NOVEMBER 2010
Vol. 33, No. 11

JED

The Journal of Electronic Defense

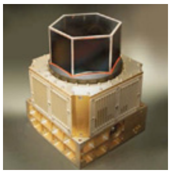
The AOC Electronic Warfare Publication
www.crows.org

Protecting Helicopters (and Their Cargoes)

Also in this issue:

Technology Profile: EW and FPGAs

Defining the EMS: The Physics of the Problem



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THE POLITICS OF PROTECTING HELICOPTERS

At *JED*, we often make the point that the wars in Iraq and Afghanistan have profoundly changed electronic warfare (EW) in many ways. This month, we are publishing an article about protecting helicopters that looks at a how EW systems are forming the heart of new capabilities well beyond "traditional" EW.

Helicopters of all types have proven to be critical assets in current irregular warfare operations, not only because they provide essential air power in support of ground forces, but also because of their ability to transport troops and equipment to the right places at the right time. Unfortunately, their strategic importance has not escaped the enemy, who targets them with SA-7s, RPGs and AK-47s, among other weapons.

Today, many countries are in the process of improving the aircraft survivability equipment (ASE) on their helicopters, mostly because of pending commitments to Iraq and Afghanistan operations. Missile warning systems (both UV and IR sensor types) are adding the capability to perform hostile fire indication (HFI) against small arms and RPGs. IR decoys and flares have improved. Laser-based directed IR countermeasures (DIRCM) systems are becoming operational. In short, a lot of new EW capabilities are being introduced that have become baseline requirements for current and future upgrades.

What is particularly interesting is how this new technology is changing the thinking of the helicopter user. With the advent of IR missile warning sensors, a helicopter crew doesn't just have a missile warning system; it has an IR camera that can extend the situational awareness of the aircrew, help prevent collisions with other helicopters and avoid hard landings in low-visibility conditions. As more capable laser-based DIRCM systems are developed, these could provide additional functionality beyond jamming IR-guided missiles. They could help aircrews to avoid hard-to-see obstacles, such as power lines. They could also be used for laser communications or as an "optical disruptor" countermeasure cued by HFI (although this is likely to spark a policy debate about the UN's 1998 Protocol on Blinding Laser Weapons).

These ASE advances cannot be fielded too soon, because the low-altitude threat environment is likely to become far more deadly in the coming years. With the advances in commercial radar, laser and IR sensor technology, and the enemy tactics learned from remote controlled IEDs in Iraq and Afghanistan, it is very likely that future adversaries will search for unrecognized EW weaknesses within the world's helicopter fleets. One only needs to consider the appalling age of many helicopter ASE equipment designs (or the lack of helicopter EW at all, in some cases) to identify those vulnerabilities.

This is the major challenge facing the helicopter user today. At a time when many countries are freezing or cutting their defense spending, can helicopter ASE remain as a front-burner defense issue and squeak past the budget axe before it falls? Or do we forfeit this opportunity until we begin losing helicopters in a future conflict and everyone decides this is an unacceptable situation (again)?

– John Knowles

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NOVEMBER

Aircraft Survivability Symposium 2010
November 2-5
Monterey, CA
www.ndia.org

Maritime and Systems Technology (MAST) 2011
November 9-11
Rome, Italy
www.mastconfex.com

Aircraft Survivability Equipment Symposium
November 15-17
Nashville, TN
www.quad-a.org

13th Annual Directed Energy Symposium
November 15-19
Bethesda, MD
www.deps.org

I/ITSEC
November 29-December 2
Orlando, FL
www.iitsec.org

Information Operations & Cyber Capabilities in 21st Century Warfare
November 30-December 2
Charleston, SC
www.crows.org

Exponaval 2010
November 30-December 2
Valparaiso, Chile
www.exponaval.cl

DECEMBER

Electronic Warfare Symposium
December 1-2
Swindon, Wiltshire, UK
Clearance: Secret Four Eyes
www.cranfield.ac.uk

International Defence Exhibition and Seminar (IDEAS) 2010
December 6-10
Karachi, Pakistan
www.ideaspakistan.gov.pk

Worldwide EW Reprogramming Conference
December 15-16
Orlando, FL
www.crows.org

JANUARY

41st Annual Collaborative EW Symposium
January 25-27
Point Mugu, CA
www.crows.org

FEBRUARY

Aero India 2011
February 9-13
Bangalore, India
www.aeroindia.in

Low Probability of Intercept Conference
February 15-17
Monterey, CA
www.crows.org

IDEX
February 20-24
Abu Dhabi, UAE
www.idexuae.ae

MARCH

Spectrum Modeling and Simulation Conference
March 15-18
Las Vegas, NV
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Dixie Crow Symposium
March 20-24
Warner Robins, GA
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Alexandria, VA
www.crows.org

Survivability
November 22-December 3
Shrivenham, UK
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November 30-December 3
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DECEMBER

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JANUARY

Radar Electronic Warfare
January 3-7
Shrivenham, UK
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Digital Radio Frequency Memory (DRFM) Technology
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MARCH

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Atlanta, GA
www.pe.gatech.edu

IR/Visible Signature Suppression
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Atlanta, GA
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Introduction to Intelligence, Surveillance, Reconnaissance (ISR) Concepts, Systems and Test & Evaluation
March 29-April 1
Atlanta, GA
www.pe.gatech.edu

APRIL

Basic RF Electronic Warfare Concepts
April 19-21
Atlanta, GA
www.pe.gatech.edu

Directed Infrared Countermeasures: Technology, Modeling and Testing
April 19-21
Atlanta, GA
www.pe.gatech.edu

JULY

Directed Infrared Countermeasures: Technology, Modeling and Testing
July 12-14
Huntsville, AL
www.pe.gatech.edu

Basic RF Electronic Warfare Concepts
July 26-28
Denver, CO
www.pe.gatech.edu

AOC courses are noted in red. For more info or to register, visit www.crows.org.

message
from the president

THE EMS DOMAIN – ALWAYS WAS AND ALWAYS WILL BE

In my March 2007 President's column, I wrote that the emergence of the Cyberspace Domain was an evolutionary step in warfare, with symmetries to the Land, Sea, Air and Space Domains. However, the next evolutionary step is evident in the growing recognition that all five of these domains are dependent on the ability to interact via the Electromagnetic Spectrum (EMS) Domain.

Over the past decade, we have increased our network-centric warfare capabilities and embraced the Cyberspace Domain. However, we have been slow to recognize that our ability to fight effectively depends more and more on our ability to access and control the EMS Domain. Through the EMS Domain, communications, navigation, sensing and countermeasures occur to enable operations in the Land, Sea, Air, Space and Cyberspace Domains. Without the EMS, operations or maneuver in any of the other five domains are severely limited and, for all intents and purposes, cannot achieve any measureable outcome. For a moment, visualize how we would work in Land, Sea, Air, Space or Cyberspace if the EMS never existed. They are meaningless without the availability of the EMS.

The EMS is the most contested and congested of all the warfighting domains, and rapidly evolving and proliferating technology is only fueling the problem. Technology has outpaced our antiquated EMS regulations and policies, as well as the very national spectrum management organizations that create and enforce governances. However, the military challenges in the EMS Domain are inherently related to a much larger EMS problem that is global in scope.

