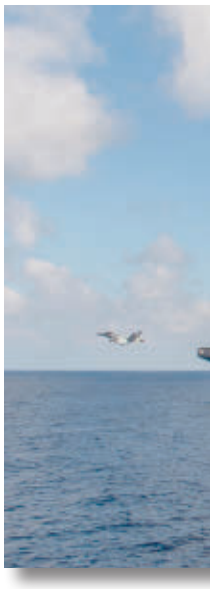
WHAT IS A DOMAIN?

The short answer to this question is that there is no simple definition of a warfighting domain. DOD doctrine spends a lot of time discussing domains, operations within domains, and more recently cross-domain operations, without ever precisely defining what a warfighting domain is. This lack of a simple definition means that all sorts of physical and non-physical maneuver spaces, such as information, human terrain, undersea, underground, etc., can be claimed as domains. This lack of a definition also means that most of these maneuver spaces can be discounted as domains, depending on the criteria used to make an argument either way.

However, the DOD does lay out some guidelines in its January 2016 planners guide for Cross-Domain Synergy in Joint Operations. It describes warfighting domains in terms of each one's unique capabilities and characteristics. For example, the Air Domain is described in terms of speed, range, detection and overflight. Land operations are described in terms of extreme variations in climate and terrain, the presence of people, the ability to sustain operations over a long period of time, and the slower and more arduous speed and duration of land operations compared with operations in the air and sea domains. Taking a stab at describing the EM Domain along these lines, you could say the EM environment is defined by photonic radiant energy, the speed of light, and wavelengths that generally characterize signal propagation.

TECHNOLOGY DOES NOT (TYPICALLY) DEFINE A DOMAIN

One important consideration worth noting is that technology does not usually define a warfighting domain. Instead, technology is merely a manmade tool that exploits the physical characteristics of a domain to allow us to maneuver in it. In the Air Domain, for example, manned flight was first achieved through balloons and gliders before powered flight enabled man to fly at greater speeds, for longer periods and over greater distances. None of these technologies define the physics of flight; they merely exploit it. The same is true of the EM Domain. Until about 1900, when radio technology was developed, humans only used the Electromagnetic Spectrum (EMS) in the visible spectrum. As we developed more advanced tools (receivers and transmitters), we began to use greater portions of the EMS, and the EM Domain became more important to military operations. But, the EM Domain exists whether we have the tools to use it or not. The same is true of the air, land, sea and space domains.



The only exception to this observation is the Cyberspace Domain. It is a physical, man-made domain. It can be turned off, which is a unique characteristic compared to the other major warfighting domains. The DOD defines it in purely technological terms as, "A global domain within the information environment consisting of the interdependent networks of information technology infrastructures and resident data, including the Internet, telecommunications networks, computer systems, and embedded processors and controllers."

Interestingly, I have occasionally heard senior DOD leaders describe the EM Domain as a "manmade" domain. I knew that they were really talking about the technologies that use the EM Domain, but this conflation of technol-

ogy and domain is still problematic and very pervasive.

DOMAINS ARE STRATEGIC MANEUVER SPACES

We've talked about some of the broad physical parameters that define a domain, but there is another dimension that is a bit more subjective. Domains are not only physics based, they are also important – strategically important – to military operations. This is why some domains have evolved over time alongside, or because of, the technologies that we use to exploit them. Yes, I just explained that technologies do not define a warfighting domain (Cyberspace excepted). However, technology does influence how we operate in certain physical maneuver spaces. As technology advances – ships, aircraft, space-lift and satellites, receivers and transmitters, etc. – we can use technology in these tactical maneuver spaces to gain military advantage. When our need to operate in these maneuver spaces becomes strategically important (i.e., we determine that we cannot win unless we can operate in that physical space and deny our adversaries' ability to operate in it), we typically recognize that maneuver space as a warfighting domain. So, it's not just about *defining* a unique physical maneuver space, it's also about *recognizing* that maneuver space as being strategically important.

Not a symbol of domain convergence. The USS John C. Stennis *(CVN 74) launches an EA-18G Growler.* US NAVY

MYTH BUSTING: DOMAIN CONVERGENCE

We often read or hear about Cyber-EW convergence. (We'll address this idea in another column.) But, sometimes we also hear about Cyberspace converging with the EM Domain, which is not the same thing. In case of Cyberspace and EM Domain convergence, either the writer/speaker is not being precise in their language or they are just plain wrong in their understanding. Warfighting domains are physically unique maneuver spaces, and they cannot "converge" in any meaningful sense. The Naval Domain and the Air Domain cannot converge, because one is defined in terms of water (the maritime environment) and the other is defined by gas (the air environment). The same is true of Cyberspace and the EM Domain. Cyberspace is part of the information environment and characterized by digital technology networks, and the EM Domain is characterized by radiant analog electromagnetic energy. These domains cannot converge, any more than air and sea, or ground and space, can.

This being said, warfighting domains often have "fuzzy edges," which is not a good fit for military precision. Where is the domain boundary between land and sea in a coastline comprised of salt water marshes? The Kármán line (100 km above the earth's surface) is generally considered the boundary between the Air Domain and the Space Domain, but what does that distinction mean for military operations? In the case of the EM Domain and cyberspace, the distinction should be a bit clearer, because the electromagnetic spectrum ranges from DC to light and this is definitely *not* Cyberspace.

Convergence confusion typically stems from technologies that operate across two or more domains simultaneously, such as an aircraft carrier (a ship that carries planes that is full of electromagnetic sensors and which is also part of a digital information network), or an amphibious assault vehicle (a weapons platform that floats on water and can drive on land). In the case of the EM Domain and cyberspace, a good example is a fiber-optic cable – a transmission line that carries a pulsed (digital) light (photonic) signal through an enclosed (non-radiant) structure. It is important to remember that these are technologies and not warfighting domains. Technological convergence is not the same thing as domain convergence. We need to be precise about our language if we are to be precise about our thinking.

WHAT'S NEXT

This month's discussion may seem a bit slow, boring and painfully obvious to most of you. But, it is necessary to define the terms of what we will be discussing in future EM Domain articles. In the next article, we will discuss how a warfighting domain is structured and, more specifically, how the EM Domain works.

We welcome your letters! One of our goals in the EM Domain series is to stimulate new thinking and to foster discussion. We do not claim a monopoly on being the only perspective on the EM Domain. Please share your ideas with us by responding with a letter, whether you agree or disagree with this article. E-mail JEDEditor@naylor.com. We will print any letters (with your permission) that move the EM Domain discussion forward.

