AUGUST 2010
Vol. 33, No. 8

The AOC Electronic Warfare Publication
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JED

The Journal of Electronic Defense

USAF UAS Flight Plan: Implications for EW

Also in this issue:

JEPAC: Enhancing Air Combat Capability

Technology Profile: DRFMs

News

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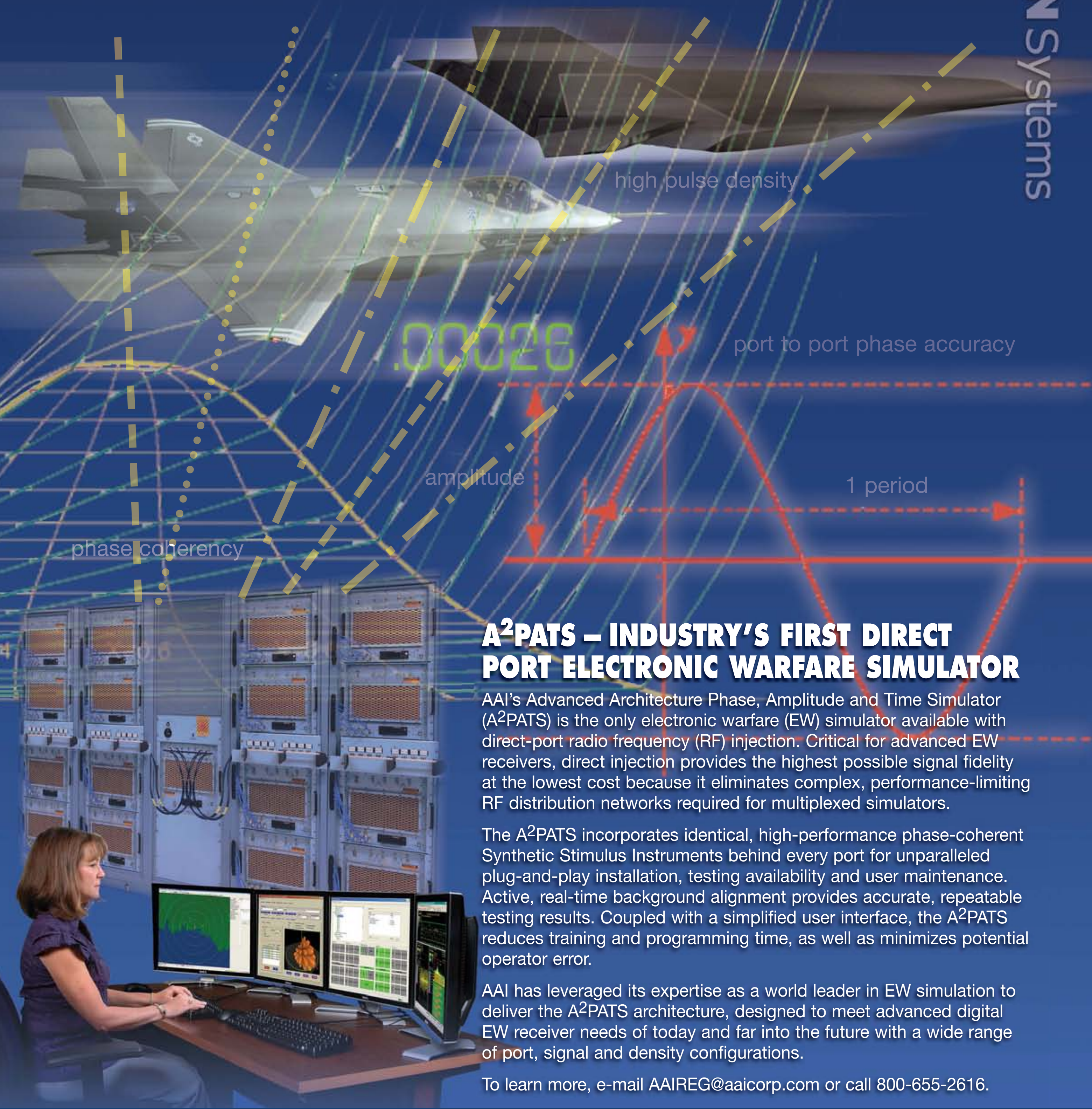

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A PROBLEMATIC TREND

I'm writing this month's editorial on my flight home from London, having just spent the week at the 2010 Farnborough Air Show. One reason that I enjoy attending events such as Farnborough is because they offer an excellent opportunity to sit down with business leaders and to take the pulse of industry.

During my meetings throughout the week, the topic of bid protests came up more than a few times. Protests once were viewed as a somewhat impolite conversation topic, akin to mentioning death, taxes or dentistry at the dinner table. That attitude has been changing in recent years, primarily because protests are becoming much more common.

I won't name any programs, but one EW company I saw at Farnborough was selected for a DOD contract in 2009. However, the decision was undergoing its third bid protest (the first two protests having been thrown out by the Government Accountability Office). As of late July, the contract award decision had not been resolved by the GAO, and the program in question is well behind schedule. While the equipment involved is not operational EW gear, it is important EW equipment that affects the combat survivability of soldiers. With so many current and upcoming EW and SIGINT competitions in the US, such as the Next Generation Jammer, Common IR Countermeasures, Joint and Allied Threat Awareness System and Enhanced Medium-Altitude Reconnaissance and Surveillance programs, I can't help wondering how many of these competitions are likely to end up in similar protest situations.

Individually, a bid protest may seem like a nuisance. But what is the cumulative effect of these protests? What is the cost to the DOD budget and to industry in terms of dollars spent defending and/or recompeting a contract? More importantly, what is the cost to the warfighter when a needed EW capability is delayed?

The DOD may not like this trend toward more protests, but the Pentagon leadership can do little to change the behavior of industry. Defense companies are responsible to shareholders, as well as to their DOD customer. Admittedly, companies do less hand-wringing these days when it comes to deciding whether or not to pursue a bid protest. They know they will risk the wrath of the military customer. But the business opportunities are too few and too valuable to let them pass without employing every possible tactic. At the same time, many defense acquisitions have become so complex that they create more opportunities for industry to challenge contract award decisions.

In order to stop this trend (and hopefully reverse it), the DOD knows it must reform its acquisition process and improve the competence of its acquisition workforce. (Companies often have a huge advantage over military program managers and government contract personnel in terms of acquisition experience, professional development and legal resources.) Fortunately, Congress seems to agree with the DOD leadership with regard to the more important aspects of acquisition reform. This is a long process however, and this cooperation must continue for many years to come before we can expect to see a substantive change.

– John Knowles

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www.afa.org

Africa Aerospace & Defence
September 21-25
Cape Town, South Africa
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October 3-6
Atlanta, GA
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NOVEMBER

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Monterey, CA
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Electronic Warfare Symposium
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Swindon, Wiltshire, UK
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FEBRUARY

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Bangalore, India
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IDEX
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WHAT IS EW BATTLE MANAGEMENT?

When I retired from the Air Force in 2004, the new term being bantered around the EW community was EW Battle Management (EWBM). I believe the term had its origins in the Joint AEA System-of-Systems (SOS) Study done at the beginning of the decade. As a result of that study, there was a realization that EW capabilities operating in a net-centric environment would require additional planning, execution, control and assessment functionality. This sparked a movement within the EW community that continues to burn brightly.

Over the last 10 years, EWBM has evolved into operational concepts of varying complexity within each of the Services and throughout an EW industry base looking to provide suitable solutions. Just this month, US Air Combat Command and the Aeronautical Systems Command (ASC) issued contracts in order to determine the art of the possible for EWBM in the 2015 timeframe. The US Navy is also addressing EWBM with regards to future Growler capability. The US Army believes it is required for the future Integrated EW System (IEWS), and the US Marine Corps requires EWBM for its aggressive vision of MAGTF EW.

Having worked within Service and Joint requirements processes, I have to ask the question: What is the agreed upon definition of EW Battle Management to which all of these efforts are working toward? Is it simply a machine-to-machine capability that allows a fighting formation of EA-18Gs to exchange EW J-Code messages, or is it a broader construct of integrated planning, connectivity, information assimilation and decision management? It finally appears as if EWBM is suffering from an identity crisis. Yes, we all have our opinions of what EWBM should look like and we will certainly see versions of all of them developed if we don't take action to agree on some EWBM fundamentals.

The Air Combat Command EWBM request for information provides a great start for establishing some fundamentals which can be used across the Services and jointly. EWBM must provide the capability to: fuse and display existing/available electromagnetic spectrum data; automate the target/weapon pairing process; automate the course of action (COA) development process; perform COA assessment and recommendation and assess planned and/or accomplished electronic attack effects.

While these requirements don't cover the waterfront of EWBM, it should become clear that it is more than the ability to exchange tactical data. For example, EWBM requires a Theater Strategic and/or Operational level planning capability that can meet the needs of the EW Coordination Cell (EWCC). It will require a network enabled connectivity that can feed both Common Operational Picture needs and meet the dynamic information exchange requirements of tactical capabilities executing the mission. EWBM capabilities will need access to a number of disparate databases and multiple levels of security. And these are just some of the myriad requirements which continue to surface.

To limit mission creep on our initial EWBM capabilities, I urge the Services and joint EW advocates like the Joint Electronic Warfare Directorate to collaborate on an initial definition for EWBM in order to solidify the requirements. EWBM is a multifaceted problem; let's find out how deep the water is before we dive in headlong.

– Chris "Bulldog" Glaze

the monitor news

NEXT-GENERATION JAMMER CONTRACTS AWARDED

US Naval Air Systems Command (NAVAIR) awarded four companies Technology Maturation (TM) contracts on July 13 in support of the Next-Generation Jammer (NGJ) program. The Navy wants to develop the NGJ to replace the venerable ALQ-99 jamming pods currently used on its EA-6B Prowler and new EA-18G Growler replacement aircraft. The NGJ pods would be integrated on the EA-18G and possibly the F-35 Joint Strike Fighter. They are slated to reach an initial operational capability in 2018.

BAE Systems, ITT, Northrop Grumman and Raytheon, which conducted NGJ trade study contracts in 2009, each received a $42 million TM contract running 21 months until April 2012. The companies submitted bids last October, at which time the Navy planned to award up to four 10- to 14-month contracts valued at $15-30 million by March 31. NAVAIR subsequently decided to stretch out the TM phase to reduce development risk.

The TM contracts have two objectives. Each company will provide a system-level concept demonstrator design, and then will mature critical technology elements (CTEs) and subsystems required to support that design. The CTEs include power generation, exciters, beam formers, radio-frequency power amplifiers and electronically steered antenna transmit arrays. Volume constraints and waste heat dissipation are key technology challenges across the CTEs for a new external jamming pod.

Following Milestone A approval by DOD officials, the program will enter an 18- to 24-month Technology Development phase with at least two contractors. Each will build a prototype of its concept demonstrator, which will undergo flight testing aboard a surrogate test bed aircraft. Following a Milestone B decision, the Navy will select a single contractor to conduct an engineering and manufacturing development phase.

The Navy's EA-6B/Airborne Electronic Attack Program Office (PMA-234) at NAVAIR (NAS Patuxent River, MD) manages the NGJ program. – *G. Goodman*

USAF SEEKS COMMS JAMMING POD

The US Air Force's Aeronautical Systems Center at Wright-Patterson AFB, OH, released a Broad Agency Announcement (BAA) last month for an Airborne Electronic Attack (AEA) Technology Maturation Study to be carried out by multiple contractors. The primary objective of the study is to better understand industry's potential solutions to meet future airborne platform requirements for an external communications jamming pod.