While the military thinks in terms of warfighting domains, each of these – Land, Sea, Air, Space, Cyberspace and the EMS – are really a system of global commons used by commercial and government interests, as well as the military. The world's operations flow through these global commons, which are natural (or in the case of Cyberspace, man-made). The EMS global common is uniquely the sole mechanism that links operations through the natural commons. Yes, it's that big and that important, and we must address the problem now.

In the case of the EMS Domain (or EMS global common), it is essential that we create a global EMS strategy based on international concurrence and cooperation that empowers allies to ensure responsible nations have the ability to operate uncontested in the EMS domain. Achieving this requires changes in EMS policies, postures and international treaties that enforce compliance and confront disruptions and exclusivity. It is essential that military organizations take part in this process, along with government and industry partners, if we are to ensure that our forces have proper access to the EMS and control of the EMS Domain in future military operations.

The phrase "EMS Domain: Always Was and Always Will Be" should become as well known in EW circles as – "First In and Last Out." The EMS has been and shall always be a warfighting domain.

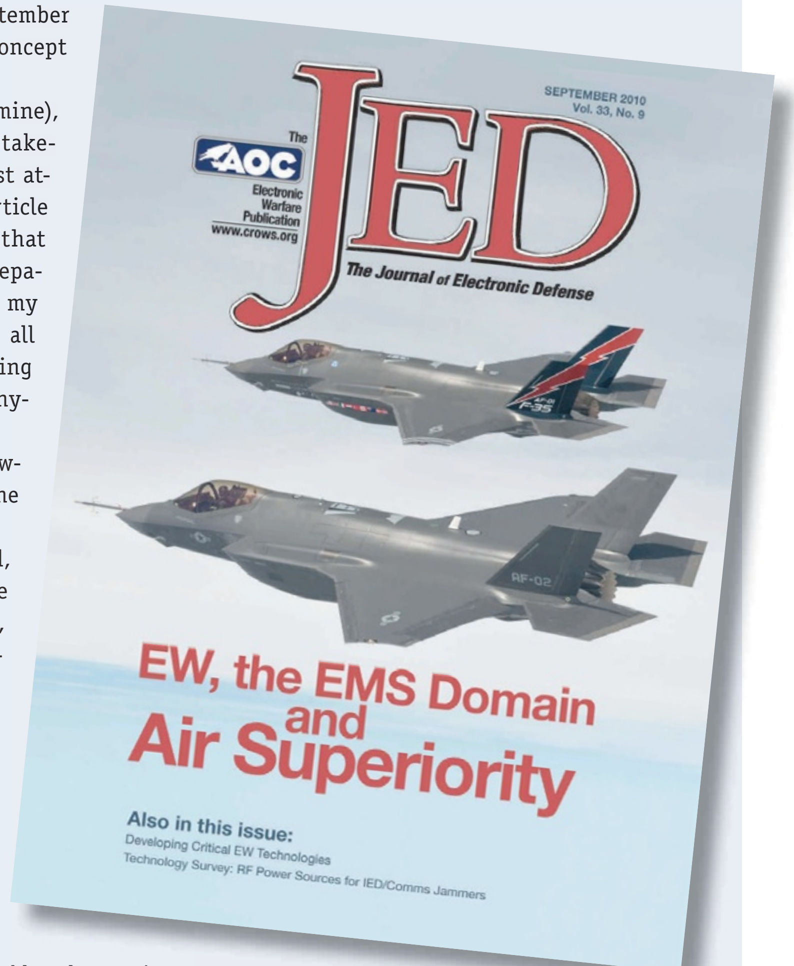
– Walter Wolf

JED welcomes and publishes letters to the editor when we're lucky enough to receive them. Please send letters to John Knowles, jknowles@naylor.com or to JEDeditor@naylor.com.

CYBERSPACE MUST BECOME PART OF EW

Let me first say to Lt Col Fischer, excellent piece of prose ("EW, the EMS Domain and Air Superiority," *JED*, September 2010). I couldn't agree more. EMS as a domain is a concept whose time is here.

As many EWOs in his generation (one removed from mine), he survived the fights against attempted Intelligence takeover of EW, attempted IO takeover of EW, and the latest attempted Cyber takeover of EW. And therefore, the article comes off as a bit cynical and makes the same mistake that I've seen repeated over the last few years in trying to separate EW from anything that smacks of cyber. For that, my generation and the succeeding generations thank you all for the sacrifices to careers, deployments and establishing a proud heritage of Electronic Warfare that we joined anywhere from weeks ago to a decade ago.



For a truly "Mitchell-esque" coup to take place, however, EW must absorb Cyberspace as one component of the greater Electronic Warfare service.

The history lesson he states in the article is good, but incomplete. EW as a legitimate warfighting service started when telegraph cable was laid for the first time, allowing for DC power over a medium to transmit relevant messages to and from the front of conflict. Think all the way back to the Civil War, where telegraph wires were intercepted by rebel and Yankee soldiers, spurious command messages were sent and then they were cut, sowing confusion and distrust among the opposing side. (Dupuy). When Marconi came up with his little invention, that medium became the EMS as we think of it today, and as early as the late 1890s, the US Navy (and other navies for that matter) were employing ES and EA techniques against each other (Price). Arguably, Electronic WARFARE has existed LONGER than air warfare, and has a more storied and checkered past.

What fires me up about this article is that he supposes EMS as a supporting function for everything else, and not as what it is – a warfighting domain meant to target the cognitive abilities and facilities of our enemies. EMS is simply one descriptor of a medium through which warfare takes place – Electronic WARFARE is a proven and separate component of warfare, and has been since man started employing DC power through wires to transmit commands and information. Cyberspace is just one of many descriptors for individuals without the full capacity to appreciate Electronic Warfare. Truly, we should be discussing the electronic domain, and the full spectrum of options that reside within it. Try and tell me there's a difference between a port scan conducted over Internet-based protocols and the excitement of various components of some air defense system to find weaknesses. Both involve an electronic signal of some sort (a radar return in one case, an electronic packet in another case), transmitted over an electronic media. How different are the concepts of attempting to spoof a control node by inputting predictive returns into a search algorithm?

It's time for EW to take its rightful place next to Land, Sea, Air and Space Warfare as an equal and full-fledged warfighting domain. Stop fighting the "cyberspace" hype, and absorb it – it's really ONLY a component of Electronic Warfare.

I welcome any comments or reasoned debates on anything stated here.

Lt Col (Sel.) Jason A. "Eck" Eckberg, USAF
Kettering, OH


TAKING YOUR MISSION TO
THE PEAK OF SUCCESS

JATAS GEARS UP FOR NEXT PHASE

US Naval Air Systems Command (NAVAIR) last month released a draft request for proposals (RFP) and a draft Statement of Work (SOW) for the planned engineering and manufacturing development (EMD) phase of its Joint and Allied Threat Awareness System (JATAS) acquisition program. JATAS is currently in the Technology Demonstration (TD) phase with two contractor teams, ATK (Clearwater, FL) with BAE Systems (Nashua, NH) competing against a team led by Lockheed Martin Missiles & Fire Control (Orlando, FL). JATAS entered the TD phase in September 2009 with the award of a 16-month, $32.2 million contract to each team. The EMD phase is slated to begin in FY2011 with a single contractor team. The EMD contract will include options for low-rate initial production and full-rate production lots.