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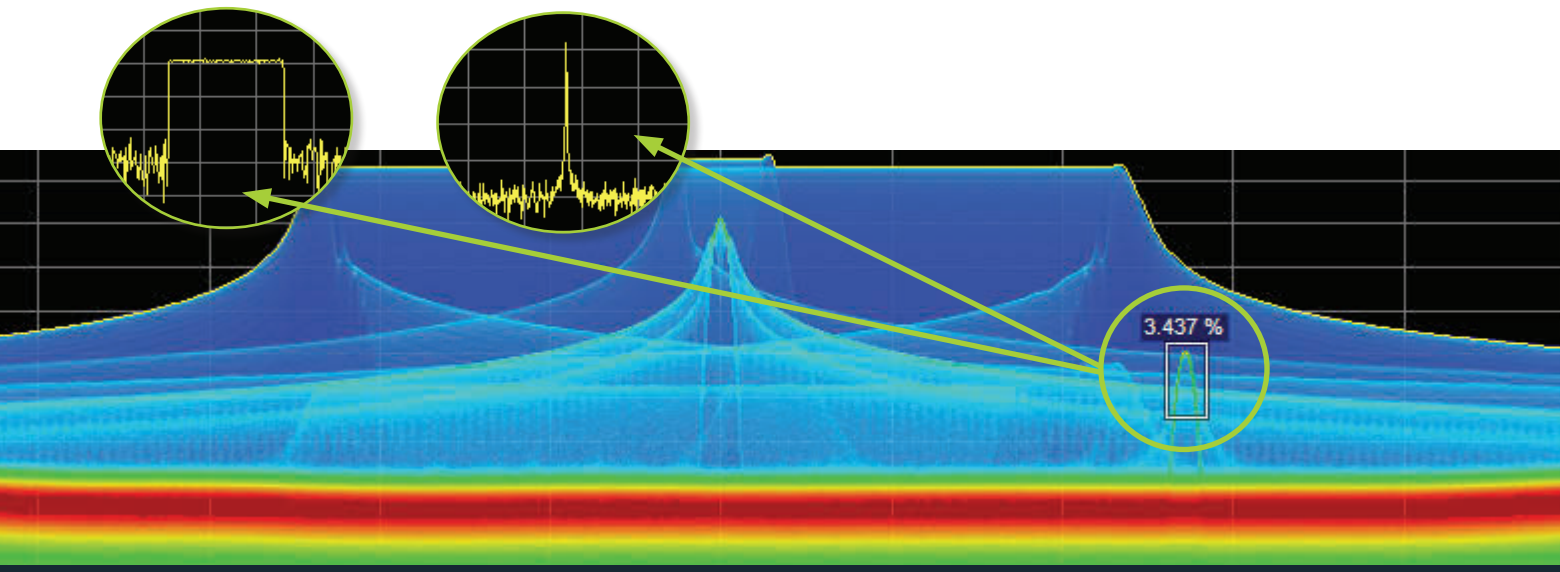

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New EA Techniques Part 2

Jamming Semi-Active Guided Threats

By Dave Adamy

Last month, we talked about stand-off jamming of legacy threats. This month, we will consider the jamming of semi-actively-guided threats as shown in **Figure 1**.

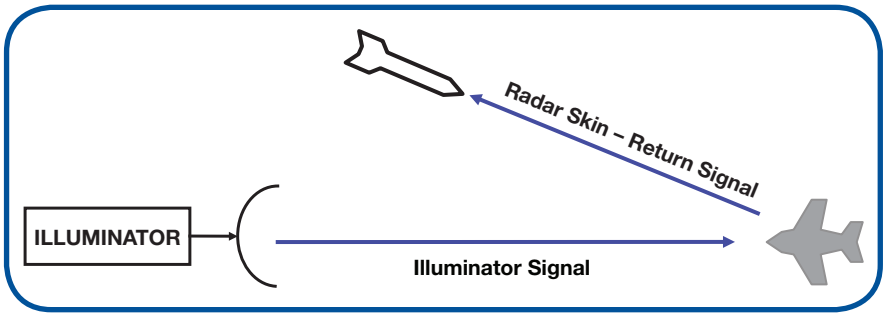


Figure 1: A threat that employs semi-active guidance illuminates an area that contains the target. The illuminator signal is reflected from the target and is received by a receiver in the missile, which guides the missile toward the target.

SEMI-ACTIVE GUIDANCE

A semi-active-guided threat uses an illuminator to cover a large area of space that is expected to include the target being attacked by the threat missile. The missile seeker has a receiver and direction finding capability that allows the missile to home on the illuminator signal being reflected from the target. The illuminator signal is reflected from the target toward the missile with an effective radiated power that is a function of the received power and the bi-static radar cross section (RCS). The RCS included in the earlier formulas is the effective size of the target as reflected back at the radar. The bi-static RCS is the target's effective size as observed from a direction other than that to the radar. In this case, it is the effective size of the target as seen from the missile when the illuminator signal is reflected from the target. The bi-static RCS can be either larger or smaller than the retro-direction RCS depending on the geometry of the target and the intercept geometry.

Like all homing weapons, the miss distance decreases as the range from the target to the receiver (in the missile) decreases. However the illuminator power received by the target decreases as the square of the range from the illuminator to the target. In the case of a missile using semi-active guidance, the signal power from the bi-static illuminator increases as the threat missile approaches the target aircraft.

JAMMING-TO-SIGNAL RATIO FOR SELF-PROTECTION JAMMING OF A SEMI-ACTIVE THREAT

The self-protection jamming geometry is shown in **Figure 2** and the formula for the jamming-to-signal ratio achieved is:

$$J/S = 71 + ERP_J - ERP_I + 20 \log(R_{IT}) - 10 \log RCS_B$$

Where: *J/S* is the jamming-to-signal ratio in dB,

ERP_J is the effective radiated power of the jammer in dBm,

ERP_I is the effective radiated power of the radar illuminator in dBm,

R_{IT} is the range from the illuminator to the target in km, and

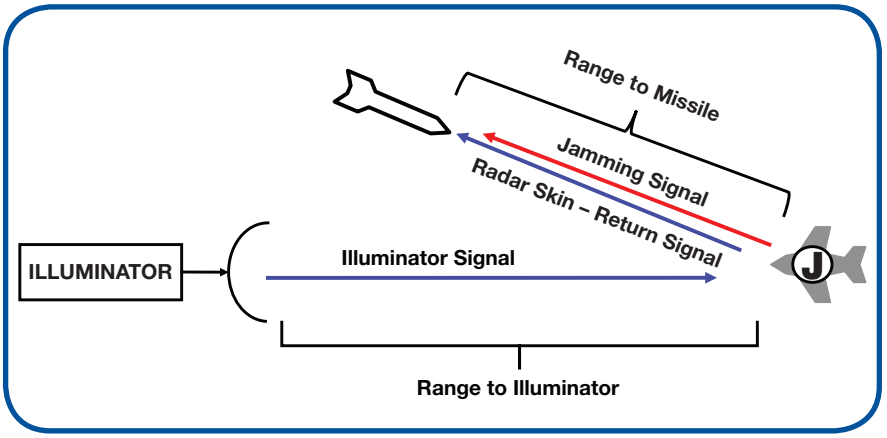


Figure 2: For self-protection jamming against a semi-active guided threat, the jamming signal broadcasts from the target to the missile.

RCS_B is the bi-static radar cross section of the target in m^2

Note that the jammer is located on the target, so the range to the missile is the same for the jammer and the target.

This greatly simplifies the self-protection J/S equation.

An example engagement geometry that has the ERP of the jammer is: (ERP_J) at 1 watt; the ERP of the illuminator (ERP_I) is 1 kw, R_{IT} is 10 km, and RCS_B is 10 square meters:

J/S = 71 + 30 – 60 + 20 – 10 = 51 dB

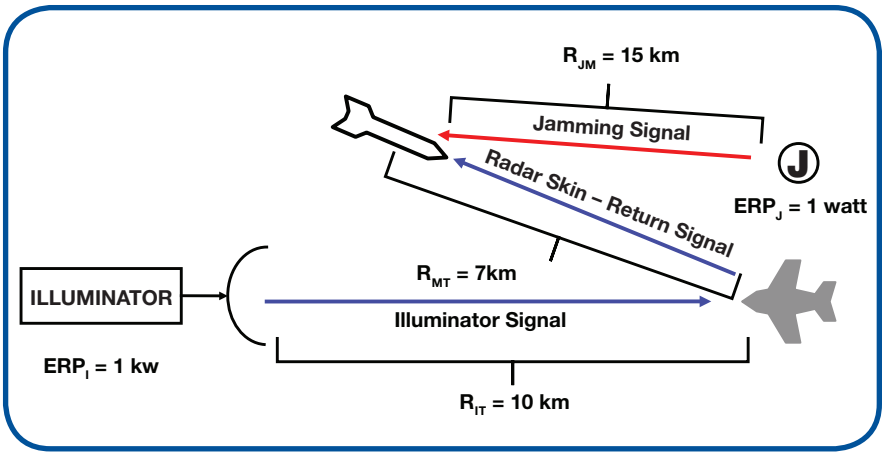


Figure 4: Engagement geometry for remote jamming against a semi-active threat.