The EC-130H Compass Call aircraft currently perform the Air Force's standoff communication-jamming missions. However, while their primary purpose is to jam command-and-control networks to disrupt enemy coordination, the four-engine turboprops have logged countless flight hours carrying out non-primary counter-improvised explosive device jamming missions for Army and Marine ground forces in Iraq and Afghanistan. Thus, Air Force officials want to ease the burden on the workhorse EC-130s

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Agenda Highlights

(as of July 19, 2010)

Sunday, October 3

6:30 p.m. - 9:30 p.m.	Welcome Reception at the Georgia Aquarium *Sponsored by Convention Host, Elettronica*

Monday, October 4

9:00 a.m. - 11:00 a.m.	Opening Session – Awards Ceremony and Keynote Speaker
11:15 a.m. - 1:15 p.m.	Symposium Session 1 – The One Constant in EW
2:00 p.m. - 4:00 p.m.	Symposium Session 2 – Military Services Requirements Session 3 – Evolving Policy in Regard to EW Session 4 – New Technology Planning and Insertion
4:00 p.m. - 7:30 p.m.	Exhibit Hall Open
7:30 p.m. - 11:00 p.m.	ITT Roost

Tuesday, October 5

8:00 a.m. - 8:45 a.m.	General Session and Keynote Speaker
9:00 a.m. - 10:50 a.m.	Symposium Session 5 – National Agencies' Requirements Session 6 – New Military Service Programs Session 7 – Evolving Policy on Spectrum Warfare and Management
11:10 a.m. - 1:00 p.m.	Symposium Session 8 – International Military Services/Agencies/NATO Session 9 – Resiliency as a Means of Achieving Mission Assurance Session 10 – Policy in Regard to Cyber Warfare
1:00 p.m. - 6:00 p.m.	Exhibit Hall Open

Wednesday, October 6

8:00 a.m. - 8:45 a.m.	General Session and Keynote Speaker
9:00 a.m. - 10:50 a.m.	Symposium Session 11 – International Activities and Technologies Session 12 – Experimentation: Finding the Needle Amidst the Incredibly Complex Haystacks
11:10 a.m. - 1:00 p.m.	Symposium Session 13 – International EW Opportunities and Challenges Session 14 – Policy and Planning for Law Enforcement and Homeland Security Operations Session 15 – The Real World
1:00 p.m. - 3:00 p.m.	AOC Annual Awards Luncheon *(Open to all Full Symposium attendees)*
3:00 p.m. - 5:00 p.m.	Exhibit Hall Open

by acquiring a new communications-jamming pod – essentially off the shelf and as early as possible -- that could be carried externally on one or more types of other tactical aircraft.

Industry bids are due August 2, and the Air Force plans to award up to three contracts worth $1 million each on September 12. The contractors will define and mature critical technologies enabling effective communications attack with an airborne pod. The goal is to mature these technologies to Technology Readiness Level 6+ by the middle of FY12. It is anticipated that this effort will then transition into an engineering and manufacturing development program.

As the BAA states, "The project vision is to mitigate a significant portion of the capability and capacity gaps that hamper DOD Airborne Electronic Attack by pursuing a common delivery system with mature technology to minimize development time and reduce time required for airworthiness certification on multiple airframes. The results of this study could flow into many current and/or planned USAF acquisition programs."

The solicitation number is ASC-XR-BAA-08-01-01. The contracting point of contact is Anthony Fisher, e-mail anthony.fisher@wpafb.af.mil, (937) 255-7761. The technical point of contact is Robert Matthews, e-mail robert.matthews@wpafb.af.mil, (937) 904-4427. – *G. Goodman*

UPGRADED HARM IN PRODUCTION

The US Navy accepted the first deliveries of full-rate production AGM-88E Advanced Anti-Radiation Guided Missiles (AARGMs) on July 14 from ATK (Woodland Hills, CA). The AARGM

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See a full list of exhibiting companies and register now at www.crows.org team successfully completed both the Developmental and Operational Assessment test phases of the program. The Navy expects to achieve an initial operational capability on F/A-18C/D Hornet fighters within the next couple of months. AARGM entered low-rate initial production in December 2008.

AARGM is a derivative of Raytheon's AGM-88 High-Speed Anti-Radiation Missile (HARM), the primary air-to-surface stand-off weapon used for lethal suppression of enemy air defenses by Navy and Air Force aircraft since 1984. AARGM retains HARM's warhead, wings, fins and rocket motors. The HARM control section is upgraded with a GPS/inertial navigation system (GPS/INS), and its front-end seeker section is completely replaced.

The new multi-mode seeker section features a more sensitive anti-radiation homing seeker with a digital receiver, and an active millimeter-wave (MMW)-radar seeker. The latter is used for terminal guidance when a target radar shuts down after the supersonic AARGM is launched. The GPS/INS allows the missile to attack a non-emitting time-sensitive target if its coordinates are known. The MMW radar seeker can actively search to find a non-emitting target whose exact location is not known or when the target is mobile and likely to leave a known location.

Other aircraft slated to carry AARGM are the Navy's F/A-18E/F Super Hornets and EA-18G Growlers and Italian Air Force Tornado ECR aircraft. AARGM is a cooperative development and production program with Italy. – *G. Goodman*

USSOCOM SET TO RELEASE SIGINT QRC RFP

US Special Operations Command (MacDill AFB, FL) is preparing to release a request for proposals (RFP) from which it will select a prime contractor to carry out task orders under a signals-intelligence (SIGINT) quick-reaction capability (QRC) multiple award contract (QRC MAC).

USSOCOM is interested in finding mature SIGINT systems capabilities that can be ready for fielding within 180 days from the date of order. Specifically, USSOCOM is interested in industry capabilities in tactical SIGINT receivers, tactical SIGINT antennas, SIGINT payloads for unmanned aerial vehicles, signals processing, precision direction finding and geo-locating, net-centric SIGINT systems (to include mobile ad hoc networking technology, secure mesh technology, secure high-speed wireless networking and data links), and all packaging and power management capabilities.

The contract's potential value is $20 million to $50 million per year. The contract will include one base year and four options years. The point of contact is Gerald McGhee at (813) 281-0560, ext. 304, or e-mail jerry.mcghee@socom.mil. The solicitation number is H92222-10-R-0024. – *G. Goodman*

IN BRIEF

Argon ST (Fairfax, VA) announced that it has agreed to be acquired by **Boeing** for $775 million. If the deal is approved, Argon ST will be a stand-alone subsidiary of Boeing and a new division of Boeing Network & Space Systems, a business within the Boeing Defense, Space & Security operating unit. Argon ST will continue to be led by the same management team, including Dr. Terry Collins, its chairman and CEO, and Kerry Rowe, its president and COO. Boeing expects to complete the acquisition by the end of September. Founded in 1997, Argon ST develops sensors and networks, particularly signals-intelligence systems, designed to exploit, analyze and deliver information for real-time situational awareness. In FY09, the company generated $366 million in revenues.

✪ ✪ ✪

Northrop Grumman Intelligence Systems' Electromagnetic Systems Laboratory (San Jose, CA) received a $14.5 million Airborne Signals Intelligence Payload (ASIP) add-on contract from US Air Force Aeronautical Systems Division (Wright-Patterson AFB, OH) that extended its baseline contract to support ASIP sensor flight testing on the Global Hawk unmanned aerial vehicle.

✪ ✪ ✪

BAE Systems Electronics, Intelligence and Support (Nashua, NH) received a $13.7 million US Army contract to supply 80 Advanced Threat Infrared Countermeasures (ATIRCM) Quick-Reaction Capability A-kits and 24 B-kit line-replaceable units for CH-47 Chinook helicopters. The company separately received a $31 million contract from Naval Air Systems Command for Lot 6 low-rate initial production of ALE-55 fiber-optic towed decoys for US Navy and Royal

Australian Air Force F/A-18E/F Super Hornet fighter aircraft.

✪ ✪ ✪

Lockheed Martin Corp. (Fort Worth, TX) has received an advance acquisition contract worth $522.2 million for long-lead efforts and materials for production and delivery of 42 low-rate initial production Lot V F-35 Joint Strike Fighter aircraft. The contract combines purchases for the US Navy and US Air Force and provides for convention take off and landing aircraft for the Air Force, 13 short take off and vertical landing aircraft for the Marine Corps and seven carrier variant aircraft for the US Navy. Work is expected to be completed by May 2011. In July, Lockheed Martin also received an $819.6 million cost-plus-incentive fee modification to this contract for special tools and test equipment in support of the JSF, combining purchases for the Navy, Air Force and international partners. Naval Air Systems Command, Patuxent River, MD, is the contracting agency.

✪ ✪ ✪

ITT (Clifton, NJ) has been awarded a $7.4 million contract from the Warner Robins Air Logistics Center, Robins Air Force Base, GA, to provide block cycle software support and maintenance test set engineering services for the ALQ-172 countermeasures system. The ALQ-172 is used board the B-52 and C-130 Special Operations aircraft.

✪ ✪ ✪

AAI Corp. (Hunt Valley, MD) received a $37.9 million contract from US Army Contracting Command, Redstone Arsenal, AL, to increase funds and exercise options on an existing Shadow tactical unmanned aircraft system performance-based logistics contract. Work is estimated for completion by Oct. 31, 2010.

✪ ✪ ✪

Aegis Technologies Group, Inc. (Huntsville, AL) has been awarded an $8 million contract from US Army Research, Aberdeen Proving Ground, MD, for development of a reconfigurable arbitrary-waveform scene projector under the "OSD, Test Resource Management Center Multispectral Test" program. The work has an estimated completion date of Dec. 5, 2013.

✪ ✪ ✪

Cobham Sensor and Antenna Systems (Lansdale, PA) received a maximum $49 million firm-fixed-price, indefinite-delivery/indefinite-quantity contract for procured antenna detectors. Work is expected to be complete by July 15, 2015. The Defense Logistics Agency, Warren, MI, is the contracting agency.

✪ ✪ ✪

BAE Systems, Information & Electronics Systems Integration (Nashua, NH) has been awarded a maximum $7 million firm-fixed-price, sole-source, undefinitized contract for electronic frequency convertor units. Work should be complete by Sept. 1, 2011. The Defense Logistics Agency, Philadelphia, PA, is the contracting agency.

washington report

AOC OPPOSES HASTY SPECTRUM AUCTION

The Association of Old Crows (AOC) announced June 30 that it opposed efforts by the Obama Administration to sell 500 megahertz of the electromagnetic spectrum for commercial wireless use and cautioned against expeditious passage of the Radio Spectrum Inventory Act and other spectrum auction legislation by Congress.

The National Broadband Plan calls for the sale of 300 MHz of spectrum in five years and a total of 500 MHz in 10 years. In a letter to the FCC, AOC President Christopher Glaze wrote, "We recognize the growing need for commercial spectrum, but the FCC, the DOD and the entire Administration must understand how vital the spectrum is to every warfighting capability in the 21st century."

The Broadband Plan and efforts by Congress to expedite the auction process, the AOC says, will significantly and disproportionately affect the joint warfighters who rely on the spectrum to train and fight in demanding environments such as Iraq and Afghanistan.

There are currently two bills before Congress that the AOC believes will negatively affect the military services: the Radio Spectrum Inventory Act and the Spectrum Relocation Improvement Act. "The AOC has worked hard to make substantive improvements [to the Radio Spectrum Inventory Act]," wrote Glaze. "While pleased with many of the improvements in the House version of the bill, we are concerned by reports that the FCC is already trying to identify military spectrum for auction."

The problem, according to the AOC, is that there are no common standards or metrics to properly determine [military] spectrum utilization and the true impact that losing such spectrum will have on training and the operation of existing and future military technology.

"The DOD has a long way to go toward making the necessary changes in doctrine, organization and development of a spectrum enterprise workforce. As such, it is careless and short-sighted to hastily auction any military spectrum until such measures are taken to ensure that spectrum relocation does not significantly and disproportionately affect the joint warfighters who rely on the electromagnetic spectrum [EMS] to train and fight."

Mr. Glaze closes by stating, "[T]he prosperity and security of nations will rely on the use of the [spectrum] to achieve strategic advantage and to strengthen all instruments of national power. Unfortunately, the US is no longer a generation ahead of its peer competitors in managing and controlling the EMS and our military is now at a crossroads. It sends a wrong message to our warfighters that the US is preparing to limit the ability to fight in the very electronic environment that 21st century combat requires." – *JED Staff*

HOUSE TO MARK-UP FY2011 DEFENSE BILL

In the last week of July, as this issue of *JED* went to press, the US House of Representatives was scheduled to begin marking up its version of the FY2011 Defense Appropriations Bill. At the same time, the House and Senate were trying to resolve major disagreements over an FY2010 supplemental spending bill, which includes funding for military operations in Afghanistan and Iraq.