JATAS is a next-generation missile warning system for Marine Corps, Navy (and potentially Army) rotary-wing aircraft. It would detect incoming infrared-guided missiles, particularly those launched by shoulder-fired, man-portable air defense systems, and would cue the aircraft's expendable flare decoy dispenser or laser-based directed IR countermeasures (DIRCM) system to defeat the attacking missiles. JATAS also would provide warning of enemy laser range finders, illuminators and beam riders.

JATAS will feature imaging IR sensors, which offer faster and longer-range missile detection compared with the ultra-violet sensors used on the existing ATK AAR-47, Northrop Grumman AAR-54, and BAE Systems AAR-57 missile warning systems. The latest US system, in production for Air Force transports as well as the Marine Corps' large CH-53E, CH-46E and CH-53D helicopters, is Northrop Grumman's Next-Generation (NexGen) MWS. It uses two-color imaging IR sensors, which evaluate threat missiles in two separate frequency bands.

JED reported in September that the Navy had decided to open up the competition for the JATAS EMD phase, allowing Northrop Grumman (Rolling Meadows, IL), or any other bidder, to re-enter the competition against ATK and Lockheed Martin. The JATAS program is managed by the Advanced Tactical Aircraft Protection Systems Program Office (PMA-272) within the Program Executive Office for Tactical Aircraft Programs at NAVAIR (NAS Patuxent River, MD).

The lead platform for the JATAS program is the US Marine Corps' MV-22 tilt-rotor aircraft. JATAS is also slated for installation on the Corps' AH-1Z, UH-1Y and planned CH-53K helicopters and on the Navy's MH-60R and MH-60S helicopters.

An additional capability desired for JATAS is hostile-fire indication (HFI) of small arms, rocket-propelled grenades and other ground-fire threats, which currently is not part of the EMD baseline design. "It is, however, identified as an EMD technology option," the JATAS SOW stated, "which is being developed and matured via a separate and distinct effort from the current TD Phase JATAS contract and this planned EMD Phase JATAS contract. PMA-272's plan is to continue to mature this technology in a parallel effort, and if and when its recognized maturity level coincides that required for the corresponding phase of the baseline program, it would be reconsidered as a viable option to add to the baseline threshold compliant design." – *G. Goodman*

US ARMY PLANS UNMANNED SIGINT CAPABILITY

The US Army released a "sources sought" solicitation to industry for a market survey it is conducting to identify companies qualified to conduct engineering and manufacturing development (EMD), low-rate initial production and full-rate production of the service's planned Tactical Signals-Intelligence (SIGINT) Payload (TSP). The Army aims to integrate TSP in an external pod configuration on its Extended-Range Multi-Purpose (ERMP) unmanned aircraft system (UAS), a variant of General Atomics' Predator formerly called Sky Warrior. BAE Systems (Nashua, NH) has been developing a TSP for the Army since 2004. Northrop Grumman (San Diego, CA) is expected to bid for the TSP EMD contract, as well. It has developed the Airborne SIGINT Payload (ASIP) for the Air Force's Predator and larger Reaper sibling, in addition to the Global Hawk. The Office of the Secretary of Defense has questioned the need for funding two different Predator SIGINT payloads.

According to the solicitation, TSP would provide a UAS-borne capability for emitter mapping – "a comprehensive picture of electronic emitters and the ability to detect, identify, geo-locate and copy emitters, including High-Value Targets." The specific objective of the market survey is to "identify sources with a mature SIGINT Payload which is at a Technology Readiness Level 6 or better, and that has the capability with, minimal design changes, of being upgraded to the desired pod configuration for the ERMP UAS." The TSP package onboard the ERMP UAS cannot exceed 200 pounds and 3 cubic feet in size or require more than 1,200W. A workstation also will be developed that will control the payload and display the data it collects.

The Army plans to award a single EMD contract and procure 12 production-representative pod-configured TSP systems for installation on board a surrogate RC-12 aircraft for performance tests, a flight demonstration and an Operational Assessment. The contact will include options for up to 97 full-rate production systems.

The TSP program is managed by the Army's Project Manager for Aerial Common Sensors at Aberdeen Proving Ground, MD, which falls under the Program Executive Officer for Intelligence, Electronic Warfare and Sensors. The technical point of contact is Kahraman Koseoglu at Ft. Monmouth, NJ, e-mail kahraman.koseoglu@us.army.mil. – *G. Goodman*

INTEGRATED TOPSIDE CONTRACTS AWARDED

The Office of Naval Research (ONR) awarded Northrop Grumman (Linthicum Heights, MD) and Raytheon (Tewksbury, MA) task order contracts last month under its Integrated Topside (InTop) technology project. Northrop Grumman's contract is potentially worth $109.4 million for a seven-month base period and four 12-month option periods. Raytheon's $108.6 million contract is for a 12-month base period with the same options.

The InTop project's aim is to reduce the number of topside radio-frequency (RF) apertures present on Navy surface ships through the use of integrated, multi-function, multi-beam, shared transmit-and-receive antenna arrays.

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InTop will develop and demonstrate an open-architecture, scalable family of multi-function RF equipment that could be installed on different ship classes. An initial InTop task has involved identifying issues associated with developing a combined system that would provide both communications electronic attack capability and line-of-sight communications (via the Tactical Common Data Link) and could be integrated with the electric support system on new and existing Navy surface ships. Northrop Grumman and Raytheon will build advanced development models to demonstrate the desired InTop capabilities.

In May 2009, ONR awarded a five-year, indefinite delivery-indefinite quantity (ID/IQ) InTop task order contract to 18 different companies. The other 16 firms competing for InTop task orders are ATK Space Systems (Dayton, OH); Argon ST (Fairfax, VA); BAE Systems (Nashua, NH); Ball Aerospace (Broomfield, CO); Boeing (Seattle, WA); Cobham Defense Systems (Landsdale, PA); Colorado Engineering Inc. (Colorado Springs, CO); DRS Signal Solutions (Gaithersburg, MD); FTL Systems (Rochester, MN); General Dynamics Advanced Information Systems (Fairfax, VA); HYPRES Inc. (Elmsford, NY); ITT Electronic Systems & Radar Systems (Van Nuys, CA); ITT Force Protection Systems (Thousand Oaks, CA); Lockheed Martin (Moorestown, NJ); S2 Corp. (Bozeman, MT); and Southwest Research Institute (San Antonio, TX).

ONR and the contractors will define the RF form, fit, function and interface standards for a common set of open-architecture hardware and software, pursue different array architectures and support development of component technology to reduce the cost of the arrays. – *G. Goodman*

AFRL SEEKS "PROACTIVE" ELECTRONIC PROTECTION

The Air Force Research Laboratory (AFRL), RY Sensors Directorate, has released a Broad Agency Announcement (BAA) soliciting technical and cost proposals for development of proactive electronic protect (EP) techniques and concepts that will allow maintenance of or re-establishment of "spectral dominance" in air-to-air engagements, both in short- and long-term applications.

The objective is development of "proactive" EP techniques specifically for the advanced air-to-air electronic attack (EA) threat – proactive referring to "measures taken to actively disrupt an adversary's capability to effectively employ EA." The measures can involve operational EW, radar or development systems, and the BAA seeks to explore the breadth of proactive EP concepts to determine the best options for further development.