BURN-THROUGH RANGE

The burn-through range is a complex concept for semi-active threats, since there are two ranges in play: the range from the illuminator to the target and the range from the missile to the target. The burn-through range is the illuminator to target range at which the jammer can no longer protect the target. First, we set the minimum J/S ratio that will protect the target. This depends on the jamming technique applied. We will use the arbitrary value of 2 dB in this exercise.

First, we solve for the range term in the J/S formula:

$$20 \log R_{IT} = -71 + ERP_I - ERP_J + J/S_{MIN} + 10 \log RCS_B$$

Where: J/S_{MIN} is the minimum J/S at which the target is protected

To calculate a burn-through range with the same ERPs and RCS and 2-dB minimum J/S:

$$20 \log R_{IT} = -71 + 60 - 30 + 2 + 10 = -29$$

Now solving for the actual burn-through range:

R_{BT} is the value of R_{IT} at the burn-through point.

R_{BT} = Anti-log[(value of 20 log R_{IT}) / 20] = anti-log[-0.145] = .035 km = 35 meters

JAMMING-TO-SIGNAL RATIO FOR REMOTE JAMMING OF A SEMI-ACTIVE THREAT

Now, let's assume that the jammer is remote from the target, as shown in **Figure 3.** This could be an expendable jammer or a stand-off jamming UAV, or a support-jamming aircraft protecting several target aircraft.

This is a little more complex than the self-protection jamming case because the jammer-to-missile range is independent of the missile-to-target range, so there are two more terms in the equation:

$$J/S = 71 + ERP_J - ERP_I + 20 \log R_{IT} + 20 \log(R_{MT}) - 20 \log(R_{JM}) - 10 \log RCS_B$$

Where: R_{JM} is the range from the jammer to the missile.

For example, let the intercept geometry be as shown in **Figure 4.** ERP_J is 1 watt, ERP_I is 1 kw, R_{IT} is 10 km, R_{MT} is 7 km, R_{JM} is 15 km, and RCS_B is 10 square meters.

J/S = 71 + 30 – 60 + 20 + 16.9 – 23.5 – 10 = 44.4 dB

BURN-THROUGH RANGE

For a practical example, let's calculate the range from the illuminator to the target at which the jammer can no longer prevent the missile from tracking the target – with the illuminator, jammer and target placed as shown in **Figure 4.**

$$20 \log R_{IT} = -71 + ERP_I - ERPJ - 20 \log R_{MT} + 20 \log R_{JM} + 10 \log RCS_B + J/S_{MIN} (-71 + 60 - 30 - 16.9 + 23.5 + 10 + 2) = - 22.4$$

Now, solving for the actual burn-through range:

R_{BT} = Anti-log[(value of 20 log R_{IT}) / 20] = anti-log[-1.12] = .0759 km = 75.9 meters

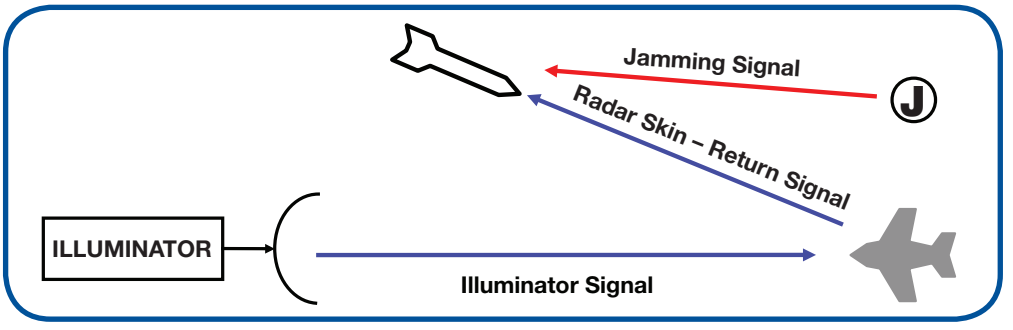


Figure 3: If the jammer is remote from the target (i.e. a support jammer), it still broadcasts to the semi-active threat missile.

WHAT'S NEXT

Next month, we will continue our discussion of jamming techniques and the associated formulas for radars with track-via-missile features. For your comments and suggestions, Dave Adamy can be reached at dave@.lynxpub.com.

AOC ELECTRONIC WARFARE 2019 STOCKHOLM

Unifying Electromagnetic Warfare in a Complex World – Together

The last decade has been a period of great change for military forces looking to control the electromagnetic (EM) spectrum on the battlefield. For many years, the industry was focused on traditional platform-based electronic warfare (EW) systems, something that presented a significant challenge to forces in Afghanistan. The wide use of inexpensive commercial spectrum technologies enabled asymmetric threats – such as radio controlled improvised explosive devices (IEDs) – took a significant toll on operations and required new thinking to overcome. At the same time, peer and near-peer adversaries have continued to improve their capabilities, with radar technologies and guided munitions impeding the ability for friendly forces to manoeuvre unharmed. Compounded by the increasing sophistication of directed energy weapons and the ever-present threat of cyber attack, the EM environment is more complex and challenging than ever before.

For their part, military forces are increasingly aware that winning the fight means being able to operate effectively in a complex EM operating environment. Recognising the electromagnetic domain as a manoeuvre warfare space has placed increased emphasis on the need for electromagnetic manoeuvre warfare (EMW) capabilities such as directed energy, high energy lasers, and investment in solid-state digital systems that will enable them to increase their ability to control the EM space, and exploit integrated C2 and fires to deliver kinetic and non-kinetic effects where and when required to meet emerging threats. Furthermore, they must be able to continue to operate in the face of the enemy's traditional or asymmetric EM assault techniques, including in the contested and area-denied battlespace.

STOCKHOLM

It is within this context that the Association of Old Crows (AOC) brings its 24th European event, Electronic Warfare Europe, to Stockholm in May 2019. This year's event will consider the future of EW and EM operations in the changing light of current and emerging threats including hybrid warfare, information operations/warfare, the multi-domain battle (MDB), cyber and anti-access/area denial (A2/AD) where some potential opponents are currently excelling.

Military, government, industry and academia will come together at EW Europe 2019 to look honestly at the threats and challenges facing the sector, but also the opportunities they present. Recent operations have shown that mature, offensive EW activity in the EM domain is no longer theoretical. Rather, nations and alliances hoping to maintain their security in this increasingly contested environment must adapt and advance their technologies and doctrines to confront the rapidly evolving nature of the landscape. It may well be chaotic unless the right, informed choices are made now.

Among those leading discussions on how to make those choices will be EW Europe 2019 conference chairman, Air Marshal Philip Sturley CB MBE. With a fast jet background in the Royal Air Force (RAF) and extensive attack and reconnaissance experience on the Phantom, Jaguar and Tornado aircraft, Sturley was the first EW Instructor on the Jaguar and held subsequent staff posts at the highest levels of the RAF, Ministry of Defence and NATO. He now acts as Lead Senior Military Mentor for the UK Defence Academy, advising on warfighting at the operational level.

With his deep interest in all EW-related issues, Sturley has acted as chairman for Clarion's EW Europe for a number of years, and more recently also for EW Asia in Singapore; and he is looking forward to seeing what this year's event delivers.