The FY2010 supplemental spending bill is being held up by a disagreement over what that legislation should cover. The House wants the war supplemental to include about $23 billion in provisions for domestic programs in addition to $60 billion for ongoing military operations. The Senate wants the bill to cover only military spending, with minor provisions for domestic programs. Negotiations were expected to continue during the last week of July. This month, funding for the operations in Afghanistan and Iraq will run out and Congress is scheduled to begin a month-long recess on August 9. If the House and Senate cannot agree on a final supplemental spending measure, the DOD will likely begin to place some of its personnel on temporary furloughs in order to divert funding for the overseas operations.

The disagreement over the supplemental funding has led to delays in drafting the FY2011 defense spending bill. However, the House Appropriations Committee may complete mark-up of its version of the bill before August 1. Many are watching the House version of the bill to see if it will begin a program of defense cuts independent of the DOD's own efforts to trim spending. – *J. Knowles*

world report

EUROHAWK CHARTS SUCCESSFUL FLIGHTS

EuroHawk, a signals-intelligence (SIGINT) variant of the US Air Force Global Hawk unmanned aerial vehicle (UAV) under development for the German Air Force, successfully flew for the second time on July 23 at Edwards AFB, CA. Expanding its flight envelope following its initial two-hour flight on June 29, the EuroHawk full-scale demonstrator stayed airborne for about seven hours, short of the 12 hours planned due to high winds that delayed takeoff.

EuroHawk GmbH, a 50/50 joint venture of Germany's EADS and Northrop Grumman, is the program's prime contractor. Northrop Grumman provides the Block 20 variant of USAF's Global Hawk, while EADS has developed EuroHawk's Integrated SIGINT System (ISIS), its sole mission sensor. EuroHawk will carry two large external SIGINT pods, one under each wing, and will be able to detect electronic and communications emitters from a standoff position. The UAV will have about 30.5 hours of flight endurance. EuroHawk will be controlled from the Global Hawk's Launch and Recovery Element and its Mission Control Element, both built by Raytheon. A Ground Payload Segment from EADS will receive and process the SIGINT data from EuroHawk.

Following two more envelope expansion flights, a 24-hour endurance flight and six crosswind-landing tests, the EuroHawk demonstrator will ferry itself to Manching airbase in southern Germany in March 2011 for ISIS installation and testing, according to James Kohn, the EuroHawk program director from Northrop Grumman. The demonstrator will then be transferred in December 2011 to Schleswig-Jagel airbase in northern Germany, which will be EuroHawk's main operating base, in December 2011. The German Air Force plans buy to an additional four production systems and another set of ground control elements. EuroHawk will replace Germany's three Breguet Atlantic SIGINT aircraft, which have been retired.

– G. Goodman

POLAND TO UPGRADE EW ON ITS HELOS

Poland's Ministry of Defence has awarded a contract to Terma A/S (Lystrup, Denmark) to supply new self-protection suites for 22 helicopters – seven Mi-17s and 15 Mi-24s. Terma, acting as the prime contractor, will supply IR countermeasures suites based on its Modular Aircraft Survivability Equipment (MASE) pods and the ALQ-213(V) EW Management System. EADS Defence and Security (Munich, Germany) will supply AAR-60 MILDS missile warners. Terma will collaborate with the National Aerospace Laboratory in the Netherlands to deliver the suite's chaff/flare dispensers. Terma will also work with WSL-1, Military Airworks No. 1 in Lodz on MASE pod installation and with the Air Force Institute of Technology for type testing and certification.

Each helicopter will be fitted with a pair of MASE pods, with each pod featuring three missile warning sensors and sideways and forward-firing dispensers. MASE pod deliveries are scheduled to begin in November at a rate of one pair of pods (or one full EW suite) per month. Installations will take place in Poland and will be completed before the end of 2012. The EW upgrades are part of a larger upgrade program to prepare Poland's Mi-17 and Mi-24 helicopters for service in Afghanistan.

Although the contract amount was not disclosed, Terma officials said this was the largest single EW contract it has been awarded. It also includes provisions for spares, test and maintenance equipment, chaff and flare payloads, programming tools, aircrews and maintenance training and manuals.

In the future, Poland is also considering radar warning receiver and laser warning enhancements for the MASE pods. The Polish Armed Forces maintain requirements for EW upgrades on additional Mi-17s, its MiG-29 fighters and its fleet of M-28 Bryza light cargo and reconnaissance aircraft. *– G. Goodman and J. Knowles*

IN BRIEF

- **Thales** (Neuilly-sur-Seine, France) announced that it had signed an agreement with the Royal Navy of Oman (RNO) to equip patrol boats and corvettes with the company's Vigile electronic support measures (ESM) systems. The Vigile family, including the Vigile 200 and Vigile 400, equips surface combatants and submarines in service with more than 25 countries. The systems monitor, measure and analyze electromagnetic signals, providing a ship's crew with early-warning, situational-awareness and electronic-intelligence functions in both open ocean and dense littoral environments. The Vigile systems are based on a modular architecture comprising an antenna system, signal reception and processing units and an operator display console. Vigile typically is a key sensor of the ship's electronic warfare suite and is integrated into its combat system.
- **Raytheon** (Goleta, CA) was selected by the Egyptian Air Force to supply its advanced countermeasures electronic system (ACES) for the 20 Block 52 F-16s the country is purchasing from Lockheed Martin. ACES is an integrated electronic warfare suite, encompassing a radar warning receiver, jammer and chaff and flare dispenser. Under Egypt's Peace Vector II program, Raytheon will provide the EW systems for the F-16, along with spares and maintenance support.


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USAF UAS Flight Plan: Opportunities and Implications for EW

By Wayne L. Shaw III, Lt Col, USAF (Ret.)

The US Air Force released its "Unmanned Aerial System (UAS) Flight Plan 2009-2047" in July 2009.[1] It contains several references to UASs with EW and electronic attack (EA) capabilities. As the former Chief of CENTCOM's "Theater EW Coordination Cell" (CTEWCC) for a one-year Middle Eastern remote, this brought a smile to my face. I recall writing several versions of urgent operational needs statements (UONS) calling for EA capability on existing UAVs to help address the severe shortfall in hours of airborne electronic attack (AEA) requested by the supported ground commanders in both Iraq and Afghanistan.

While the USAF's UAS Flight Plan signals many opportunities for members of the EW community, it also raises many issues. As the recent demonstration flight in the California desert of an EA-capable UAV (i.e., the "Thunderstorm Fury" built jointly by Chesapeake Technology International and AeroMech Engineering[2]) once again proves, the technical/engineering challenges involved with controlling a UAV using a command and control link that must traverse the electromagnetic spectrum (EMS) while at the same time conducting AEA can be solved. There are already numerous UAS signals intelligence (SIGINT) payloads available on the international market.[3] The US Air Force has also recently awarded a $71M contract to Northrop Grumman to produce a Airborne Signals Intelligence Payload (ASIP) version for its MQ-1 Predator aircraft.[4] Should the USAF UAS Flight Plan become reality and an EA-capable UAV like the Thunderstorm Fury becomes operational, there are many issues which need to be addressed *before* this UAS capable of EA is deployed into what is already the most congested airspace and EMS environments on the planet.

The military's "DOTMLPF-P" construct will be used to briefly discuss just some of these issues. First is the issue of doctrine.

DOCTRINE

Joint Publication 3-13.1, while a good initial attempt to capture the myriad of issues involved with coordinating joint electronic warfare operations in an unclassified document, lacks any specific content regarding EW or EA-capable UAV platform employment. The existing version, dated 25 January 2007, while being platform agnostic, will need to include (in future versions) what are sure to be some unique doctrinal issues related to the planning, integration, coordination, and execution of EW operations using EW or EA-capable UASs.[5] Certainly the UAS's reliance on its command and control (C2) link, which must traverse the EMS, deserves mention in the appropriate portions of the next revision of JP 3-13.1.

The references section needs to have cross-cues to other doctrine relating to the employment of UAVs by the Services. The abbreviation and glossary sections will need to be updated with items such as "lost link procedures," "MAC" or multi-aircraft control, and so forth. Obviously, this is not an exhaustive list. It must not fall on just the meager resources of the Joint IO Warfighting Center's (JIOWC's) Joint EW Directorate (JEWD) to re-write this document to include EW/EA-capable UAV concerns – other parts of DOD must be involved. And of course, the USAF will need to get busy writing the new Air Force Tactics, Techniques and Procedures (AFTTP) volume for how the new EA-capable UAVs will be employed tactically.

ORGANIZATION

Next are the Organization issues. Will EW/EA-capable UAVs be task-organized into separate units or combined with MQ-1, MQ-9, or whatever the mainstay MQ-X variant becomes? Separate EW/EA-capable "EQ-X" UAV units would be optimal. (The USAF UAS Flight Plan refers to multi-mission-capable medium MQ-Xa, MQ-Xb, and MQ-Xc UAVs – follow-ons to the MQ-1 and MQ-9 as well as multi-mission large MQ-La, MQ-Lb and MQ-Lc UAVs – follow-ons to the RQ-4 Global Hawk. For the purposes of this article, I will condense those six different possible designations down to just one of my own creation, an "EQ-X" designation to refer to future USAF UAVs that are specifically EW/EA capable.) Of course, separate units will require more overhead and forfeit the benefits of consolidation. However, if national treasure is to be invested to develop and field such "EQ-X" UAVs, then proper "care and feeding" demands that they be organized as separate units. They will have unique requirements, such as training and maintenance that will suffer if under the aegis of an ISR or ground attack-tasked unit. However, the Flight

Plan's slides on modularity lead me to believe that these future units will be "jack-of-all-trades" units in which EW/EA capability is just one of an incredible number of modular payloads.

TRAINING

As the saying goes, a good EWO is always training. The USAF will need to establish an initial formal training unit (FTU) as soon as possible after the "EQ-X" UAV becomes available, even if only one or two aircraft are flyable. As the experience of the first RQ-1 Predator 11th Reconnaissance Squadron can attest, this first unit will most likely become an FTU *and* an operational squadron leading to a very high operational tempo. Thus, it will need to be manned with strong players from the start who can compensate for the fact that they must teach themselves how to employ the system. Assuming that future "EQ-X" units are located at Creech AFB, NV, they will benefit from the co-location of other more mature UAS organizations such as the MQ-1 and MQ-9 units, as well as the proximity of some of the best EW training ranges in the world. However, the USAF has announced that a second FTU for MQ-1/-9 training will be established at Holloman AFB, NM, with the base having received 10 MQ-1s and five MQ-9s in 2009. The plan is to eventually have all MQ-1/-9 training at Holloman.[6] Whether these new EA-capable UAVs and units will also be located at Holloman or take over vacated spaces at Creech remains to be seen.

MODELING AND SIMULATION

Considering some of the gaps in our EW modeling and simulation capabilities, it will be necessary for these future EQ-X UAVs and their crews to actually fly into and utilize the live-fly ranges such as Nellis AFB and NAS Fallon versus depending on simulation for their EW training needs. In fact, this need for simulation capability for these EQ-X crews would seem a great opportunity for the EW industry. While the future EQ-X crews might receive sufficient training from a high quality simulator, other manned aircraft will still need the training received from integrating these EW/EA-capable UAVs into their

mission planning and live-fly execution. If UAV history is any guide, this last point will be academic for the first EQ-Xs and crews, who will most likely find themselves involved in real-world operations in Afghanistan long before they participate in a Red Flag or Mission Employment (ME) phase with the USAF's Weapons School.