Deliverable items include data and software. The contract amount is expected to be $859,000, and the overall effort will be 33 months – 30 months of technical work and three months to write the final report.

Proposals were due before press time, however, late submissions are subject to the provisions of FAR 52.215-1(c)(3). BAA Number: BAA-09-01-PKS, Call 33. Technical point of contact is Michael Murray, (937) 528-8259, michael.murray@wpafb.af.mil. Contracting point of contact is Joe Moore, (937) 255-5762, joseph.moore2@wpafb.af.mil. – *E. Richardson*

HIGHLIGHTS FROM THE AOC CONVENTION

The following are excerpts from the presentations given at the 47th Annual Association of Old Crows (AOC) International Symposium and Convention, held in Atlanta, GA, October 3-7.

In a keynote address, US Air Force **Maj Gen Thomas K. Andersen**, Director of Requirements at Air Combat Command, Langley AFB, VA, stated, "Electronic warfare [EW] may have a part in information operations, but it has no business being subverted under IO… The electromagnetic spectrum [EMS] encompasses all the domains – air, sea, land, space and cyber – and EW can come out of each one of those domains. Every one of those individual domains has to work through the EMS… We have assumed that we are going to be able to work in the EMS unabated, and that just isn't true. So we're going to make sure in the future that our aircrews train to operate in a degraded electronic environment. That's going to become standard from now on."

USAF **Col Stephen Brown**, chief of the EW operational requirements division on the Air Staff, identified several positive changes that have taken place in Air Force EW. "First is an increasing sophistication on the part of the Air Force leadership in the EW mission, and the resulting belief in its importance to the joint fight. Consequently, there is significantly more support for EW programs, manpower, training and sustainment than I can remember. There's been an unprecedented demand for EW capabilities and personnel in today's fight against what some would deem a relatively unsophisticated yet deadly improvised explosive device [IED] threat, although that fight also employs EW capabilities against an increasing array of enemy targets of increasing complexity. But the rising attention to EW in the Air Force is also driven by the rapidly increasing demand for future capabilities from our combatant commanders."

Blaise Durante, Deputy Assistant Secretary of the Air Force for Acquisition Integration, noted that, in the midst of DOD budget constraints, EW investment remains a priority to counter emerging threats. He cited $411 million allocated across the Air Force's planned FY11-15 budgets for the Miniature Air-Launched Decoy-Jammer (MALD-J) and $185 million for the nascent Airborne Electronic Attack Pod, which would jam adversary communications in irregular warfare scenarios. In the face of shrinking DOD discretionary funding, the Air Force and the other services, at the direction of Defense Secretary Robert Gates, are focused on reducing overhead costs, he said, and applying the savings to force modernization.

Brig Gen Dwyer Dennis, Director of Intelligence and Requirements at Air Force Materiel Command (AFMC), Wright-Patterson AFB, OH, said, "The Air Force is making a concerted effort – with a lot of energy and senior leadership attention – to think through the challenges we face as we try to ensure that we will have the EW capabilities we need in the future." One of the key thrusts is improving EW collaboration across the service through the EW Advisory Group (EWAG), an expanded version of the three-year-old EW Life-Cycle Management Group (EW LCMG). The latter focused on EW materiel solutions by AFMC. Its successes, Dennis said, included gaining funding for EC-130H Compass Call aircraft upgrades and ALR-69A digital radar warning receiver procurement in the FY11 budget request. The EWAG's charter will be broader, he noted, encompassing full-spectrum DOTMLPF [Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities] issues aimed at improving Air Force EW.

In a keynote address, **Brig Gen Giovanni Fantuzzi**, chief of the Italian Air Force's Aerospace Planning Division, revealed, "From the experience gained in operational theaters and from the knowledge achieved doing operational tests and demonstration trials, the Italian Air Force launched an accelerated effort to provide airborne EW support against radio-controlled IEDs. IED scenarios consisting of convoy attacks and IED detection and neutralization have been planned and executed during a tactical validation trial. A prototype communications jammer for future airborne employment has been successfully tested against a simulated terrorist C3 network as well as against a wide variety of IEDs. Therefore, a spiral development approach has been defined to field an interim operational counter-IED capability as soon as possible while minimizing technical and operational risks." – *G. Goodman*

IN BRIEF

Northrop Grumman (Rolling Meadows, IL) received a five-year indefinite-delivery indefinite-quantity contract potentially worth $457 million from the US Army to deliver APR-39C(V)1 upgrade kits and APR-39A/B(V) systems. The APR-39 is the standard radar warning receiver on Army and Marine Corps rotary-wing aircraft.

✪ ✪ ✪

SRC, Inc. has named Robert Behler as its new president and CEO, effective December 1. Behler was most recently senior vice president and general manager of the MITRE Corporation's Command and Control (C2) Center. A retired major general in the USAir Force, his military experience includes commanding the Air Force C2ISR Center at Langley Air Force Base (AFB). In related news, **SRCTec** (Syracuse, NY) has elected Drew James as its new president. James has been vice president of operations for the company since 2006.

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Sierra Nevada Corp. (Sparks, NV) has received a $91 million contract modification from the Naval Surface Warfare Center for procurement and support of the transmitting set countermeasures PLT-5. The firm-fixed-price, cost-plus-fixed-fee, indefinite-delivery/indefinite-quantity contract supports Joint Services Explosive Ordinance (JSEOD) personnel. JSEOD personnel maintain and support counter radio controlled improvised explosive device (IED) EW (CREW) program. Work should be complete by September 2011.

washington report

DHS TECH GAPS INCLUDE IED PRIORITIES

Defeat tactics for improvised explosive devices (IEDs) are not only significant for US forces overseas, but are also among high-priority technology gaps faced by the Department of Homeland Security, according to Dr. Thomas A. Cellucci, chief commercialization officer for the DHS Science and Technology Directorate.

Speaking on "Policy and Planning for Law Enforcement and Homeland Security" at last month's AOC International Symposium and Convention in Atlanta, Cellucci discussed the agency's need for private sector help in meeting critical technology needs, including domestic IED defeat.

Cellucci noted that DHS is specifically interested in gaining private sector assistance because "it increases the speed of execution of developing technologies and products and it saves the taxpayer lots of money."

Given the difficulty in countering IED attacks, DHS is developing a "layered systems" approach to the problem – by developing technologies that can, according to the most recent High-Priority Technology Needs brief, be "injected at each stage in the IED attack timeline." Among the high-priority technology needs are a capability to:

- identify and model the human precursors of IED threats and terrorist activity within the continental US using unstructured data and novel computational models;
- predict participants and locations of potential IED attacks based on existing or known geospatial, socio-cultural and behavioral information;
- non-intrusively detect vehicle-borne IEDs – in particular, technologies to detect the explosive or explosive device;
- detect person-borne IEDs from a standoff distance – in particular, technologies to detect the explosive or explosive device;
- defeat vehicle-borne IEDs – in particular, non-explosive and standoff defeat technologies;
- defeat person-borne and leave-behind IEDs;
- diagnose vehicle-borne and person-borne IEDs;
- diagnose and defeat water-borne IEDs, above and below the waterline; and
- characterize IED threats, including IED design, assembly, detonation and effects.