"I try to bring the operational commander's perspective to current EW discussions," he told *JED*. "This is not a subject just for geeks and specialists, but is a matter for commanders at all levels because of the advantage the effective use of EW – and now the wider Cyber & Electromagnetic Activities (CEMA) – brings to the warfighter."

Sturley is keen to see what practitioners and technicians from across the spectrum will bring to the table in Stockholm, with the exhibition and conference offering a unique platform for stakeholders to get together and discuss the latest developments, risks and opportunities in this fascinating, and potentially battle winning, aspect of modern warfare.

"The nature of EW has evolved over the years, but it has always struggled to attract sufficient funding, perhaps because the results are not as evident as a sexy piece of hardware on or above the battlefield," Sturley said. "This has been exacerbated over the last decade by the need to focus main effort in countering the IED threat in Iraq and Afghanistan.

"However, the wars in Ukraine and Syria have been a real wake up call, showing how our potential adversaries have continued to develop all aspects of CEMA and have employed them ruthlessly."

Across the two-day conference, speakers – many of whom are new to the conference – will address EW Europe's overarching theme: the importance of EW system adaptability, flexibility and innovation. Innovative technologies are critical, but equally important is the organisational change needed across the EW community in order to embrace innovative ideas, technologies, and tactics - and at a significantly faster pace. Part of this evolving culture is the increased need for collaboration across countries, militaries, academia and industry to embrace changing technologies, share risks and exploit opportunities, in the same way 'traditional' weapon system platform development has been shared cross-nationally for decades. As a result, changing the ingrained stove-piped nature of EW, signals intelligence, navigation and NAVWAR, communications and C4ISR development will be a central concern for EW Europe, and attendees will examine technological and conceptual means of ensuring success for free-world nations everywhere across the spectrum of operational activity.

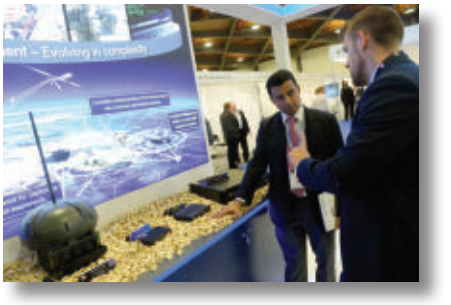
Attendees will have a rich programme to choose from, with day one kicking off with an opening address on *'New Threats and Future EW Systems'* from Johan Falk, Head of Department, Communications EW Research Department at the Swedish Defence Research Agency. This will be followed by a session focusing on the operational future of EW, including presentations on *'Electronic Warfare – The Forgotten Discipline'* from Commander von Spreckelsen, Chief Policy Section NATO Joint EW Core Staff, Germany; and *'Electronic Warfare Training for Pilots'* from Captain (A) Lars-Åke Siggelin, Electronic Warfare Officer, Swedish Air Force, Sweden.

The conference will then split into two parallel tracks: including sessions on Cyber/Artificial Intelligence, EW Data and Information, EW and EM Capabilities, and EW & EM Technology. Day two will continue the parallel tracks, including sessions on EM and Information Manoeuvre, EM Manoeuvre Operations, Testing & Technology Advances, and Technical Challenges and Opportunities. Day two will close with an afternoon session looking at 'The Future', which will include presentations on *'The Case for Machine Learning in Electronic Warfare'* from Dr Paul Brittan, Chief Scientific Officer, L3 TRL, UK; *'Directed Energy Defense Operations: A Continuing Conversation in Protecting Commercial Aerodromes Against Small Commercially Available Unmanned Aircraft Systems'*, from Dr David Stoudt, Engineering Fellow for Directed Energy, Booz Allen Hamilton, US; and *'Radio Frequency Weapons - Potential Uses and Limitations'* from Dr John O'Hara, Owner O'Hara Consulting LLC, US.

WORKSHOPS

This year's Intelligence Workshop is again being hosted by PLATH GmbH. Now in its tenth year, PLATH has once again put together an inspiring programme for the defence and security industry based around three key topics: Cyber Defence, Artificial (Signals) Intelligence, and Multi-Domain Intelligence.

A number of topics will be the subject of guest contributions. The Cyber Defence session will focus on solutions to monitor, detect and investigate any anomalies that take place within an organisation's infrastructure by constantly monitoring network traffic, as well as gathering all log sources, and processing this information in customisable dashboards. The goal here is to allow the customer to be immediately informed of any undesired activities, both external and internal, and allow him to act accordingly.



The Artificial (Signals) Intelligence session will cover not only the current status quo of possible automation in EMS operations, it will also consider the future possibility of using AI technology for more than simple routine work. Key concepts will include 'learning' algorithms in the fields of threat analysis, semantic content analysis, forensics, trend analysis and prediction.

Finally, the multi-domain intelligence session will focus on available and future multi-domain intelligence solutions - which are not limited to the traditional intelligence domains of SIGINT, LI, HUMINT, GEOINT; they also provide open interfaces and adapters also for latest and future domains including hybrid, cyber, and information operations and warfare.

"EW Europe plays a key role in helping us to achieve our goal of raising awareness of issues facing the sector as it grapples with its new multi-domain reality," John Clifford OBE, Wg Cdr RAF (Retd), Director Global Conferences, AOC, said. "This is a huge growth area, and we need leadership and investment from the brightest minds in the industry, academia and the military, which is exactly what the exhibition and conference offers us the chance to find.

"In May in Stockholm we expect more exhibitions and delegates than ever before, and we look forward to meeting with old and new colleagues and friends to share ideas and new developments."

UNIFYING ELECTROMAGNETIC WARFARE IN A COMPLEX WORLD – TOGETHER

DAY ONE – TUESDAY 14 MAY 2019

MORNING SESSION – Plenary Room		
0800 – 0900	**Registration & Refreshments**	
Session One – Welcome		
0900 – 0905	***Chairman's Opening Remarks*** **Air Marshal Philip Sturley** CB MBE BSc FRAeS CCMI, Conference Chairman, RAF (Retd) UK	
0905 – 0925	***Welcome & AOC Briefing*** **Muddy Watters, AOC President, US** **Dr Sue Robertson, AOC International Region 1 Director, UK** **Petter Bedoire, President Viking Roost Chapter, AOC, Sweden** **Magnus Bäckström, Head Business Unit EW, Saab Headline Partner Welcome**	
0925 – 0950	***Keynote Address*** **Brigadier Fredrik Bergman,** Head of Test & Evaluation Division, Defence Materiel Administration (FMV), Sweden	
0950 – 1015	***Opening Address – New Threats and Future EW Systems*** **Johan Falk**, Head of Department, Communications EW Research Department, FOI (Swedish Defence Research Agency), Sweden	
1015 – 1045	**Refreshment Break & Networking**	
Session Two – Operational Focus – The Future		
Chairman: ***Air Marshal Philip Sturley CB MBE BSc FRAeS CCMI****, Conference Chairman, RAF (Retd) UK*		
1045 – 1110	***Electronic Warfare – The Forgotten Discipline*** **Commander von Spreckelsen**, Chief Policy Section NATO Joint EW Core Staff, Germany	
1110 – 1135	***Y Squadron Royal Marines Overview and Recent Composite Team Deployment*** **Sgt Antony Smith,** Radio Reconnaissance Team Leader, Y Sqn 30 CDO IX RM, UK	
1135 – 1200	***Electronic Warfare Training for Pilots*** **Captain (A) Lars – Åke Siggelin**, Electronic Warfare Officer, Swedish Air Force, Sweden	
1200 – 1225	***Integrating & Synchronising Tactical SIGINT & EW during Exercise Dragoon Ready 19*** **Staff Sergeant Maurice Erickson**, EW NCO, 2d Cavalry Regiment, US	
1230 – 1400	**Luncheon Break & Networking**	
	AFTERNOON PARALLEL SESSION TRACK 1 – Plenary Room	***AFTERNOON PARALLEL SESSION TRACK 2 – Room TBD***
	Session Three – Cyber/AI	***Session Five – EW & EM Capabilities***
	Chairman: **Air Marshal Philip Sturley CB MBE BSc FRAeS CCMI**, Conference Chairman, RAF (Retd) UK	**Chairman:** **Dr Bob Andrews MBE,** AOC at – Large Director, UK
1400 – 1425	***Cyber-attacks: The Biggest Threat for Future Weapons*** **Julien Chesaux**, Cyber Security Consultant, Kudelski Security, Switzerland	***Achieving the Operational Goals of the Gripen E EW System, MFS-EW, from Idea to Operational Product*** **Kristoffer Broqvist**, Project Manager Survivability & EW Gripen E, FMV Swedish Defence Materiel Administration, Sweden
1425 – 1450	***Electronic Warfare and Cyber Convergence: Fact or Fiction?*** **Lt Col Wayne Shaw** (USAF Retd), Past AOC President, US	***US Army GPS Modernization and Assured PNT Update*** **Les Berry**, Global Defense Business Development, General Dynamics Mission Systems, US
1450 – 1515	***Artificial Intelligence for EW*** **Dr Henrik Holter**, Head of R&T Saab EW Systems, Sweden	***Advanced Aircraft EW Systems Integration*** **Lars Tolstrup**, Director, Business Developmezzznt, Aeronautics, Terma North America Inc., US