Assuming the USAF makes the prudent decision to have those trained in employing EW from airborne platforms man these EQ-X units to at least plan and possibly fly these new EQ-X UAV aircraft, experienced EWOs pulled from manned platforms and staffs to man these EQ-X units will exacerbate the current problem of too few active-duty EWOs. For those segments of the EW industry which provide contract service EW expertise (i.e., retired and separated EWOs who now "consult" on EW matters) to augment or backfill military staffs, this will provide a business growth opportunity. If the USAF decides it doesn't have the EWO manpower available to place any EWOs within these units, this business opportunity should be even larger.

EW PAYLOADS

The heart of this future development is materiel. As the USMC proved with the Iron Nail joint concept technology demonstration (JCTD) in Iraq in 2007-2008, and as the Thunderstorm Fury recently proved again, there is not a fundamental reason why a UAV cannot be fitted with an EA payload and successfully employed in combat. Considering that a notable USAF Crow, Brig. Gen. Larry "Puba" Henry, used BQM-74 drones in Operation Desert Storm,[7] and another USAF EWO of note, Lt. Col. Tom "TJ" Jensen used these same drones to lay chaff in the opening hours of Operation Iraqi Freedom in 2003, it's disappointing that it took until 2007 for the US to have the Iron Nail in the skies of Iraq conducting EA. However, as the small number of EA-payloads for UAVs discussed in the June 2008 issue of *The Journal of Electronic Defense* indicates, it's no doubt fraught with more technical challenges than when outfitting a UAV with a passive SIGINT sensor.[8]

The Air Force's UAS Flight Plan makes the pitch that these future EW-capable

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UAVs will have a modular payload with modularity bringing the benefits of effectiveness, affordability and flexibility. Thus, on slide 17 of the USAF UAS Flight Plan power point briefing, there is an "MQ-Xa" that can carry an EW payload, an ISR payload, a close air support (CAS) payload, etc. This modular payload continues in a near "stream of consciousness" to the point where the proposed MQ-Xc will perform EW, SEAD, ISR, CAS, Comm Relay, Combat Search and Rescue (CSAR), Missile Defense, Counter Air, and six other missions! The development of the EA payload and its integration into an airframe that is purposely designed for many other MQ-X missions yet enabled by this modularity concept could drive the EW variant of the UAV to use some sort of "ALQ-99-like" EA pod on wing hard points.

The USAF, as it retires legacy fighters, should have excess ALQ-184 and ALQ-131 pods which could be modified by the EW industry for use by the EQ-X. Engineers will have to do the size, weight, and power (SWAP) analysis to determine if internally mounted exciters, transmitters, traveling wave tubes, cooling, etc., can fit into spaces used for ISR sensors or other avionics on other MQ-X variants. The graphics on the Flight Plan's slides 17-19 depict a low radar cross section (RCS) UAV akin to the X-45, X-47 or NASA X-48B, which means high-RCS external EA pods could be counter to the intended employment profile and air defenses the EQ-X is intended to penetrate or skirt. So the model will be something similar to the EF-111, in which transmitters could be swapped out based on the mission, but externally, the EF-111 looked the same on every mission. Similar SWAP analyses will be needed to determine whether the USAF's EQ-X will use conformal antennas versus horn, spiral, blade antennas within an aerodynamic fairing for its EA payload's "business end."

LEADERSHIP

Leadership will be key. For any military leader who has had the responsibility of maintaining qualification and striving for proficiency among his unit's members in order to meet real-world wartime taskings, the realization of what a leadership challenge it will be to implement the USAF UAS Flight Plan should be easily imagined. The training regulation will be huge, the check-rides will be daunting, and the unit "Letter of X's" will be a multi-page spreadsheet for each individual aircrew. No doubt a multi-tiered qualification system will be needed. Much as in other USAF platforms such as the F-111, in which not every aircrew was qualified to drop every weapon (e.g., only a few were qualified on weapons such as the AGM-130), the future MQ-Xa/b/c and MQ-La/b/c units will need to specialize within the unit and not attempt to have every crewman be qualified on every one of a myriad of modular payloads. The leaders of these units will also face the challenges of high ops-tempo, members deploying as soon as qualified, playing catch up on training as soon as unit members re-deploy, and split-squadron operations (i.e., part of the squadron at home, part of the squadron deployed to theater(s)). Only strong leaders need

apply. There are EWOs out there who are these strong leaders and no doubt strong EW leaders will emerge from this operational caldron too.

MANPOWER

We're a long way from fully autonomous UAVs, thus "personnel" is still a big issue. So will an electronic warfare officer (EWO) need to be added to EW/EA UAV crews to control and manage the jammers and other requisite gear and to conduct radar/communications EA, ES, SEAD, and other EW missions from planning through debrief? If so, where will these EWOs come from? It's no secret that the USAF is in short supply of EWOs. Could the USAF's 563rd Flying Training Squadron ramp up *even more* to produce EWOs with the needed extra familiarization and training to remotely operate an EW/EA UAV? The 563rd already conducts a UAV Operators Familiarization Course in addition to being the USAF's EWO "schoolhouse," so it seems tailor-made for this task. Of course, the pending move of the USAF EWO "schoolhouse" back to NAS Pensacola may make this additional training burden quite challenging. The new USAF EWO training program may need some help from the EW industry to accomplish what could become a very large training load.

In order for there to be any true manpower gains with an EW or EA-capable UAV, we need to either have an autonomous UAV with no need for an EWO at the Ground Control Station (GCS) or, at the least, for that one EWO to be able to simultaneously control multiple EW-capable UAVs in multiple jamming orbits/tracks (i.e., multi-aircraft control or MAC). Given the shortage of USAF EWOs, MAC becomes even more important for EW/EA UAVs than for the existing MQ-1s and MQ-9s. According to the USAF UAS Flight Plan, for a notional 50 MQ-9 combat air patrols (CAPs), with one pilot controlling two CAPs and one bird in transit, the manpower savings are estimated at 250 pilots or 56 percent over how the USAF would now fly 50 MQ-9 CAPs.[9] It is my humble opinion that these first EA-capable UAVs will need some experienced EWOs pulled from EC-130H Compass Calls or other USAF platforms which use some form of offensive EA – those who have had their fingers on a "master rad" switch and have a feel for the non-kinetic power they are wielding. So, although it will be painful for low-density/high-demand (LD/HD) platforms like the Compass Call to give up experienced EWOs, it will be needed to ensure the success of the first of these EA-capable UAV units.

FACILITIES

The next issue is facilities. In other words, where will the squadron bar, I mean Heritage Room, be? The UAS Flight Plan is particularly sketchy on this subject; it simply lists "C2 Facility" and "CFACC Facility" (Combined Forces Air Component Command Facility) as two actions that need to be synchronized in the FY10-15 timeframe. Based on my years as an EWO in the USAF, my instincts tell me that for the "UAS EA" shown emerging in the same FY10-15 timeframe, the system will need high-powered transmitters and high-gain antennas at the C2 and CFACC facilities to ensure that jamming harmonics, spurs, jammer roll-off and so on do not prevent the reception of C2 transmissions at the UAV receiver. My experience tells me this receiver will experience quite a bit of electro-magnetic interference (EMI) in spite of some of our best engineering efforts. Also, despite destructive interference of the EQ-X's telemetry by its onboard jammers, this weakened telemetry can still be received at the C2 facility as long as these facility concerns are addressed. The onboard EMI should theoretically be more of an issue with the smaller "medium" UAVs, since they will have less platform "real estate" to separate the EA antennas and C2 receiver antennas. However, it's still doable: EA antennas pointed at the ground where the targets will be and C2 antennas pointed towards the sky where the satellites are.

POLICY

Last but not least is the issue of policy. For testing and training in the US, how will the FAA rule on this new UAS in which the UAV – while dependent on the EMS for control while in all types of airspace – is also deliberately "jamming" in select portions of the EMS? The USAF UAS Flight Plan also envisions autonomous UAVs (to include some with that modular EW/EA payload), which raises a plethora of additional issues. Deliberately jamming a foreign country's frequencies is not looked upon favorably (see CJCSI 3121.01B for an exact policy answer). So how do we deal with the situation when an autonomous EA-capable UAV points its antennas left instead of right and accidentally starts something against the wrong country? (For an extensive discussion of a veritable Pandora's Box of policy implications for the entire field of robotics [which includes UAVs], see the recent book by P.W. Singer, *Wired for War*.[10])

OTHER CONCERNS

Other concerns based on the author's field experience: will these EA-capable UAVs be able to satisfy the demand? Even with all the existing AEA assets in theater flying at maximum capacity during the Aug 2007-Aug 2008 timeframe, we could only provide about 50 percent of the hours of AEA requested by the ground commanders. Will control of these EW/EA UAVs devolve into a turf battle about who controls them? Already, ground commanders have made pitch after pitch to control all the UAVs providing ISR.[11] The ISR staffs – even forward-deployed in theater – are *huge* compared to the forward-deployed EWO "staffs." These forward-deployed EWOs (individuals or cells) simply cannot perform their deployed jobs *and* prepare briefing book after briefing book for the Combined Forces Air Component Commander's (CFACC's) next pointed discussion with a ground echelon general officer over who should control the CFACC's EW UASs so that they might get more Air Support Requests (ASRs) filled.

Regarding ASRs, will we continue with the current system of bottom-up air support requests working their way up to the Combined Air Operations Center (CAOC), where the existing AEA assets are spread among the 24-hour Air Tasking Order (ATO) to cover as many of the highest priorities as possible, until we're out of AEA assets? With totally new platforms that are flown and controlled in fundamentally different

ways, there will be an opportunity to critically review the existing request system and its two primary documents: the DD Form 1972 Joint Air Support Request (JTASR, also abbreviated as JTAR, or ASR) and for EA missions, the Electronic Attack Request Form (EARF). Since whatever industry ultimately delivers to the warfighter will no doubt have unique attributes with regard to EA bands, communication requirements, airframe or system limitations, important C2 link prohibitions, etc., this will likely require changes to the JTASR, EARF or both. In addition, the CAOC will need to craft new ATO special instructions (SPINS) for items such as "cease buzzer" – since no EWO will be aboard the actual jamming platform, this drives a different notification mechanism. These aspects of the EW/EA-capable UAVs and those aspects unforeseen will provide a great opportunity to re-examine in-theater processes with regard to providing EW effects and how to improve them.

On the subject of unique requirements and important C2 link prohibitions, remotely controlled aircraft do not respond well when they lose their C2 link. Although the software and procedures have improved since UAVs were first introduced, it will be important for these new EA UAVs to be able to maintain their link or have very robust programming and sensible procedures encoded should they lose that C2 link. For instance, how do we command the EQ-X to stop jamming if its jamming starts interfering with the C2 link that would carry the message to tell it to stop jamming? A timeout option? A required refresh command to maintain "jam on" status? This will not be easy and it demands robust engineering with multiple backups. We have enough issues already in our congested EMS without rogue UAVs conducting EA without the ability to turn off the jamming. How do we integrate this new EW/EA UAV and protect its important C2 link?

The Joint Restricted Frequency List (JRFL) is part of the answer from a procedural standpoint.

Considering the likely cost of these new EW/EA UAVs and their dependence on the EMS, both for achieving their warfighting effect and how they are commanded and controlled, perhaps it is time to update the JRFL process, software tools, and manning of the frequency manager positions in theater. Industry has some great ideas for how we can do better at the entire frequency management problem (e.g., Coalition Joint Spectrum Management Planning Tool and THESIS to name a couple) and specifically how the EW Coordination Cell can do this so that we can manage the EMS, conduct all aspects of EW, and do it in a much more timely and sophisticated manner than what I endured in 2007-2008. Who knows, we *might* even be able to control the spectrum, at least for the time and place needed for a tactical operation.

What's really needed for this is a "Frequency Tasking Order" which has been discussed previously in *Joint Forces Quarterly*.[12] Considering how many personnel man today's CAOC in theater (~1,000) to produce an *air* tasking order, how many personnel are in an EW Coordination Cell (~10) and how many of those – if any – are frequency management personnel (~1), we are a *long, long* way from being able to produce a Frequency Tasking Order. For now, all these things remain "a bridge too far."