Among the difficulties with domestic IED defeat are the regulatory constraints on what can be done to the radio spectrum, specifically in terms of jamming. For countering radio-controlled IEDs (RCIED), DHS is looking for better optimization of existing electronic countermeasures (ECM) systems using current antenna technologies, but also development of alternate approaches for interference with initiation or control of IEDs with electromagnetic radiation, rather than jamming. – *E. Richardson*

LAW ENFORCEMENT AGENCIES STRUGGLE WITH TECH REQUIREMENTS

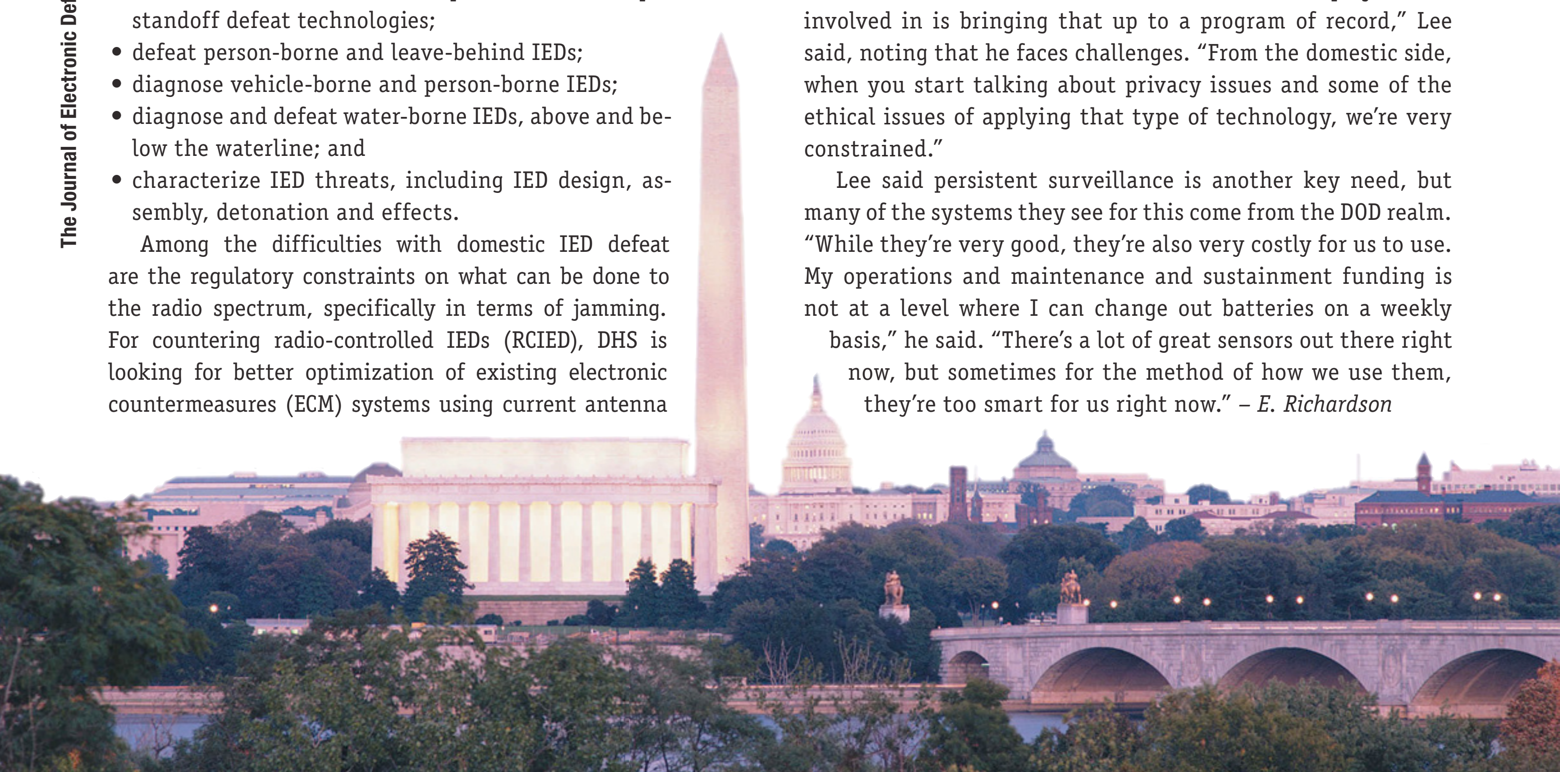
Also speaking on the panel "Policy and Planning for Law Enforcement and Homeland Security" at last month's AOC International Symposium and Convention in Atlanta, two different law enforcement officers spoke to the difficulties faced in trying to meet their technology needs. A key point made was that while electronic warfare has interesting capabilities to offer local law enforcement, the learning curve for agencies to understand EW is steep and the technologies coming from military applications can simply be too sophisticated for what they can use and afford.

Aaron Kustermann, chief of intelligence for the Illinois State Police noted that without an acquisition system in place, agencies can struggle with determining their requirements. "We have to do that and have to do it right," Kustermann said. "We've bought a lot of tech and built a lot of tech – sole source stuff where we thought it wasn't out there and then come to find out it really is, it's everywhere."

"One of the things we're doing that we've never done before are cost-capability tradeoffs," said Woody Lee, director, operational integration and analysis for the US Customs and Border Protection Office of Technology Innovation and Acquisition. "I know for the people in DOD this may sound kind of silly, but that's where we are right now. We're in the infant stages of this."

As part of this process, Customs and Border Patrol is also looking at its aging signals intelligence (SIGINT) resources. "We have signals intelligence stuff across the United States, but most of it dates back to the 1990s. One of the projects I'm involved in is bringing that up to a program of record," Lee said, noting that he faces challenges. "From the domestic side, when you start talking about privacy issues and some of the ethical issues of applying that type of technology, we're very constrained."

Lee said persistent surveillance is another key need, but many of the systems they see for this come from the DOD realm. "While they're very good, they're also very costly for us to use. My operations and maintenance and sustainment funding is not at a level where I can change out batteries on a weekly basis," he said. "There's a lot of great sensors out there right now, but sometimes for the method of how we use them, they're too smart for us right now." – *E. Richardson*



world report

SAUDI ARABIA TO BUY F-15s, APACHES AND BLACKHAWKS

The US Defense Security Cooperation Agency (DSCA) announced that Saudi Arabia has requested the purchase of aircraft and helicopters, including F-15SA fighters, AH-64D Apache helicopters, UH-60M Blackhawk helicopters, along with associated EW systems via Foreign Military Sales (FMS) channels. The total package is valued at $60 billion.

The request encompasses a significant number of aircraft and systems, including 84 new F-15SA aircraft (plus an additional 12 for training), as well as the upgrade of the existing Royal Saudi Air Force's fleet of 80 F-15S fighters to the F-15SA configuration. The SA configuration adds key systems, including the Digital Electronic Warfare Suite (DEWS) from BAE Systems, third-generation LANTIRN navigation pods, APG-63(V)3 Active Electronically Scanned Array (AESA) radars, AAQ-33 Sniper targeting pods and AAS-42 infrared search and track (IRST) systems. The request also includes improved munitions, including the AGM-88B High-Speed Anti-Radiation Missile (HARM) and JDAM, as well as GPS-guided dual mode laser munitions, RR-188 chaff and MJU-7/10 flares.