1515 – 1545	**Refreshment Break and Networking in the Exhibition Hall**	
	Session Four – EW Data & Information Session Four	***Session Six – EW & EM Technology***
1545 – 1610	***Transmuted EW for New Scenarios*** **Captain (N Retd) Antonio Dias de Macedo Filho, PhD,** Director, Alfadelta-Rio Densenvolvimento De Sistemas Ltda, Brazil	***Complex Source Detection and Threat Simulation in an Ambiguous Era*** **Sylwester Sobolewski**, Electronics Engineer, EW & Avionics Division, US Air force, US
1610 – 1635	***Spectrum: Multi-Domain and Multi-National*** **Dustan Hellwig,** Chief Technical Officer, Chesapeake Technology International, US	***How ELINT Can Deal With the Current and Future Radar Threat*** **Andrew Owen**, Business Development Manager ELINT/ RESM, Rohde & Schwarz, Germany
1635 – 1700	***The EM Spectrum is Changing – Exploiting Your Data to Achieve Operational Advantage*** **Shaun Vickery**, EW Business Development Manager, MASS, UK	***Hard Wired Data Transmission Security and Performance in a Virtual World*** **Joseph Warren**, Global Product Line Manager, Network Security, Thales e-Security
1700 – 1725	***Deep Learning Applications to Electronic Intelligence*** **Assistant Professor Kyle Davidson**, Chief EW Engineer, MDA, Canada	***CONOPS on Optimizing Joint ISR/EW Operations Interoperability & Effectiveness with Integrated Network-centric C2BM Systems*** **Colonel (HAF Retd) Athanasios Chouliaras**, Airborne ISR & CBM Platform Evaluator, Greece
1725	**Day One Announcements / wash-up**	
1730	**DAY ONE CLOSE**	

DAY TWO –THURSDAY 7 JUNE 2018

	MORNING PARALLEL SESSION TRACK 1	***MORNING PARALLEL SESSION TRACK 2***
	Session Seven – EM and Information Manoeuvre	***Session Nine – Testing & Technology Advances***
0900 – 0905	**Chairman – Opening Remarks** ***Air Marshal Philip Sturley CB MBE BSc FRAeS CCMI****, Conference Chairman, RAF (Retd), UK*	**Chairman – Opening Remarks** ***Dr Sue Robertson*** *AOC International Region 1 Director, UK*
0905 – 0930	***A Method For Optimal Scheduling of AESA Antennas*** **Mrs Sevda Sahin**, Lead System Engineer, Turkey	***Test & Evaluation of Cognitive EA Systems – Requirements for Future Test Systems*** **Dan Pleasant**, Solutions Architect, Keysight Technologies Inc., US
0930 – 0955	***Deployable EW Threat Range Systems – the Why and the How*** **Paul "Heywood" Vavra**, Business Development Executive, Leonardo DRS, US	***System-Level Verification of Modern EW and Radar*** **Jeremy Twaits**, Solutions Manager, Aerospace & Defence, National Instruments, UK
0955 – 1020	***Passive ESM Tracker as part of GBAD*** **Vojtěch Stejskal**, Strategy Development, ERA a.s., Czech Republic	***Testing of Integrated Multifunction Systems*** **Harold Scriven**, Deputy Operating Unit Chief Technology Officer, Northrop Grumman
1020 – 1045	***Element & Techniques for Situational Awareness Using Networked Passive Sensors*** **Christo Pelster**, Product Unit Electronic Surveillance, Saab, Sweden	***New Techniques for Determining Radar ECM Effectiveness*** **Dr Bob Andrews MBE**, EW Consultant, Eldes S.r.l, Italy

1045 – 1115	**Refreshment Break & Networking**	
	Session Eight – EM Manoeuvre Operations	***Session Ten – Technical Challenges and Opportunities***
1115 – 1135	***Portable Cost-Effective 3D AESA Radar – Technology Development & Its Impact on EW*** **Dr Yu-Jiu Wang,** Founder and CEO, Tron Future Tech Inc., Taiwan	***Introduction of Commercial Space-Based EMS Analytics as a Valuable Source of Information*** **Chris DeMay**, CTO, HawkEye 360, US
1135 – 1155	***Proven Airborne Passive Radar Sensor Technology*** **Sebastiaan Verton**, Managing Director, Raytheon Deutschland GmbH, Germany	***Enabling Technologies for the Defense Sector*** **Asif Anwar**, Executive Director Strategic Technologies, Strategy Analytics, UK
1155 – 1215	***Airborne Next Generation V/UHF Ground Emitter Location System*** **Marc Houry**, Head of Product Management, Avantix, France	***High Power Solid State Advances in Technology*** **Paul Correa**, Chief technology Officer, Empower RF, US
1215 – 1235	***Multifunction AESA For EW Missions*** **Dr Nitzan Barkay**, Chief Technology Officer, IAI-ELTA Systems (Intelligence, EW & Comms Division), Israel	***Industry Leadership Panel on the Domain of Vacuum Electron Devices*** **Moderator: Ken Miller**, AOC Director Advocacy and Outreach, US
1235 – 1300	***Spectrum Dominance in a Changing World*** **Frank Kessler**, Product Manager SIGINT and Electronic Support, Spectrum Dominance, Hensoldt Sensors GmbH, Germany	
1300 – 1400	**Luncheon Break & Networking**	