Although it's not a major part of the manpower equation, for any platform in theater there is a liaison officer (LNO) for that platform at the CAOC. This means an LNO will be needed for these new EW UAVs. Although the LNO wouldn't have to be an EWO, but could instead be an EW UAV pilot (considering what the major mission and payload of this new platform will be), an EWO to work with the various CAOC Divisions and Cells makes the most sense. Certainly, it will be some time before anyone assigned to the EW Coordination Cell (EWCC) has any EW/EA UAV experience, which leads to another small issue.

There are two organizations that currently provide the only existing training for those assigned to work in an EWCC "downrange." One is the USAF's 563rd FTS, which conducts the two-

week "Air Force EW Coordinators Course" at Randolph AFB – at least until it moves to Pensacola by 1 October 2010. The other is the JEWD in San Antonio, TX, which provides a two-week "Joint EW Theater Operations Course" attended by members of all US Services. These courses will need to be revamped to include as much EW/EA UAV information as early as possible to educate the leaders and members of EWCCs. They will be impacting the fate of these newest airborne EW platforms every day as they work the ATO, revise SPINS and do the detail work of component EW planning and execution.

It will also be critical for EWCC Chiefs to be as smart as possible on these new EW UASs before deploying, because once deployed, these EWCC Chiefs are looked to by theater leadership to "be all things EW." The more optimally these new UASs can be employed and the more ground commander requirements for airborne EA they can meet, the better chance we have of finally reducing the ops-tempo of manned platforms through redeployment. This in turn will facilitate much needed depot-level upgrades, address huge backlogs in aircrew training, allow manned EW/AEA platform units to truly reconstitute, conduct testing and evaluation of new EA techniques at stateside ranges, and help us to be ready for the many other threat scenarios in the DOD's "Guidance for the Employment of Forces."[13]

A NEW PATH, A NEW SET OF OPPORTUNITIES

Although not the only bright spot in EW's promising future, the USAF's UAS Flight Plan does indicate a new path for EW in future air operations. If Wall Street analyst projections are correct, what's now a $4.5 billion-per-year global UAV business will become a $10 billion-per-year business within a decade.[14] The recently released USAF UAS Flight Plan shows some of that business will likely be coming to the EW Industry. It also follows that there will be a need for more EWOs or at least EW expertise, and the potential for revitalization of in-theater EW processes. Finally, once EW/EA UAVs are robustly deployed, perhaps we will be able to support our forward-deployed ground commanders to their requested levels while permitting manned EW platforms and their squadrons see a little less of the Middle East. As we used to say in VAQ-133, *Push it up!*

Photos courtesy US Department of Defense.

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JEPAC: Enhancing Air Combat Capability

By Jim Thompson and
COL Robin Vanderberry

The Combat Air Forces of the United States have been so effective over the last half-century that US forces have not had to deal with an enemy who has been able to take advantage of military airpower. Air superiority, and subsequently air supremacy, are commonly assumed to be in effect during combat operations. Our investments enabled us to organize, train, and equip our forces, and in particular our air forces, such that we had no peer in the battlespace. Our investment in technology and training has been key to our ascendance to the pinnacle of air power. Our national strategic policies combined with strong defense budgets, military visionaries and industrial entrepreneurs provided an unparalleled opportunity for the US to pursue capabilities in stealth, long-range radar, active missile systems, data link architectures, and training centers that ensured US aviators and those who support them maintained an unstoppable advantage.

Abraham Lincoln once said, *"The dogmas of the quiet past are inadequate to the stormy present. The occasion is piled high with difficulty, and we must rise to the occasion. As our case is new, so must we think anew and act anew."* Lincoln's words are as true today as they were nearly 150 years ago. US ground forces in Iraq and Afghanistan have had to face a stormy present in the form of improvised explosive devices (IEDs).

The asymmetric threat of the IED was the new case, and we were able to think anew and act anew. Our actions resulted in a significant capability to mitigate the IED as a tool of war in those theaters. We reacted as quickly and effectively as we could, but reaction is not enough when lives are at risk. We failed to see the threat before the threat saw us. We must remember that our adversaries also have the capacity to learn from the past and to see the battlespace in new and different ways. They will seek to engage us not at our strongest points, but rather at those points where they can garner the greatest return on their investment. One of the greatest enablers to our would-be foes is the rapid growth and globalization of technologies. As the radio-controlled IED (RCIED) so clearly illustrates, one of the most lucrative markets for our would-be foes' investments is the electromagnetic spectrum (EMS). Understanding and utilization of the electromagnetic spectrum will be the cornerstone of success in all future conflicts. Our ability to protect, manage, and exploit the EMS is the common denominator across all five domains of warfare (air, land, sea, space, and cyber). We can no longer afford to assume superior capability or subordinate investment but must improve our ability in the EMS.

Just as they did with our ground forces in Iraq and Afghanistan, adversaries seek to challenge historical

US air supremacy through asymmetric methods of attack that are now feasible because of significant advancements in and proliferation of technology. One particular area of concern to US forces is electronic warfare (EW). EW in the form of advanced electronic attack (EA) has the potential to negatively impact US air combat supremacy. Fielded air forces and our historical approach to air combat do not fully counter the effect of enemy advanced EA. Rapid improvement in many of the technology bases that provide the foundation of EA systems have enabled these technologies to mature faster than we have been able to acquire and fully integrate them into our major weapons systems. Greatly increased processing speed, miniature and nano manufacturing, enhanced analog-to-digital and digital-to-analog conversion, field programmable gate arrays (FPGAs), and digital radio frequency memory (DRFM) kernels provide a means for a determined adversary to outpace our acquisition strategy and bring enhanced EA capability to the battlespace faster than we can acquire the same capability and faster than we can counter the advanced EA within our own systems.

ACTION AND ADAPTATION OVERCOME NEW THREATS

This is not news to frontline warfighters. We have long known and adapted to the reality that acquisition of new systems and technologies is not the only tool available to counter a threat. In fact, it is common for emergent technology to outpace our ability to implement a materiel solution. In these situations, it is the ingenuity and tactical savvy of the fielded forces that rises to the occasion.

To address the specific issue of proliferating EW capability in air combat, the Joint Test and Evaluation (JT&E) Program, under the leadership of the Director, Operational Test and Evaluation (DOT&E) chartered the three-year Joint Electronic Protection for Air Combat (JEPAC) Joint Test (JT) on August 15, 2007. The JEPAC JT is designed to develop tactics, techniques and procedures (TTP) that enhance air combat capability in the presence of advanced EA waveforms using cooperative targeting, tactics, and off-board sensor data. The JT&E Program specializes in bringing two or more military Services or other components together to provide non-materiel solutions to joint operational problems. The program charters operational test projects that improve joint warfighting capabilities with existing equipment. Products are delivered in the form of improved TTP, enhanced test and evaluation methodologies, and improved architectures. In short, the JT&E Program is focused on *"doing better with what we have."*

TTP are a series of documents ranging from joint doctrine publications to field manuals to weapon-specific guidebooks. At the highest level, TTP are codified, specific, and measurable actions and methods that implement doctrine or policy. At the lowest level, TTP are how soldiers, sailors, Marines and airmen get the job done. Implementations of TTP represent the lowest level of doctrine. Here is a short summary of TTP from CJCSI 5120.02A and FM 3-0, Appendix D:

Tactics: The employment and ordered arrangement of forces in relation to each other. Effective tactics translate combat power into decisive results. Tactics are primarily descriptive and vary with environment and other circumstances; they change frequently as the enemy reacts and friendly forces explore new approaches. Applying tactics usually entails acting under time constraints with incomplete information. Tactics always require judgment.

Techniques: Non-prescriptive ways or methods used to perform missions, functions, or tasks. Techniques are the primary means of conveying the lessons learned that units gain in operations.

Procedures: Standard, detailed steps that prescribe how to perform specific tasks. Procedures normally consist of a series of steps in a set order. They are prescriptive; regardless of circumstances, they are executed in the same manner.

TTP are often based on equipment and are specific to particular types of units. This results in a requirement for a dedicated effort to advance TTP across multiple weapons systems and services. The DOD recognized this requirement and has established numerous methodologies for advancing the joint application of forces at the operational and tacti-

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cal levels. The Services have dedicated approaches for publishing and updating platform-specific, multi-platform, and multi-Service TTP.

JEPAC LEADS COUNTER EA EFFORT DOD-WIDE

In the process of developing the expected test product, the JEPAC test team conducted its first Field Test (FT-1) during the Northern Edge 2008 (NE08) exercise conducted May 5-16, 2008 at the Joint Pacific Alaskan Range Complex. The field test was highly successful and provided sufficient data to meet JEPAC test objectives. The successful execution of FT-1 marked a major milestone for the project, as JEPAC was able to test the newly developed TTP in an operationally representative environment. The two-week field training exercise is focused on execution of tactical-level, joint interoperability tasks associated with Pacific Command's war-fighting missions. Northern Edge utilizes vignettes designed to practice TTP and enhance interoperability among the Services. The exercise also trains to improve command, control, and communication relationships and develops interoperable plans and programs. Over 5,000 participants from all the Services, Coast Guard, and National Guard took part.

The primary objective of FT-1 was to collect and analyze data to evaluate the effectiveness of the JEPAC-developed TTP employed during the exercise. Members of the JEPAC team were intimately involved in both the planning and execution of NE08 scenario development and threat presentation portrayed during the exercise. The team facilitated the integration of a realistic opposition force that included a robust EA representation. JEPAC maintained close communication with unit training officers and exercise participants to help resolve issues, provide clarification, and ensure familiarity with the TTP and advanced EA. JEPAC coordinated to get fighter jets from the 422 Test Evaluation Squadron, 65 Aggressor Squadron (AGRS), and Naval Strike and Air Warfare Center to augment the aggressor forces (18 AGRS) already resident in Alaska.

JEPAC also facilitated the availability and integration of additional advanced EA pods (e.g., Air Force and Navy Advanced Capabilities Pods, Navy Have All pods, ALQ-167 pods, and ALQ-188(V)4 pods) into NE08. The result was a joint aggressor force that was able to present an operationally relevant threat with an unprecedented level of advanced EA complexity and realism.

The JEPAC-developed TTP were distributed to all NE08 participants and planners prior to execution of the exercise. These TTP were based largely on existing TTP standards combined with results of recent advanced EA testing efforts. As a result, the majority of these tactics are currently being promulgated and taught at air warfare centers of excellence (Marines Aviation and Weapons Tactics Squadron 1, as well as the Naval Strike and Air Warfare Centers). NE08 proved a mutually beneficial event that enabled the JEPAC team to accomplish FT-1 objectives while providing a highly valuable and realistic training environment that exposed the warfighter to an unprecedented level of advanced EA. The JEPAC team analyzed more than 1,000 hours of cockpit recordings and 3,300 individual data sources from FT-1. In-depth analyses of FT-1 data provided the combatant commanders with an accurate assessment of force capabilities within an operationally representative advanced EA environment.

Following FT-1, the team hosted Joint Warfighter Advisory Group and General Officers Steering Committee conferences to present FT-1 analytical results and solicit inputs for version 2 (V2) of the JEPAC-developed counter-EA TTP. JEPAC completed its analysis and reporting on FT-1 and incorporated leadership and warfighter input in finalizing V2 of the counter-EA TTP, which was provided to training officers and used as the basis for a training travel team that was dispatched to brief the units scheduled for participation in Field Test-2 (FT-2).