Also requested by the Saudis are 36 Block III AH-64D Apache helicopters, 36 AH-6i Light Attack Helicopters and 72 UH-60M Blackhawk helicopters for the Saudi Arabian National Guard. This potential sale includes 171 each of the AAR-57(V)3/5 Common Missile Warning System, APR-39 RWR and AVR-2B laser warning receiver, as well as 318 Improved Countermeasures Dispensers. In addition, the Saudis could buy up to 20 APR-48 RF Interferometers for their Apaches. Another 34 Block III AH-64D Apache Longbow helicopters, also featuring the APR-48, AAR-57 and APR-39 and adding the AVR-2B Laser Warning System, are also requested for the Royal Saudi Land Forces.

In late 2009 and early 2010, Saudi forces fought against Houthi rebels based along the country's southern border with Yemen. The rebels' incursion into Saudi territory highlighted the country's need for better irregular warfare capabilities, including helicopters. –*E. Richardson* and *J. Knowles*

IN BRIEF

- **Thailand** has requested, via FMS channels, a Mid-Life Upgrade to 18 F-16A/B Block 16 aircraft. The request includes a three-phase program that would upgrade six aircraft a year, over a three-year period, each phase overlapping by one year. The Mid-Life Upgrade provides a new modular mission computer, along with the ALQ-213 electronic warfare system and the ALE-47 countermeasures dispenser. The entire sale package of upgrades, repairs, spares, training and support is estimated at $700 million. The prime contractor is **Lockheed Martin** (Fort Worth, TX).
- **Germany** has announced its intent to purchase six AAQ-24(V) Large Aircraft Infrared Countermeasures (LAIRCM) Systems from the US, via FMS channels, from **Northrop Grumman** (Rolling Meadows, IL). The sale would include the systems and installation on two German Airbus A-319 and four Bombardier Global 5000 aircraft, providing protection for the German head-of-state aircraft fleet. The full sale is estimated at $146 million.
- **Kuwait** has requested the purchase of one C-17 Globemaster III aircraft and associated parts, equipment and logistics, from the US, via FMS channels in a package worth approximately $693 million. The aircraft, from Boeing (Chicago, IL), includes an ALE-47 Countermeasures Dispensing System, as well as the AAR-47 Missile Warning System, and would provide long-range, strategic airlift capabilities to the Kuwaiti Air Force.
- **Sweden** has requested the sale of 15 UH-60M Blackhawk helicopters, along with associated parts, equipment and logistical support, for a total package worth $546 million. The helicopters would include the AAR-57(V)3 CMWS, the APR-39 RWR and AVR-2B LWR. The new equipment will help Sweden meet urgent combat search and rescue and operational medical evacuation transport needs.
- As the result of a severe funding shortfall, the **South African Air Force** may have to stop flying its Gripen fighters, according to the annual report by the South African Department of Defense. The report warns that if current funding levels are maintained, only the BAE Systems Hawk Mk120 training jets will be able to be maintained. The report also warned that, due to obsolescence of systems, some crucial EW capabilities could be lost in the future.
- **Grintek Ewation** (Pretoria, South Africa), has received a R23.8 million (approximately US$3.4 million) contract to maintain the EW and COMINT systems aboard the Denel Oryx medium utility helicopter and Douglas C47TP Dakota aircraft. The contract follows a smaller award from February for maintenance on the Oryx comms jammer, COMINT and EW systems.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Protecting Helicopters

Why ASE is About to Change the Game

By John Knowles and Jon Pasierb

Editor's Note: This is the first of two related articles that JED *will publish on protecting helicopters. This month's article looks at developments and trends in infrared (IR) countermeasures, which is a particular focus area for aircraft survivability equipment (ASE) at the moment. The second article, which will be published in the January 2011 issue, will focus on ASE integration and data fusion, which is another focus area. Although the two topics are obviously closely related,* JED *chose to separate them into two articles in order to treat them in greater depth.*

Helicopter missions continue to play an integral role in the success of current military operations, and the threats to these aircraft – and the men and women who fly them – are as varied as they are deadly. Radio frequency (RF)-guided missiles and anti-aircraft artillery, IR-guided missiles, laser-guided weapons and laser rangefinders, small arms and rocket-propelled grenades (RPGs) are all part of the low-altitude threat environment in which helicopters fly.

Current operations in Afghanistan and Iraq have focused attention on IR-guided threats and ground fire from small arms and RPGs. But the real challenge is to look holistically at helicopter protection and equip these aircraft for a more complex threat environment in a future conflict. Achieving that goal presents a dual challenge for aircraft survivability equipment (ASE) developers. How can new ASE capabilities and functions be added while minimizing the size, weight and power (SWAP) impacts, as well as cost? In addition, how can ASE suites become more useful to the aircrew through better integration? These two challenges are not new to the helicopter user. What is new, however, is the urgency to address these challenges and the maturity of the EW industry's ASE solutions.

MORE THAN A MISSILE WARNER

The US maintains the largest combat helicopter inventory in the world, and it is no surprise that the DOD is leading many of the initiatives to develop advanced aircraft survivability equipment. In some cases, ASE upgrades entail installation of new systems, such as directed IR countermeasures (DIRCM) systems. In other cases, new functions can be added within existing systems, without adding weight or incurring aircraft installation costs. In the latter case, the key is to improve the processing power within the ASE suite in order to accommodate the new functions.

In the IR realm, man-portable air defense systems (MANPADS) remain the primary focus of missile warning systems. However, hostile fire detection has emerged as a new priority based on experiences in current operations. The Army and the Navy/Marine Corps are taking slightly different approaches to this problem, with a combination of near- and longer-term efforts.

The US Army is in the process of equipping its helicopter fleet with the AAR-57 Common Missile Warning System (CMWS) and the Improved Countermeasures Dispenser (ICMD), both of which are made by BAE Systems. The Army has ordered 2,000 AAR-57 systems, and to date it has installed just over half of those, mostly on its UH-60s, AH-64s and CH-47s. The next installations are slated for the OH-58, with the 82nd Airborne receiving the first of those systems ahead of its scheduled rotation to Afghanistan next year.

In the near-term, explained COL John Leaphart, the Army's program manager for ASE, the Army hopes to field a third-generation AAR-57 electronic control unit in mid-2011. Not only does this upgrade provide the AAR-57 with significantly more processing power, it also will enable the Army to conduct a Quick Reaction Capability (QRC) effort to add new hostile fire indication (HFI) algorithms that allow the AAR-57 to detect tracer rounds and RPGs. The Army could kick off this HFI QRC effort with a Materiel Development Decision (MDD) in January. Colonel Leaphart said this is one example of adding an important ASE function without adding a whole new system.

Colonel Leaphart described the AAR-57 HFI QRC as an initial step toward a more comprehensive HFI capability that it wants to develop based around the AAR-57. This larger effort, known as the Hostile Fire Detection System (HFDS), will take a multispectral approach to both missile warning and HFI. Structured in three increments, it will integrate ultraviolet (UV), IR and acoustic sensors and process their inputs to detect, identify and locate IR missiles, gunfire and RPGs. Because HFDS can provide more information about the threats, such as missile type or whether detected gunfire is being directed at the helicopter or somewhere else, the countermeasure response can be tailored more effectively, whether it is a specific jamming algorithm, a particular maneuver or return gunfire.