AFTERNOON SESSION – Plenary Room	
Session Eleven – The Future	
Chairman: Air Marshal Philip Sturley CB MBE BSc FRAeS CCMI, Conference Chairman, RAF (Retd) UK	
1400 – 1425	***The Case for Machine Learning in Electronic Warfare*** **Dr Paul Brittan**, Chief Scientific Officer, L3 TRL, UK
1425 – 1450	***Directed Energy Defense Operations: A Continuing Conversation in Protecting Commercial Aerodromes Against Small Commercially Available Unmanned Aircraft Systems*** **Dr David Stoudt,** Engineering Fellow for Directed Energy, Booz Allen Hamilton, US
1450 – 1515	***Radio Frequency Weapons – Potential Uses and Limitations*** **Dr John O'Hara,** Owner O'Hara Consulting LLC, US
1515 – 1540	***The Future of EW and CEMA?*** **Colonel Alan Blackwell** (British Army, Retd), Director, ABAL Insight Ltd, UK
1540 – 1600	***Closing Keynote Address*** **Professor David Stupples TBC**
1600 – 1630	**Refreshment Break & Networking**
Session Twelve – Closing Session & Prize Draw	
Chairman: Air Marshal Philip Sturley CB MBE BSc FRAeS CCMI, Conference Chairman, RAF (Retd) UK	
1630 – 1645	Review – Appreciation – Farewell Chairman Air Marshal Philip Sturley John Clifford OBE, AOC Director Global Conferences AOC EW Europe 2020 Followed by the AOC Prize Draw
CONFERENCE CLOSE	

AOC EW Asia 2019

The third edition of AOC EW Asia was held at the Marina Bay Sands convention center in Singapore, January 29-30, 2019. AOC President Muddy Watters, in his first overseas role as AOC President, welcomed delegates along with Singapore Chapter President Dr. LEE Kar Heng, who delivered an excellent upbeat message. Jeff Walsh, AOC International Region 2 Director, was in support of the event, throughout. Air Marshal Philip Sturley CB MBE BSc FRAeS CCMI RAF (Retd) presided as conference Chair. Other AOC BOD representatives included Professor David Stupples, AOC At Large Director, who also presented two great briefs, as Opening and Closing speaker, and several Chapter Presidents. In his opening address, Professor Stupples covered threats from Russia, the Peoples Republic of China, and North Korea in terms of cyber espionage and its effect on democracy. He also discussed opportunities from CubeSats for western SIGINT space systems in his closing address. Marshal Daljit Singh India Air Force (Retd) started the proceedings to great effect with his keynote address on managing multiple-origin operational systems in the EM domain, touching on core issues which affect many nations in the Indo-Asia Pacific region. In all there were 24 separate presentations from the military, academia and industry covering the entire AOC Mission Area.

AOC President Muddy Watters Welcomes AOC EW Delegates at the start of the 3rd Asia conference.

The Exhibition Hall, which opened at the same time as the conference early on Day 1, supported multiple concurrent Asia Defence Expo and Conference Series (ADECS) conferences and was busy throughout the two-days of EW Singapore. Delegates joined exhibitors in a networking reception in the Exhibition Hall at the end of the first day. The EW element of the exhibition was the largest (over 50% of the 4 collocated defense-related exhibitors were EW/EM companies). Two sponsors contributed greatly to the AOC conference – IAI ELTA and Keysight Technologies. All the EW exhibitors I spoke to remarked on the fact that the level of delegate engagement was outstanding, with many searching questions and excellent participation in the demonstrations the EW exhibitors provided throughout. A big AOC thanks to sponsors and exhibitors at this third concurrent AOC event in the Asia Pacific region.

Some 300 delegates plus attended the EW conference on Day 1 and there were 180 present at the end of Day 2. Altogether, around 1,000 individuals attended the 4-conference ADECS event; EW Singapore was by far the largest. Individuals from 50 countries visited at some point with many of them attending the for the entire EW conference program. Approximately 35% of attendees were serving military. There were 23 specific VIP delegations and 107 VIPs in total. The survey revealed 100% satisfaction with every aspect of the conference and exhibition with 95% of responders saying that the event was good or better and 35% stating it was excellent in every aspect. There were some great testimonials and comments including a number about the breadth and depth of content, which broadly covered the whole AOC Mission Area.

AOC EW Asia 2020 is scheduled for the Marina Bay Sands Convention Centre in Singapore in late January 2020 or early February (to avoid the Chinese New Year in 2020 – fixed dates coming soon) – see you there! – *John Clifford OBE*

The AOC finishes setting up the AOC exhibition stand in Singapore, just prior to the rush of delegates and visitors.

Security Cooperation Symposium
Interoperability, EW, & FMS
29 APRIL – 1 MAY 2019 Atlanta, Georgia

ASSOCIATION of OLD CROWS

STILL TIME TO REGISTER!

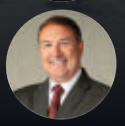
"Interoperability, Electronic Warfare (EW), and Foreign Military Sales (FMS)"

The Association of Old Crows (AOC) and the Georgia Tech Research Institute (GTRI) look forward to hosting International and U.S. attendees at the 2019 Security Cooperation Symposium at the GTRI Conference Center in Atlanta, Georgia, April 29 – May 1, 2019. This world-class symposium will serve as a platform for information exchange and education on defense technology interoperability (EW, Datalinks, Communications, Command and Control (C2), Navigation, and Avionics systems) and associated U.S. FMS and Export Control policies and processes.

KEYNOTE AND DISTINGUISHED SPEAKERS

Vice Admiral Giuseppe Cavodragone, Italian Navy Joint Operations Commander *(invited)*

Rear Admiral Francis D. Morley, USN, Director, Navy International Programs Office (IPO), Washington Navy Yard *(invited)*



Lt. Gen. (Ret) Chris Bogdan, USAF retired and former PEO-JSF

Mr. Michael Shoults, SES, Director of Policy, Programs and Strategy, International Affairs, Office of the Deputy Under Secretary of the Air Force (International Affairs)

Ms. Ann Cataldo, SES, Deputy Assistant Secretary of the Army for Defense Export & Control (DASA DE&C)

Mr. Patrick Mason, SES, Deputy, US Army Deputy Program Executive Officer (PEO) for Aviation, Redstone Arsenal, AL

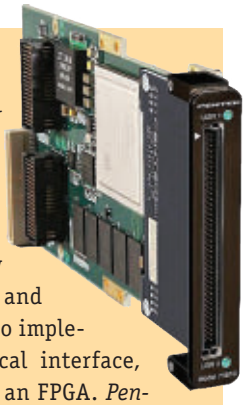
More than 10 distinguished speakers will be in attendance!

VISIT **CROWS.ORG** FOR MORE INFORMATION

FPGA BOARD

Annapolis Micro Systems has added the WILDSTAR 3XBM 3U OpenVPX FPGA board to its Wild100 Eco-System family of boards and systems. The new board offers 100 GBPS Ethernet (GbE) capability, and 16 LVDS and 12 HSS backplane connections for high-bandwidth backplane connectivity. The 3XBM processor is intended for real-time data digitization, processing and storage. *Annapolis Micro Systems; Annapolis, MD, USA; +1 410-841-2514; www.annapmicro.com.*

DATA CONVERTER XMC MODULES

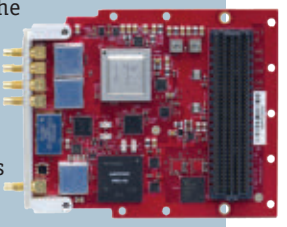


Pentek has introduced the Model 71813 to its Jade family of data converter XMC modules. The new model features 28 LVDS digital I/O pairs to meet Sensor Open Systems Architecture (SOSA) requirements and allow for a customizable I/O signal status and control interface. The Model 71813 also implements an optional front panel optical interface, which supports four 12 GBPS lanes to an FPGA. *Pentek, Inc.; Upper Saddle River, NJ, USA; +1 (201) 818-5900; www.pentek.com.*