FT-2 was conducted in conjunction with USPACOM's Northern Edge 2009 (NE09) exercise and marked the second major milestone for the JEPAC effort. The exercise was conducted in the Joint Pacific Alaska Range Complex and the Gulf of Alaska from June 15-26, 2009. The exercise included over 9,000 participants, 200 aircraft, the aircraft carrier *USS John C. Stennis*, and the cruiser *USS Antietam*. JEPAC was able to work with the executive agency (Alaskan Command), USPACOM, and the Services to facilitate the integration of the largest and most diverse opposition force using unprecedented levels of advanced EA in a joint


The newest CREW devices provided to U.S. Forces, CREW Vehicle Receiver Jammers (CVRJs), are based on a technically mature, low-risk architecture and have the capacity to address threats at operationally effective distances, while maintaining high levels of performance in the presence of multiple threats. ITT is dedicated to ensuring our systems will always support the Warfighters' missions, providing protection and flexibility in the evolving threat environment. While threats have been the principal focus, interoperability with other CREW systems and compatibility with tactical communications systems have been priorities at ITT and are reflected in our designs and in continuing research and development activities. Learn more at www.ITT.com.
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air combat exercise. The JEPAC test team was well supported by exercise aircrews and planners and initial review of data indicates that this field test was highly successful and provided sufficient data to meet all JEPAC test objectives. Since the completion of FT-2 the JEPAC test team has been working diligently to analyze and refine the tested TTP. FT-1 and FT-2 final reports are complete and will be used to update the TTP, which will be tested during FT-3, scheduled to be in a virtual environment in September 2010.

IMPACT

JEPAC has already made wide-ranging impacts and elevated the importance of advanced EA across all Services. Results from JEPAC's efforts provided empirical data for Combat Air Forces to advocate for and ultimately increase acquisition of additional advanced EA training devices. Construction of counter-EA TTP has already resulted in updated training syllabi for TOPGUN, Marine Aviation Weapons and Tactics Squadron 1, and Air Force Weapons School. JEPAC's work with joint warfighters across the Combat Air Forces and Fleet influenced the modification of USAF 3-1 shot-kill criteria for operating in an EA environment, enhanced databases for requirements development and industry analysis, and integrated opposition force strategies across Service lines. JEPAC continues to promote collaborative efforts among industry, testing and warfighting communities. Increasing awareness and training on the advanced EA threat remains an essential key to the preservation of our nation's air supremacy, and JEPAC is meeting its charter in ensuring the joint forces are doing just that.

Senior leadership recognized JEPAC's potential to continue its contributions in the EW arena and directed it to transition to a permanent organization, expanding its aperture to address EW aspects of the air, land, sea, space, and cyber domains. JEPAC will formalize its association with the Joint EW Division of the Joint Information Operations Warfighting Center in San Antonio, TX, by the end of FY10. The follow on organization will be known as the JIOWC/JEPAC, where JEPAC stands for Joint Electromagnetic Preparedness for Advanced Combat.

Photos courtesy JEPAC and the US Department of Defense.

The JEPAC test team received the 2008 National Defense Industry Association (NDIA) Test Team of the Year Award in recognition of exemplary initiative, superior team work, and outstanding performance. JEPAC Test Director COL Robin Vanderberry won the 2009 NDIA Tester of the Year. JEPAC's superior record of professionalism, expertise, and attention to detail has made it a focal point for counter-EA methods within the Department of Defense.

Jim Thompson is the program director-manager for the Joint Test and Evaluations (JT&E) Program under the Director, Operational Test and Evaluation (DOT&E) in the Office of the Secretary of Defense. To learn more about JEPAC or other JT&E activites, visit the JT&E website at www.jte.osd.mil.

DRFMs Grow to Meet New Threats

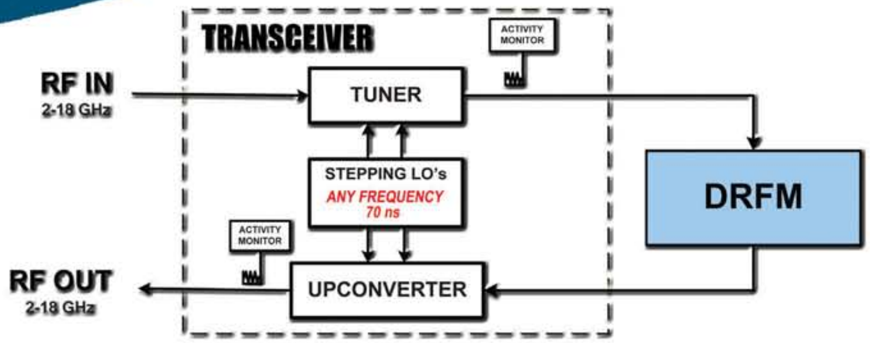
By Barry Manz

Of the broad array of functional elements in EW and ECM systems, the Digital RF Memory (DRFM) has risen from a “nice thing to have” to become one of their critical elements because of the increasing sophistication of the threats they must defeat. Consequently, DRFMs today are vastly superior to those of only a decade ago, both for threat simulation and tactical applications. In the future, it’s hard to imagine any platform, large or small, that will be complete without the unique capabilities these subsystems provide.

SO WHAT EXACTLY IS A DRFM?

This simple question takes longer to answer than its name implies: a subsystem that digitizes RF (analog) signals and stores them in memory. In fact “dirfums” never fit that description, as it covers only one of the basic functions a DRFM performs, and current DRFMs stray even further from that definition. A DRFM has always captured signals, digitized them, reconverted them to their analog origin, and then rebroadcast them, usually but not always after modifying them in a bewildering number of ways based on its (or the host system’s) library of known emitters.

For example, the rebroadcast signal can be altered to change the target’s radar cross-section, range, speed, angle of arrival and direction. It can also deal with the various radar modulation schemes such as phase coding and chirp, create false targets behind the target (reactive jamming)



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and ahead of it (predictive jamming), as well as many other tweaks that can drive a radar's processing system into a frenzy. The goal in every case is, in a precious few moments, to confuse enemy radar sufficiently so it mislocates or misidentifies the target or can't find it at all.

From a historical perspective, the first DRFM can be traced to William Schneider and Joseph Dautremont, Jr., who in 1974 patented a "digital storage system for high frequency signals," under the auspices of Whittaker Corp., for "later reproduction with any desired degree of fidelity." Since then, the DRFM has been viewed as "a magic black box that could be added to an existing system," says Chris Lewis, chief technical officer at KOR Electronics in Cypress, CA. "This requires capabilities to support the DRFM that are already present in the host system, since the DRFM is "duct taped" so to speak, to the host. Lewis' first DRFM accomplishment was in 1983 at Design Engineering Labs for the Navy at Point Mugu, CA. "It was a 4-bit system with 500 MHz of instantaneous bandwidth (IBW), and required a lot of 'eye of newt and wing of bat' to make it work. The techniques generator was PROM-based and one of four programs was selected with a pair of digital lines. It had roughly 20 µs of delay."

A DRFM can perform more functions when integrated within the system design so according to Lewis, "you can refresh older systems today and dramatically reduce the volume required by their functions, achieve a 10-times improvement in performance, and free up space for an integrated DRFM. So now we're folding the DRFM into the system. When compared to previous levels of performance, we're expanding the bandwidth, improving spectral performance, increasing techniques, reducing power consumption, and driving the cost down. We end up with the same size box but far more capability and incorporate functions that were once independent subsystems."

For example, he cites a system the company is developing that is basically plug-and-play, with different modules that allow different frequency bands to be plugged in for wider coverage. It delivers better spurious performance, multiple channels and threat handling capability, all in a box the same size as before. "It's actually pretty much a stand-alone ECM system that does traditional noise jamming, threat differentiation, deception, controlling antennas to perform angular techniques and has its own decision-making ability to detect waveforms, differentiate one from the other, and use different techniques against each one – deinterleaving multiple threats and steering jamming energy to an area if the system is configured that way."

One among many of the basic DRFM figures of merit is the number of bits of resolution and sampling rate it uses at the input for analog-to-digital conversion and at the output for digital-to-analog conversion. Fundamentally, the higher the captured signal frequency, the higher the sampling rate required to digitally characterize it. Previous generations of DRFMs used 1-bit sampling. At this minimal level, the spectrum of the incoming radar signal could easily exceed the IBW of the DRFM, so some of

the signal would be lost. Such a DRFM is no match for today's most sophisticated of radars.

Another DRFM veteran, Richard Damon, general manager of the RF Simulation Systems Group at Herley Industries' Micro Systems division in Irvine, CA, says "most tactical systems use a small number of bits, which does not cut it anymore, and a 3-bit DRFM will not fool any radar out there. It's so easy to see a DRFM when it has only 2 bits because radars are using 16-bit A/D converters and can easily determine if they are being jammed."

A 1-bit DRFM will generate a signal at the input frequency along with copious amounts of spurious and harmonic content about 6 to 9 dB below the level of the main signal. When viewed on a spectrum analyzer, this would produce a display that "looks like a wheat field," says Damon. Better would be a sunflower in that wheat field. "A 3-bit DRFM might provide 18 dB of spurious free dynamic range (SFDR) or about 6 dB per bit," Damon continues, "and with an 8-bit DRFM a 40 to 50 dBc SFDR, at which point other signals would be very far below the main signal. An SFDR of 60 dBc requires a 10- or 12-bit DRFM."

However, as Lewis points out, "a higher number of bits may deliver superb spectral performance, but with the caveat that there is more data to handle, the system is more expensive, and the data itself can be overpowering. He cites as an example one of their systems that uses a high-speed bus to offload in near real time the terabytes of data the company's systems generate. "However, to offload this data via a VMEbus backplane would take about 12 hours."

Of the two applications, simulation and verification and tactical jamming, in which DRFMs are used, the former must deliver the highest fidelity, and best represents the DRFM "state of the art." This is where the DRFMs with double-digit conversion resolution are found and the most comprehensive array of capabilities are achieved because they are used as reference systems for evaluating and verifying the performance of radar and ECM systems, as well as for training.

This is evident in the simulation systems offered by Micro Systems and KOR Electronics. "Our goal is to be able to run radar simulations 16 hours a day, 6 days a week, for 15 years and never let the radar think that what we are generating in the DRFM is not a target," says Damon. "We're pushing 2 GHz of bandwidth at Micro Systems and we currently have DRFMs that sample over 2 GHz using a 10-bit A/D converter and 12-bit DAC. Our intention is within 12 months to have a DRFM with a 12-bit front end and 14-bit back end that samples at 4 GHz. With an IBW of 4 GHz, we will sample at 4 GHz and get 2 GHz of bandwidth."

A simulator from Micro Systems is an extraordinarily complex animal. It offers up to 500 targets per scenario, 20 simultaneous generator channels, 16 jammers per scenario, four jammers in the antenna beam, accepts 24 phase and amplitude inputs, handles any modulation type, and provides pulse widths of 25 ns to CW and pulse repetition intervals of less than 10 Hz to more than 5 MHz. The company also offers board-level DRFMs for inclusion in simulators, such as a single-slot VME model with 1 GHz IBW, 2.5 GHz sampling, 10-bit A/D conversion and 12-bit D/A resolution, 250 ms of memory depth, and an SFDR greater than -47 dBc.

TACTICAL DECISIONS

While its core business is the test and evaluation market, Micro Systems is addressing the tactical environment with a VME board that provides what the company claims is the best combination of bandwidth and fidelity of any module on the market. It offers 500 MHz sampling, 200 MHz IBW, 12-bit A/D and 16-bit D/A resolution, an SFDR of -65 dBc, delay resolution of less than 2 ns, and up to 16 coordinated range, Doppler, and amplitude target returns per channel. Another similar board samples at 2.5 and 5 GHz with 10-bit A/D and 12-bit D/A resolution, features an IBW of 1 to 2 GHz, and offers delay resolution of less than 0.4 ns, 32 target returns per channel, 500 ms of memory depth and VMEbus, Ethernet, Fibre Channel interfaces. The A/D and D/A modules are on daughter boards, so they can be removed and upgraded without a massive infusion of cash.

KOR Electronics' Model 1225 DRFM is a ruggedized, air-cooled, 3-bit DRFM for airborne applications (internally-mounted, podded or as a UAV payload), with 1.2 GHz IBW and internal techniques. It measures 4.75 x 6.25 x 12 in., and weighs less than 13 lb. The Model 1225 has more than 15 dBc (more than 20 dB is typical) of spurious suppression, stores 48 user-defined deception programs, and its ECM techniques include pipeline, stretched pulse, and synthetic CW and Multiple False Target (MFT) modes that are user-definable. Pulse width ranges from 20 ns to CW, and it withstands shock of 12G for 11 ms, vibration of 10 to 200 Hz (+/-10G), and operates to 50,000 ft.