Like the Army, the Navy and Marine Corps want to field a basic HFI capability as soon as possible. For the past several years, the Navy and the Marines have been upgrading their AAR-47 missile warners to the AAR-47B(V)2 standard, which will provide additional processing power in the system. This allows the Navy and the Marines to add HFI algorithms without any further hardware changes, according to CAPT Paul Overstreet, Program Manager of the Advanced Tactical Aircraft Protection Systems Program Office (PMA-272) at Naval Air Systems Command. The HFI upgrade provides a basic capability to detect tracer rounds and RPGs. "We are likely to deploy this [HFI capability] early next year in theater," he explained. One question that had to be addressed is how to

display the information to the aircrews. To answer this, PMA-272 flew the software in cockpit trainers with test pilots and training instructors, who provided helpful inputs. Operational testing is scheduled to wrap up in early 2011, and fielding should begin shortly afterward. Captain Overstreet added that his office is sharing all of the lessons learned and HFI data with the Army, which should help it in its upcoming AAR-57 HFI QRC program.

One interesting aspect of these efforts is how quickly industry was able to respond to the rapidly emerging HFI requirement. Ground-based acoustic hostile fire detection and location systems have been fielded in Iraq and Afghanistan. But helicopters are noisy and not well suited to acoustic-only HFI solutions. "Two years ago, there was not a clear path for HFI," Captain Overstreet explained. As industry began to understand the problem better, technical solutions were rapidly developed. "Right now there are probably about 15 different solutions for it. Some companies are pushing RF for detecting ground fire. Some are acoustic. Some are high-speed cameras. So there is a tremendous amount of technology out there."

HFI certainly adds new functionality to missile warners, and it addresses the most prevalent class of threats to helicopters in Iraq and Afghanistan. However, the main focus of missile warning systems will continue to be IR missiles. As Captain Overstreet noted, "The thing we worry most about is the MANPADS threat… Our focus is still to protect helicopters from that. Because typically it's a short time from the engagement end, and without a missile warning system and without the automated expendables and/or an IR jammer, you could be in serious trouble."

The Navy and Marine Corps are moving onto the next generation of missile warners with their Joint and Allied Threat Awareness System (JATAS) program. Under JATAS, the Navy and Marine Corps are planning to buy an IR missile warning system that will eventually incorporate HFI, which is being developed for JATAS in a parallel program. Its IR sensors will provide a longer detection range compared with the UV sensor on the AAR-47s it will replace, and it will be able to cue DIRCM systems, which the Navy and the Marines also plan to buy.

PMA-272 is currently winding up the JATAS Technology Demonstration (TD) phase, having recently completed evaluation of prototypes from Lockheed Martin Missiles and Fire Control (Orlando, FL) and ATK Missile Systems (Woodland Hills, CA), which has teamed with BAE Systems (Nashua, NH). The next phase of the JATAS program will see a single contract awarded for engineering and manufacturing development (EMD). This EMD phase will be a full and open competition, allowing other companies that have conducted the appropriate program reviews to submit bids. PMA-272 released a draft solicitation for JATAS EMD in October (see Monitor, p.17), and a final request for proposals is expected this month. Captain Overstreet said the Navy expects to award the JATAS EMD contract in the spring of 2011. Initial Operational Capability is slated for 2014. The Marine Corps' tilt-rotor MV-22 will be the first aircraft equipped, and its A-kit (wiring provisions) is already in development, Overstreet said.

Once JATAS enters production, it is slated for installation on every rotary-wing platform type in the Navy and Marine Corps, from the MV-22 to the AH-1 to MH-53s and MH-60s. The JATAS production program is estimated at over $1.1 billion, although it is not clear if future DOD budget plans will cut into that number or stretch the JATAS production schedule.

COUNTERING THE IR THREAT

One ASE area that has gained significant ground in recent years is IR countermeasures – more specifically, flares and DIRCM systems. Current operations have driven a huge demand for countermeasures flares. The US and UK subsidiaries of Esterline and Chemring have expanded production for basic magnesium-teflon-viton (MTV) flares, such as the M206 and 118 MTV, and advanced IR decoys, such as the pyrophoric M211, the kinematic M212 and the dual-band spectral 118. These have been the backbone of protection against IR MANPADS throughout the past several years. With improved missile warning systems that feature lower false-alarm rates, flares have remained an operationally effective, low-cost solution for the current threat environment.

One complaint from helicopter users has been the limited number of flares that helicopters can dispense. This is because no single flare can defeat all types of IR threats. IR MANPADS could include various types of SA-7, SA-14, SA-16 and SA-18 missiles. Because existing missile warners cannot identify incoming IR threats, flare dispensers


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are loaded with two or more types of flares and each type is dispensed during a missile engagement or pre-emptively when an aircrew thinks it is in a particularly dangerous situation. What the Army would like is a single flare that is effective against multiple types of IR threats and meets safety standards. According to industry sources, the Army is planning to procure a flare that meets these requirements.

While shoulder-launched SA-7s are by far the most widely fielded threat, the number of newer and more sophisticated threats is increasing. It is not clear if advanced flares alone will be able to handle these newer threats. The US, UK, Israel and a small number of other nations have gradually been adding DIRCM systems to their helicopters to address this changing threat environment. Over the past 20 years, DIRCM technology has advanced from flash lamp sources to more effective and more reliable multi-band laser sources. Although in the past it was believed by some that DIRCM systems would replace flares on helicopters, most of the ASE suites that

include DIRCM systems today have also retained a full flare dispensing capability. This is because there is considerable interest in exploiting potential countermeasures synergies between flares and DIRCM systems in some types of IR threat engagements. In addition, flares offer an effective backup should a DIRCM system fail during a mission.

In the US, two ongoing helicopter DIRCM programs have proven critical for protecting transport helicopters. In 2007, PMA-272 launched the Department of Navy Large Aircraft IR Countermeasures (DoN LAIRCM) program to protect 156 Marine Corps and Navy CH-53D/E and CH-46E medium- and heavy-lift helicopters against IR threats. Under this effort, Northrop Grumman is installing its AAQ-24(V)25 DIRCM system on these aircraft. More recently the Army has begun installing the ALQ-212 Advanced Threat IR Countermeasures (ATIRCM) system from BAE Systems on 83 of its CH-47D/F Chinooks via a QRC program. The goal of both these programs was to fit existing DIRCM systems to large helicopters, and they have been very successful in the field. Earlier this year, *Aviation Week and Space Technology* reported how the ATIRCM is believed to have saved an Army CH-47 in a multi-threat engagement.