ARBITRARY WAVEFORM GENERATOR

Tektronix has released the AWG70000B Series Arbitrary Waveform Generator (AWG) for use in radar, electronic warfare (EW) and threat detection simulation. The new AWG offers sample rates up to 50 GSPS, 32 GSample waveform memory, and streaming waveform identification, a new capability for Tektronix AWGs. The AWG70000B also allows access to more than 16,000 sequences and makes it possible to change modulation types during simulation. *Tektronix; Beaverton, OR, USA; +1 (800) 833-9200; www.tek.com.*

WIDEBAND FPGA MEZZANINE CARD



Abaco Systems has released the FMC172 FPGA Mezzanine Card (FMC), a wideband, low latency FMC module. Combining a high sampling rate, low latency and a bandwidth of more than 6.0 GHz, this module is intended for high-speed electronic warfare (EW) applications, including advanced digital RF memory (DRFM) systems. This module delivers up to 6.4 GSPS analog-to-digital conversion (ADC) on a single channel, or two channels at 3.2 GSPS, and up to 6.0 GSPS digital-to-analog conversion (DAC). *Abaco Systems; Huntsville, AL, USA; +1 (256) 382-8200; www.abaco.com.*

SIGNAL ANALYSIS SOFTWARE INTEGRATION

IZT has announced an option for integration of new IZT Modulation Recognition (ModRec) signal analysis software in its IZT Signal Suite of receivers. ModRec offers automatic modulation recognition, intended for use in characterizing the RF environment; identifying signals in specific frequency bands; and detecting, classifying and demodulating radio signals. This software offers easy upgrades with future technologies, faster automated processing time and an increased number of supported modulation schemes. *Innovationszentrum für Telekommunikationstechnik GmbH IZT; Erlangen, Germany; +49-9131-9162-0; www.izt-labs.de.*

GAN AMPLIFIERS

Qorvo has expanded its line of gallium nitride (GaN) amplifiers to include the QPA2213 and QPA2213D 2 Watt, wideband driver amplifiers. Both amplifiers cover a frequency of 2-20 GHz, and provide 16 dB of large-signal gain while achieving more than 23 percent power added efficiency (PAE). The two models are intended for use in electronic warfare (EW), radar and communication applications. *Qorvo; Richardson, TX, USA; +1 (972) 994-8200; www.qorvo.com.*

FEATURED LIVE WEB COURSES:

EDUCATIONAL COURSES

DRFM Technology and Design for Electromagnetic Maneuver Warfare

MONDAYS & WEDNESDAYS
13:00 – 16:00 EDT (17:00 – 20:00 UTC)
June 3rd – June 26th, 2019
Instructor: Dr. Phillip E. Pace, Naval Postgraduate School

Digital RF memories (DRFMs), are arguably, the most important technology and a driving force in electromagnetic maneuver warfare (EMW). This course examines both the design of the DRFM as well as the technologies and strategies used to create superior false target decoys.

Introduction to Radar Systems

MONDAYS, WEDNESDAYS, & FRIDAYS
13:00 – 16:00 EDT (17:00 – 20:00 UTC)
July 29th – August 9th, 2019
Instructor: Kyle Davidson

This course introduces the audience to radar systems in a military context, with a focus on search and tracking radars associated with modern day threats. Conducted in six modules covering: radar fundamentals, the electromagnetic environment, target detection, antennas, arrays, signal processing, search radars, and tracking radars. At the end of this course students will be able to understand and model threat radar systems, and possess the required knowledge for further training in electronic intelligence (ELINT) and countermeasure development.

Airborne Expendables/ UAS Capabilities and Potential

MONDAYS & WEDNESDAYS
13:00 – 16:00 EDT (17:00 – 20:00 UTC)
August 19th – August 28th
Instructor: Dr. Patrick Ford

Expendables and small unmanned aerial systems (sUAS) are playing an increasing role in both commercial and military operations, due in large part to their unique capabilities, as well as their (often) low development and deployment costs. This course provides attendees with a strong foundation in expendables/sUAS, from basic airframe classes and capabilities, to EW potential, to the current FAA airframe and pilot certification/ flight approval process.

SPACE EW

MONDAYS, WEDNESDAYS, & FRIDAYS
13:00 – 16:00 EDT (17:00 – 20:00 UTC)
September 4th – 20th
Instructor: Dave Adamy

Space is an Electronic Warfare domain, just like land, sea and air. We significantly dependent on satellite assets and those assets are vulnerable to enemy kinetic or electronic attack. In the eight sessions of the Course, we will cover the nature of EW in space and go on to work practical EW problems appropriate to the space environment. Each session will include a lecture and hands-on problem solutions.

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

ASSOCIATION OF OLD CROWS news

BILLY MITCHELL CHAPTER STEM PROGRAM REACHES HECTOR GARCIA MIDDLE SCHOOL

On January 27, the Billy Mitchell Chapter (BMC) taught electromagnetic principles to over 500 eighth grade students at Hector Garcia Middle School for the third year as part of the Chapter's Science, Technology, Engineering and Mathematics (STEM) program. The instructors were Kent Namikas, Ross Vincent, Captain Ajay Reddy, Gary Henley and Dr. Marius Necsoiu, supported by the STEM lead, Candace Schantz.

Instructors worked with classes of 30 to more than 100 students, providing examples of how we use the EMS to sense, communicate and transfer energy; and explaining and demonstrating wave theory and antenna theory, and principles like propagation, polarity, refraction, reflection and absorption.

For the class's climax, instructors demonstrated a software-defined-radio setup they'd put together, – a simple device that costs about $20 and could plug into almost any computer. They explained that the device is easy to program, and demonstrated FM broadcast signals, discussing the importance of matching the bandwidth of the transmitted signal. One of the students volunteered to key the mic of the handheld radio, and students' eyes lit up as they saw the signal appear on the screen. The instructors had been talking about electromagnetic signals throughout the class, but now the students could actually see them on the screen. The BMC members had the student talk into the radio, causing the signal to shift around as the system displayed the frequency modulated transmission.

BILLY MITCHELL CHAPTER HOSTS TECHNICAL PRESENTATION LUNCHEON

On February 12, the Billy Mitchell Chapter hosted a luncheon at the Lackland Club with over 50 crows in attendance, including Sam Roberts, the Western-Mountain Regional Director.

The first presentation related to Operation Bolo, led by Col (ret) JB Stone. While on active duty, Stone flew the F-102 and F-4. Then, later in the Colorado Air National Guard, he flew the F-100 and A-7. During his brief, Stone explained his role as a wing tactics officer, when he worked closely with then Col Robin Olds to develop the plan to lure and trap North Vietnamese MiG-21s by mimicking F-105 bombing formations. They used F-105 call-signs, routes and flight profiles. In the end, it was a highly successful operation that led to the highest number of downed enemy aircraft for one mission during the Vietnam War – seven MiGs in 15 minutes.

Col (ret) Dave "Tooms" Toomey was the event's second speaker. While in the Air Force, he flew F-4G Wild Weasels and F-117A stealth fighters in operations Desert Storm, Southern Watch, and Iraqi Freedom. He was the Commander of the 8th Fighter Squadron Black Sheep at Holloman AFB as well as the Air Force Information Operations Center at Lackland AFB. Stone spoke about his experience flying F-117As during operation Iraqi Freedom, a mission that was conducted days sooner than anticipated and with very little information available at takeoff. After being given target specifics and departing under radio silence for the flight into country, they met a KC-10 tanker and had to request the tanker push north into country to maintain their tight requirement of the time on target. Soon after, they met up with EA-6Bs and F-16s that would provide support for the mission. They pressed inbound and struck their target just seconds before Tomahawk cruise missiles leveled surrounding targets. Stone returned to base without incident after participating in the opening round of the war.