Another KOR Electronics system developed for a customer updating an existing system is the same size, handles four times more simultaneous threats, has a wider frequency range, and can be configured to operate against ground, airborne, and sea threats of different types at the same time. The unit is programmable and operates autonomously or interactively if there is a high level of intelligence in the platform. It can perform threat identification from a library, sorting and techniques selection based on the threat.

LNX Corp. (Salem, NH) takes a different approach, offering a DRFM kernel for system integrators to build on. The company's products are based on an ASIC that was jointly developed with a

customer but which LNX retained the rights to further develop and sell. "We compete in the low-cost area in UAV applications, for example, and even decoys," says Mike Groden, vice president of digital technology at LNX. "People looking for small size, low cost, and low power consumption are our customers. Our strength is integrating RF and digital technologies, and our capabilities include products such as block up or down converters, IFM receivers, and other microwave building blocks."

The ASIC is a 4-bit, phase-sampling DRFM kernel with a 600-MHz IBW that consists of the baseband components including input A/D, pipeline registers, an external memory interface, and a dual 4-bit D/A converter to reconstruct the signal. It accepts an IQ input at 600 MHz and has clock rate up to 720 MHz. The data can either be run through the ASIC or stored and read data from external memory.

LNX has built several products around the ASIC. The first is the DRFM0101-001, a low-cost, Compact PCI board that has an FPGA for external memory, an IF center frequency of 1 GHz, 4-bit sampling at up to 640 MHz, throughput delay of less than 25 ns, 20 Hz frequency accuracy, 60 dB of input dynamic range, and the ability to store four signal files of 200 µs each. It can perform Doppler, pseudorandom, and phase modulation on the output waveform.

The SP030302 is a 6U VME-based, dual-channel DRFM with an IBW of 600 MHz, 4-bit sampling, and a clock rate of 720 MHz, phase modulation and P/N noise generation, and 50 dB of input dynamic range. IF center frequency is 2.5 to 3.5 GHz and spurious rejection is better than 20 dBc over the entire band. "For a 4-bit phase-sampled system, spurious rejection is within a dB or so of the theoretical limit," says Groden. Another model builds on the dual-channel model with 600 MHz of IBW in each channel and includes a companion multiplexer card to provide two-slot solution with an IBW up to 1.2 GHz. "We heard that people wanted more IBW and we had dual-channel version, so we combined 2 channels to get it. The board decides where in that bandwidth the signal resides and routes it to the appropriate channel," Groden says.

Other manufacturers include Systems & Processes Engineering Corp, which manufactures products such as the ADEP-800/1 DRFM-based jammer based on its Agile Digital Effects Processor (ADEP). The unit is designed for airborne applications and measures 3 x 4.5 x 9.7 in. and weighs less than 3.4 lb. It generates multiple crossing targets, extended range and SAR images, and frequency-compensated Doppler for wideband chirps and other complex waveforms. The company's S-DRFM subsystem has expandable cascading channels, an IBW of 2 GHz, 10-bit resolution and 12-bit output resolution, more than 40 dB of spurious rejection, 250 ps time delay resolution, and 0.1 Hz Doppler resolution. It is available in 19-in. rack mount or flight-qualified payload configurations, and has comprehensive waveform generation capabilities.

CSIR, a government-owned research institute in Pretoria, South Africa, has made considerable advances in radar technology in general, and simulation and DRFMs in particular. The organization has a fascinating history dating back to 1939 when sensitive radar technology was transferred to South Africa as part of the war effort, which led to CSIR's first radar system shortly thereafter. In 1988, as the future need for DRFMs became obvious, it became equally obvious to CSIR that this technology would also not be exported to South Africa – so the organization built its own. It has since designed and built many DRFM-based simulators and today is widely recognized for its work in EW and radar. Technology or hardware from CSIR today is used in the US, France, Australia, Finland, Switzerland, NATO facilities, and the UK.

CSIR's DRFM focus is on high-fidelity simulation, integrating the results from its radar and EW research activities into DRFM simulators. CSIR has delivered DRFM-based simulators with 24 scatterers per target and 2 GHz IBW within a single-module. It can simulate 12 independent scatterers on the target so rather than representing a helicopter with a single point, scatterers can be assigned to resemble rotating blades, the body, and tail rotor, for example. Ongoing activities include modeling of radar cross section, and Sensor and EW Engagement Simulation (SEWES) which within a real-time DRFM simulator enables very high fidelity.

Another interesting trend in the DRFM world is the use of Field Programmable Gate Arrays (FPGAs), which are being utilized in DRFM applications. This approach has enabled companies such as Northrop Grumman and BAE Systems to develop DRFMs in-house rather than turning to traditional DRFM suppliers. Many other EW companies are expected to follow this trend. Admittedly, this is not yet a solution for many of the high-end DRFM applications, but this should continue to develop as FPGA technology evolves.

NO DRFM IS AN ISLAND

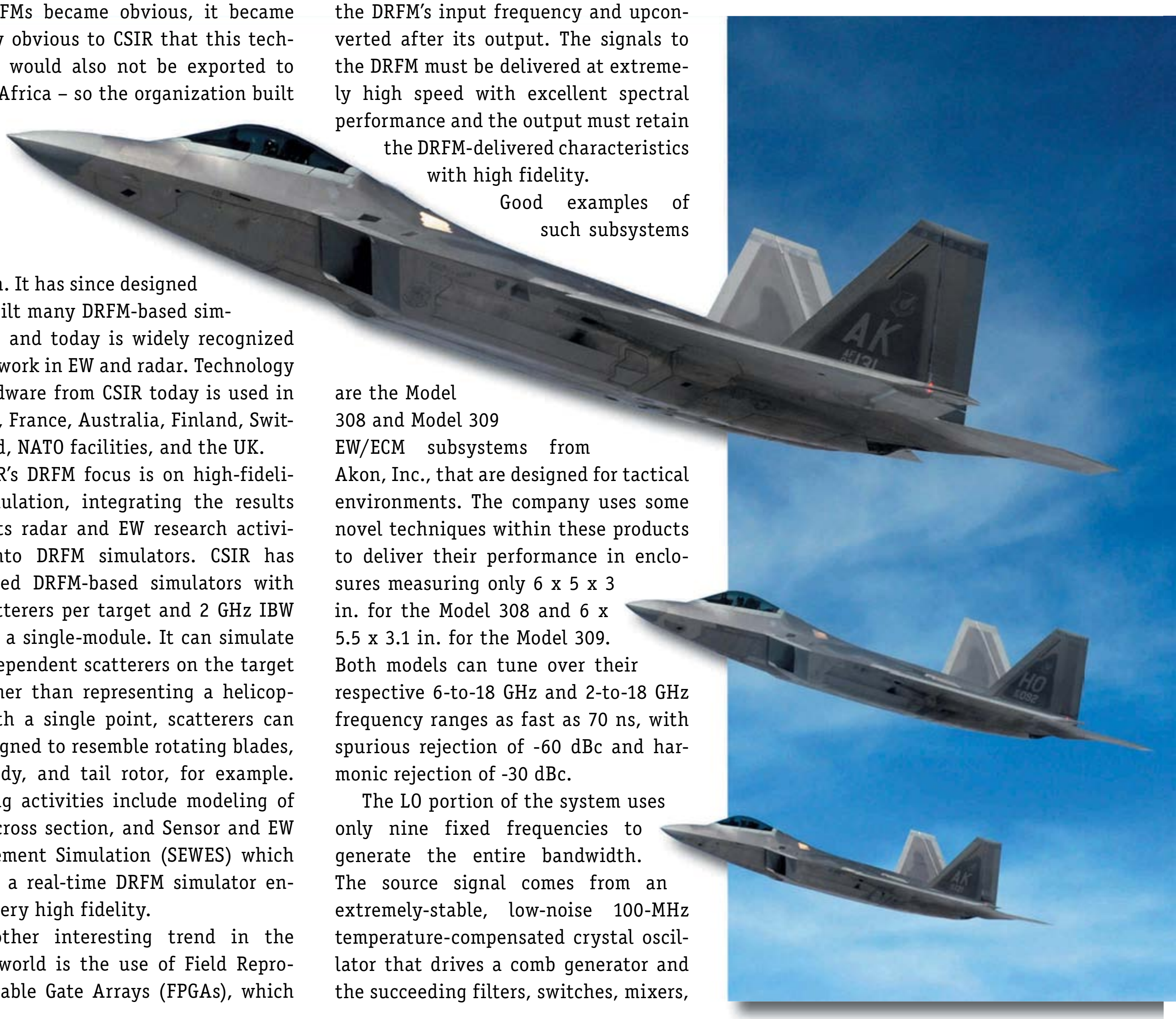
Regardless of how complex and multifunctional a DRFM may be, it can do nothing without the equally complex RF and microwave subsystems that surround it. The input signals, which can cover extremely broad bandwidths (such as 2-18 GHz), must be downconverted to the DRFM's input frequency and upconverted after its output. The signals to the DRFM must be delivered at extremely high speed with excellent spectral performance and the output must retain the DRFM-delivered characteristics with high fidelity.

Good examples of such subsystems are the Model 308 and Model 309 EW/ECM subsystems from Akon, Inc., that are designed for tactical environments. The company uses some novel techniques within these products to deliver their performance in enclosures measuring only 6 x 5 x 3 in. for the Model 308 and 6 x 5.5 x 3.1 in. for the Model 309. Both models can tune over their respective 6-to-18 GHz and 2-to-18 GHz frequency ranges as fast as 70 ns, with spurious rejection of -60 dBc and harmonic rejection of -30 dBc.

The LO portion of the system uses only nine fixed frequencies to generate the entire bandwidth. The source signal comes from an extremely-stable, low-noise 100-MHz temperature-compensated crystal oscillator that drives a comb generator and the succeeding filters, switches, mixers, and amplifiers that produce the required frequencies. Outputs include video, RF processor, and DRFM (variable from -55 to +5 dBm), and there is a built-in test port at the input.

THE UBIQUITOUS DRFM?

DRFMs have become an indispensible component in the spiraling cat and mouse game played for keeps in the world of EW and ECM. From their inception more than 35 years ago when digital technology severely limited designers' efforts to create "something that worked," DRFMs are now highly intelligent, exceptionally fast, and capable of performing truly impressive feats of magic on their captured signals. No EW system today or tomorrow can afford to be without one.



EW Against Modern Radars – Part 9

Pulse Compression Techniques

By Dave Adamy

The purpose of pulse compression is to reduce the range resolution distance for radars, but it also has the effect of reducing the effectiveness of jammers unless they mimic the pulse compression techniques of the target radars. We will consider two types of pulse compression, linear frequency modulation on pulse (LFMOP), also called "Chirp," and binary coding on pulse, called "Barker code."

Chirped Radar

A chirped radar has a linear frequency modulation across each pulse. It is called chirped because it sounds like a bird's chirp when received by some receivers. **Figure 1** shows the block diagram of a chirped radar. These are normally thought of as long range acquisition radars, with long pulses to provide the necessary signal energy. However, LFMOP can also be used in shorter range tracking radars. Note that the return pulse into the radar receiver is passed through a compressive filter. The filter has a delay that varies with frequency. The filter slope matches the FM on the pulse – i.e., the frequency variation vs. time curve is the same as the delay vs. frequency curve. This has the effect of delaying each part of the pulse to the end of the pulse. Thus, after processing, the long pulse is collapsed into a much shorter pulse.

A radar's resolution cell is the region in which the radar cannot distinguish multiple targets. **Figure 2** shows the resolution cell in two dimensions; actually it is a three-dimensional volume rather like a huge wash tub. As shown in the figure, the cross range dimension of the cell is determined by the 3 dB beam width of the radar's antenna. The range resolution limitation is determined by the radar's pulse duration (1/6 meter per nanosecond of pulse duration). A long pulse, while it has more energy, causes poor range resolution. The darker band at the top of the resolution cell in **Figure 2** shows the reduced range uncertainty caused by LFMOP. Because the effective pulse is shorter after passing through the compressive filter, the range resolution is improved.

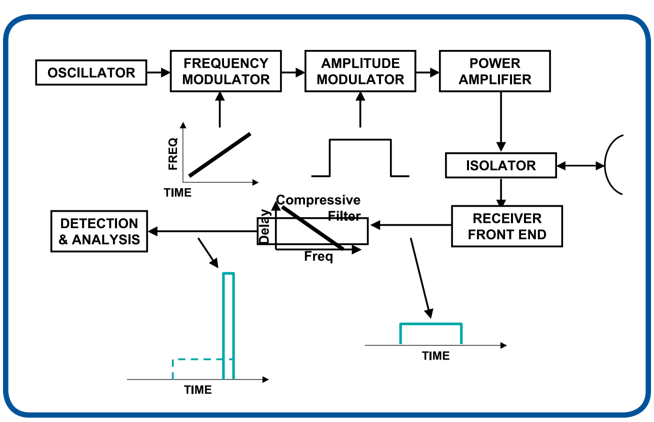


Figure 1: A chirped pulse has a linear frequency modulation on its pulse, which allows the received pulse to be shortened in receiver processing.

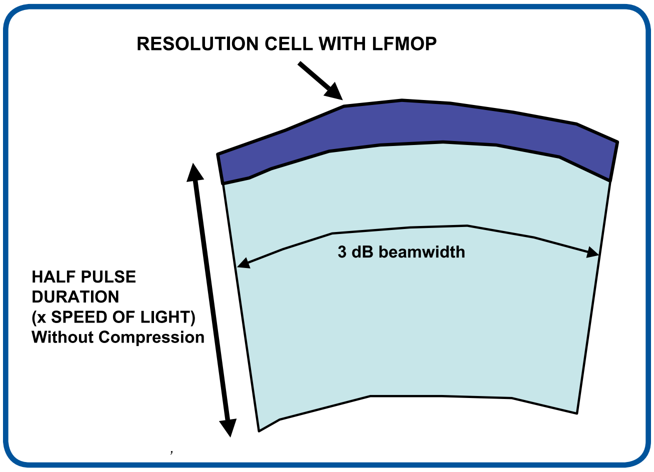


Figure 2: The radar's resolution cell is determined by the antenna beamwidth and the pulse duration. With LFMOP, the effective pulse duration is significantly reduced.

The amount of range compression is the ratio of the frequency modulation range to the inverse of the pulse width. Thus, a 10 microsecond pulse with 2 MHz of frequency modulation range would have its range resolution improved by a factor of 20.

The impact on jamming is shown in **Figure 3**. The green pulse is the radar signal with LFMOP; it is compressed by the compressive filter as shown in green at the right of the figure. The red pulse is a jamming pulse without LFMOP. As shown in red at the right of the figure, its energy does not build up at the end of the pulse. The radar processing is focused only on the time period that the compressed pulse is present, so the energy of the non-compressed jamming pulse is significantly below that of the compressed pulse. This has the effect of reducing whatever jamming to signal ratio (J/S) that would otherwise be created. The J/S reduction is equal to the pulse compression factor. In the example above, this would be 13 dB reduction of J/S.

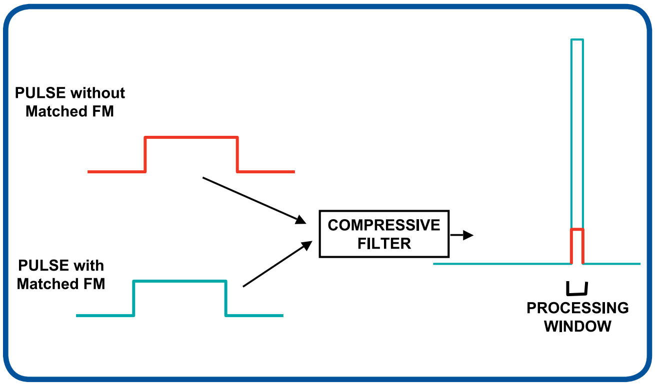


Figure 3: Unless jamming has the correct frequency slope, the effective J/S is reduced by the compression factor.

If a jammer places the appropriate LFMOP on its jamming signal, this EP feature of the radar will be countered. A matching LFMOP can be created by a jammer using direct digital synthesis (DDS) or a digital RF memory (DRFM). Both of these technologies will be discussed in later "EW 101" columns.

Barker Code

The block diagram of a radar with Barker code pulse compression is shown in **Figure 4**. A binary phase shift keyed (BPSK) modulation is placed on each of a radar's pulses, and pulse compression is achieved by passing the returned pulses through a tapped delay line. The top of **Figure 5** shows an example maximal length code with seven bits. Radars typically use much longer codes. This code is 1110010, where the "0" bits are shifted 180 degrees relative to the signal phase during "1" bits. As the pulse passes through the tapped delay line, the sum of the signals on all of the taps add to 0 or -1… except when the pulse exactly fills the shift register. Note that the fourth, fifth and seventh taps have 180-degree phase shifts, so an exactly aligned pulse will cause all of the taps to add constructively. This causes a large output for the time of one bit duration. Therefore, the pulse duration after the tapped delay line is effectively one bit long. This compresses the pulse (and improves the range resolution) by the number of bits of the code placed on each pulse.

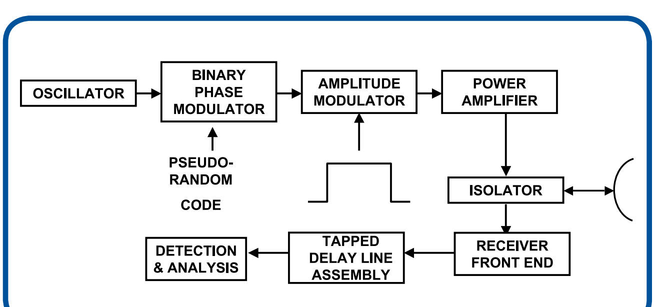


Figure 4: A binary frequency shift keyed code is modulated onto each pulse; a tapped delay line in the receiver reduces the effective pulse width, improving range resolution.

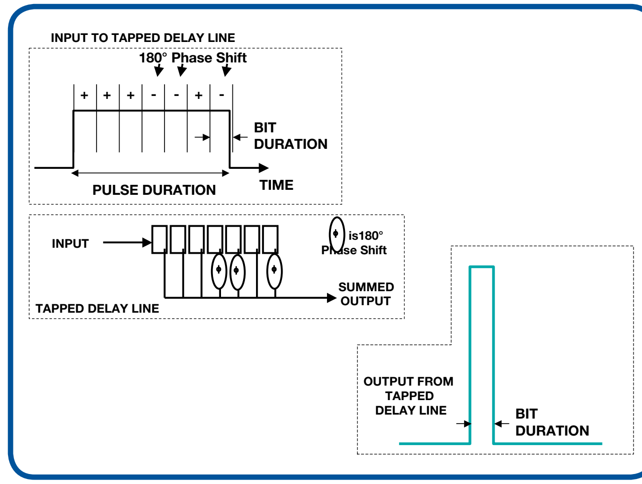


Figure 5: The coded pulse produces a large output from the delay line when all of its bits align to the taps.

For example, if there were 31 bits in the code during each pulse, the range resolution would be improved by a factor of 31.

Now consider **Figure 6**. The green pulse is the radar signal with the proper binary code to match the tapped delay line, it is compressed by the delay line as shown in green at the right of the figure. The red pulse is a jamming pulse without a code. As shown in red at the right of the figure, its energy is not collapsed into the one bit duration output. Like LFMOP, digital code compression reduces the J/S that would otherwise have been achieved. The J/S reduction factor is the same as the compression factor. In the 31-bit code example above, this would cause 15 dB reduction in the effective J/S.

If a jammer places the appropriate binary code on its jamming signal (by use of a DRFM), this EP feature of the radar will be countered.

What's Next

Next month, we will continue our discussion of Radar EP with leading edge tracking and Dicke fix techniques. For your comments and suggestions, Dave Adamy can be reached at dave@lynxpub.com.

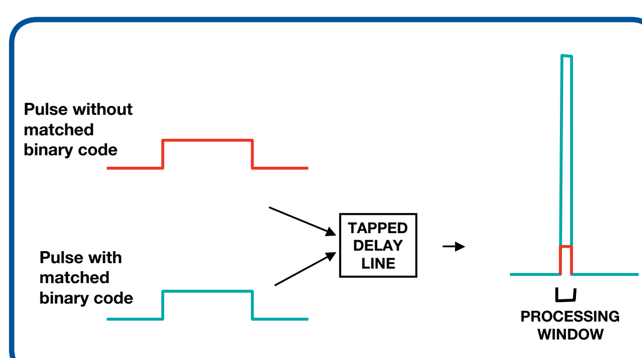


Figure 6: Unless jamming has the correct binary code, the effective J/S is reduced by the compression factor.

THE ORIGINAL EA-6B PROWLER RETIRES

By LCDR Donald "Bucket" Costello, USN and Maj Timothy "Timmeh!" Davis, USMC

June 30 this year marked the end of an era in aviation as the U.S. Navy's oldest EA-6B Prowler engines were silenced forever after its final flight from Naval Air Station Patuxent River, MD, to its new home at NAS Pensacola, FL.

The "Salty Dog" test pilots and aircrew of Air Test and Evaluation Squadron Two-Three (VX-23) at NAVAIR had utilized aircraft side-number SD 534 (BuNo 156481) for more than a decade as a platform for developmental testing of the latest EA-6B components, systems and capabilities. Now, it will inspire future generations of Navy and Marine Corps aviators in its final duty assignment as a static display at the National Naval Aviation Museum in Pensacola.

The P4 with NAS Patuxent River in the background on its final flight. Photo courtesy MAJ "Irish" Kelly USMC.

EA-6B BuNo 156481 was the fourth Prowler (P-4) of five aircraft initially assembled, and was accepted on December 31,1969. Airframes P-1 through P-3 began their lives at the Grumman Iron Works as A-6 Intruders but were diverted to the EA-6B line after production began. Thus, P-4 was the first aircraft actually built from start to finish as a Prowler.

Of the five original developmental aircraft delivered by Grumman, P-4 was the only one still flying more than 40 years later. After more than 20 years flying, including turns with the "Zappers" of VAQ-130, the "Patriots" of VAQ-140 and the "Rooks" of VAQ-137, in April 2002, P-4 finally became "Salty Dog" 534 when it was delivered to Strike Aircraft Test and Evaluation Squadron, VX-23. Since then, SD 534 has been a staple of nearly every EA-6B Improved Capability-II (ICAP-II) test program to include several major aircraft avionics and weapons system block upgrades, night vision goggle integration, aircraft component carrier suitability testing, and the addition of the LITENING pod ISR capability – to name a few.

P-4 may have been the oldest among active EA-6Bs, but it did not boast some of the typical flight statistics of fleet aircraft. When 534 shutdown for the last time, it had logged 924 carrier arrested landings and 6,185.9 flight hours. While P-4 may not have broken trap or flight hour records, her initial ground-breaking production test flights, carrier suitability "off-nominal" catapult launches and arrested landings and envelope expanding developmental test flight hours certainly rank among the most unique and challenging experiences among EA-6B airframes.

At the time of this article, 93 of the 170 EA-6Bs originally produced were still considered to be active. The fact that the fourth aircraft ever produced was still flying for more than 40 years after it was delivered to the Navy serves as a testament to the excellence of both the original Northrop Grumman design and craftsmanship as well as the continuing dedication of the Navy and contract maintenance departments that keep Prowlers flying today.

P-4 has now been successfully delivered to her final respite aboard NAS Pensacola, where she will continue to serve in a new and enduring capacity as a static display in the National Naval Aviation Museum – providing inspiration to future aviators and engineers alike.

FROM THE BILLY MITCHELL CHAPTER


Billy Mitchell Chapter President Greg Radabaugh presents Dr. Randall Janka, of Zeta Associates, Inc. in Fairfax, VA, with some AOC mementos following his talk to the chapter on electronic attack/electronic support scheduling optimization.

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