DIXIE CROW CHAPTER SUPPORTS HABITAT FOR HUMANITY

The Dixie Crow Chapter chuck wagon crew, led by Chef Roadkill, aka Mark Leslein, assembled on February 16 to feed the Habitat for Humanity crew that was working on the "wall raising" for their 59th Habitat for Humanity Home in Warner Robins, Georgia. The crew prepared and served over 40 volunteers with a barbecued meal.

Dixie Crow Members, from left to right: Betsy Moore, Lisa Frugé-Cirilli, Ron Herpst, Debbie Koenig, Ken Cirilli, Tom Miller, Mark Leslein, Lynwood Moore, Martha Leslein, Dave Coley and Scott Wolf.

11th Annual Electronic Warfare Capability Gaps and Enabling Technologies

ASSOCIATION OF OLD CROWS

14-16 MAY 2019 — Crane, Indiana

Achieving Freedom to Maneuver Leveraging Non-Kinetic Capabilities

REGISTER NOW!

This forum provides a venue for stakeholders, thought-leaders and experts in Electronic Warfare to come together to focus on the technologies the services require to ensure freedom to maneuver through leveraging the Electromagnetic Spectrum and Non-Kinetic Capabilities and discuss issues related to the requirements of EW programs, platforms, and operations. Panel sessions will provide insight into EW Roadmaps for the Services, Integrated Non-Kinetic Fires, and Enabling Future Technologies for EW. Presenters will highlight capability gaps and motivate the attendees to provide innovative EW concepts and solutions to expand the advantage for our military forces leveraging non-kinetic capabilities.

DISTINGUISHED SPEAKER

Mr. Bryan Clark
Senior Fellow, CSBA

Sponsorship opportunities available!

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AOC Industry and Institute/University Members

SUSTAINING

BAE Systems
Ball Aerospace & Technologies Group
Bharat Electronics LTD
The Boeing Company
CACI
Chemring Group Plc
DRS Defense Solutions
Electronic Warfare Associates
General Atomics
General Dynamics
Harris Corp.
Keysight Technologies
Leonardo MW Ltd.
Lockheed Martin Mission Systems and Training (MST)
Mercury Systems
Northrop Grumman Corporation
Raytheon Company
Rockwell Collins
Rohde & Schwarz USA
Saab

MILITARY UNITS

453 EW Squadron Research
51 Sqn, Royal Air Force
French Air Force EW Unit
Helicopter Wing 64
Japan Air Self-Defense Force
JEWOSU
MAG-14
New Zealand Defence Force
Saudi Ministry of Defense
VMAQ-2
VMFAT-501
Zentrum Elektronischer Kampf Fliegende Waffensysteme

INSTITUTES/UNIVERSITIES

Electronic Warfare Studying Group, Korean Institute of Electromagnetic Engineering & Science
Georgia Tech Research Institute (GTRI)
Mercer Engineering Research Center
Riverside Research Institute

GOVERNMENT GROUPS

Defence Science & Technology Agency (DSTA)
SAGE

GROUPS

3dB Labs Inc.
Aeronix, Inc.
Aethercomm, Inc.
A.G. Franz, LLC
ALARIS Antennas
Allen-Vanguard
Amplus Corporation
Anaren Microwave, Inc.
Annapolis Micro Systems, Inc.
Anritsu Company
Antenna Research Associates, Inc.
ApisSys SAS
Applied Systems Engineering, Inc.
Arch Systems
Arctan, Inc.
Aselsan A.S.
Atkinson Aeronautics & Technology, Inc.
Atlanta Micro, Inc.
Azure Summit Technologies, Inc.
Base2 Engineering LLC
Battlespace Simulations, Inc.
Bird Technologies
Blue Ridge Envisioneering, Inc.
Booz Allen Hamilton, Inc.
Boyd Corporation
Broadern
Bryant Solutions, Inc.
Cablex PTY LTD
CDM Electronics
Centerline Technologies LLC
Clearbox Systems
Cobham Advanced Electronic Solutions
Collins Aerospace
Colorado Engineering Inc.
Communication Power Corporation
Communications & Power Industries LLC
COMSEC LLC
Comtech PST Corporation
CRFS Inc.
Cubic Global Defence
Darkblade Systems
Dayton-Granger, Inc.
DCS Corp
Decodio AG
Defense Research Associates
DEFTEC Corporation
DEWC Pty Ltd
DHPC Technologies, Inc.
Digital Receiver Technology
DragoonITCN
D-TA Systems, Inc.
Dynetics, Inc.
Elbit Systems EW and SIGINT – Elisra
ELDES S.r.l.
Elettronica SpA
ELTA Systems Ltd.
Empower RF Systems
Epiq Design Solutions, Inc.
ERZIA Technologies S.L.
ESROE Limited
Esterline Defense Technologies
Evans Capacitor Company
EW Solutions
FEI-Elcom Tech, Inc.
Galleon Embedded Computing Norway
GFB GmbH
Hammer Defense Technologies LLC
Hanwha Systems
HASCALL-DENKE
Hensoldt Sensors GmbH
Hermetic Solutions
Herrick Technology Laboratories, Inc.
Huntington Ingalls Industries
Independent Conultant, Jeffry Edgar
INDRA
Information Systems Babcock International Group
Innovationszentrum Fur Telekommunikations -technik GmbH (IZT)
Interface Concepts
Invisible Interdiction, Inc.
ISPAS AS
IW Mircowave Products Division
JT4 LLC
Kerberos International Inc.
Kirintec
Kranze Technology Solutions, Inc. (KTS)
KRATOS GENERAL MICROWAVE CORPORATION
Kudelski Security, A Division of Nagravision S.A.
L-3 Communications Cincinnati Electronics
L3 Micreo
L3 Randtron Antenna Systems (L3 Randtron)
L3 TRL Technology
Leonardo DRS
LGS Innovations
Liteye Systems, Inc.
LS Telcom AG
MacAulay-Brown
MarServices GmbH
Mass Consultants
MBDA France
MC Countermeasures, Inc.
Meggitt Defense Systems
Metamagnetics
Micro Lambda Wireless
Microwave Products Group
Military College of Telecommunication Engineering
Milso AB
MilSource
Mission Microwave Technologies
The MITRE Corporation
Modern Technology Solutions, Inc.
Motorola Solutions
MRC Gigacomp
MULTICONSULT SRL
My-konsult
MyDefence
N-Ask Incorporated
National Technical Research Organization
Narda Safety Test Solutions GmbH
Northeast Information Discovery, Inc.
Novator Solutions AB
Nuvotronics, Inc.
Overlook Systems Technology
Parry Labs
Pentek
Peralex
Peraton
Phase II Staffing and Contracting LLC
Phasor Innovation
Photonis Defense, Inc.
Physical Optics Corporation
Planar Monolithics Industries
Plath, GmbH
Plexsa Manufacturing
Polaris Alpha (formerly EOIR Technologies Inc.)
Professional Development Tech Group Inc.
QinetiQ Target Systems
Qnion Co., Ltd.
Quarterwave Corp.
RADA Technologies LLC
RADX Technologies, Inc.
Reliant Global Solution
RFHIC US CORPORATION
Rincon Research Corporation
Rohde & Schwarz GmbH & Co. KG
Rohde & Schwarz Norge AS
Roschi Rohde & Schwarz AG
Rotating Precision Mechanisms
S2 Corporation
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JED, The Journal of Electronic Defense (ISSN 0192-429X), is published monthly by Naylor, LLC, for the Association of Old Crows, 1555 King St., Suite 500, Alexandria, VA 22314.

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

POSTMASTER:
Send address changes to
JED, The Journal of Electronic Defense,
c/o Association of Old Crows,
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