The DOD is looking beyond these two programs, because it wants to buy a smaller Common IR Countermeasures (CIRCM) system that can be installed across its helicopter fleet. The Army is leading this program, and it is expected to release a solicitation for a CIRCM TD program this month. Functionally,

CIRCM is the same as ATIRCM, explained Colonel Leaphart. It defeats IR-guided missiles. What CIRCM should be able to provide is higher reliability and much lower system weight than its larger predecessors. At least four companies – BAE Systems, Northrop Grumman, Raytheon Missile Systems and ITT Electronic Systems – are expected to submit proposals for the CIRCM TD program. BAE Systems will bid its Boldstroke DIRCM system. Northrop Grumman and teammate Selex Galileo of the UK will bid a solution that includes the Viper Laser. Raytheon, a relative newcomer to the DIRCM market, will bid its Scorpion DIRCM, which incorporates AIM-9X air-to-air missile seeker technology in its pointer-tracker subsystem and a commercially available Quantum Cascade fiber laser. The company said its bid will emphasize the lifecycle cost advantages of its system. ITT is teamed with Lockheed Martin's Aculight subsidiary, which has extensive experience providing lasers for DIRCM applications. It will focus on its open-architecture approach, which it hopes will prove attractive to the Army.

CIRCM's future is not as certain as it was a year ago, primarily because the solicitation for the TD phase has been delayed for various reasons. In the meantime, the DOD faces more pressure from Congress to trim its acquisition budget, which could affect the funding and schedule for CIRCM. The Army, Navy and Marine Corps still maintain a significant requirement for CIRCM. Although production is a long way off and quantities are not certain, Army officials have said they would like to install CIRCM on every aircraft that carries the AAR-57 missile warner. The Navy and Marines Corps are expected to take a similar approach, installing a CIRCM system any platform that is fitted with JATAS. This will, of course, depend on the price of a production CIRCM system. The current schedule calls for CIRCM fielding to begin in 2017, although this could change when the final solicitation is released.

A NEW GENERATION OF IRCM CAPABILITY

Programs, such as the Army's AAR-57 Hostile Fire Detection System upgrade and the Navy's JATAS, will increase the utility of what were once single-function missile warning systems. Adding new function to missile warners has become possible because new sensor technology is available, advanced algorithms have been developed and the required processing power has been added or built into the systems. However, this trend is also possible because industry and operational experience with missile warning systems is very deep. As industry and helicopter users become more experienced with DIRCM systems, additional functions may be added to these systems, as well. After all, the DIRCM system is essentially a high-resolution electro-optical (EO)/IR sensor and a laser. DIRCMs could eventually be used for other functions, such as obstacle warning, line-of-site laser communications between helicopters or as optical disruptors against small arms fire. The list of possibilities will be very interesting to future DOD leaders.

Photos courtesy US Department of Defense.

The Rise... and Further

By Barry Manz

The Field Programmable Gate Array (FPGA) as it applies to EW subsystems is very much like a sponge. Every new generation of FPGA, which appears every 18 to 24 months, typically provides twice the logic functions of its predecessor in the same sized package with roughly the same power consumption. It absorbs more and more of the tasks previously performed by other devices, ranging from discrete analog components to digital signal processors and general-purpose processors. Relying on their massively parallel architecture, today's large FPGAs can be programmed to implement nearly every function of a basic ESM system, and when coupled with high-performance analog-to-digital and digital-to–analog converters (along with a smattering of RF components at the front end) a digital RF memory – in a single packaged device. Think of them as the Swiss Army Knife of the embedded computing industry.

Xilinx and Altera are the two FPGA market leaders with Xilinx owning 55-60 percent of the market and Altera 15-20 percent. At Xilinx, revenues from the defense sector represent 15 percent of its business (of which EW is the greatest contributor), and 9-10 percent for Altera. This makes defense a significant FPGA market, even though the devices are used in many other applications as well. "It's really no surprise," said Amit Dhir, senior director for aerospace and defense & high performance computing at Xilinx, "because if you look at the volumes of devices required by EW, RWR, and radar systems, they're not at the level where it's desirable to use an ASIC. In fact, EW is the perfect intersection for FPGAs from both a volume standpoint and because of the types of things they can do. They're a pretty natural fit as underlying technology for radar and EW."

THE FPGA DEFINED

An FPGA consists of an array of configurable logic cells (logic blocks) and each cell can be configured, or programmed, to perform one of many functions. The difference between FPGAs and most other semiconductor devices is that rather than being endowed by their manufacturers with a specific function or functions, they are essentially a "blank canvas" when delivered to the designer, who must "paint" the desired functionality by programming it. This makes the FPGA an extraordinarily versatile device, as it can perform computing, signal processing and high-speed communication functions with little need for external resources.

The individual cells within an FPGA are interconnected by a matrix of wires and programmable switches. The logic cells become building blocks from which virtually any type of functionality can be created, from simple-state machines to complete microprocessors. The ultimate functionality that an FPGA will perform is created by programming the logic cells and selectively closing the switches in the aforementioned matrix of interconnected wires, and then combining these blocks to create the desired result.

Defining the characteristics of the huge number of connections and cell logic functions in an FPGA has traditionally been an immense task and has given them a reputation as being "a bear" to program. Of necessity, FPGA manufacturers and design software vendors have developed software tools that make the process less difficult. In addition, predesigned and verified intellectual property (IP) functional blocks are available from FPGA manufacturers and third parties to help speed the programming process.

FPGAs have, throughout most of their history, been extremely well suited for performing fixed-point arithmetic rather than floating-point arithmetic. Fixed point is a number format where the binary point is in a fixed location using a fixed number of bits, one subset specifying the integer part and another specifying the fractional part. It is typically less expensive to execute in hardware and is more efficient than its floating-point counterpart, but this approach offers less dynamic range and requires values to be carefully scaled to avoid overflow or saturation.

In contrast, in the floating-point format the position of the binary point "floats" depending on the magnitude of the number being represented. Floating-point arithmetic delivers high dynamic range and is very precise, but it comes with the caveat of being less frugal with power and more expensive to build. However, FPGAs are increasingly capable of performing both fixed- and floating-point arithmetic, which further increases their usefulness in defense systems.

THE PATH TO THE FPGA

This was not always the case. The FPGA was invented by Ross Freeman, the late co-founder of Xilinx, and the company's first FPGA was introduced in 1985. It was an entirely new form of programmable logic, and it took a while for its potential to grab the full attention of designers throughout the electronics industry. At the time, Application-Specific Integrated Circuits (ASICs) and digital signal processor (DSP) chips, both of which were first offered in 1980, along with other types of logic, were the designer's primary tools. Both the ASIC and DSP are still used in large numbers throughout the electronics industry. However, the ASIC is best suited for volumes much larger than those required for increasingly smaller defense systems, and the DSP's functionality has been absorbed by the FPGA. The result has been an almost universal transition to the FPGA.

Pentek's story is fairly typical of how this transition was made by most

Rise of FPGAs in EW

embedded-systems companies. After using DSPs coupled to high-speed ADCs to build its products, the company in the mid 1990s began to use FPGAs because they offered configurable glue logic to interface specialized parts of the ADC with an interface a processor could use. "Instead of having registers and gates on the board, we replaced tons of those with a single FPGA that could absorb all that random custom logic that would otherwise would take up a lot of space and consume a lot of power," said Rodger Hosking, Pentek's vice president. "When Xilinx began pushing the DSP aspects of FPGAs by including hardware multipliers, adders and accumulators to implement DSP functions, it was a big hit. Instead of doing DSP on DSP chips, we did it on FPGAs. It was a real game-changer, a real shift in what we were able to offer."

For example, Pentek had been using quad digital downconverter ASICs to implement four digital downconverters. The signal from the ADC was sent to a local oscillator, mixer and filter, and frequency translation was performed in the mixer. Additionally, a slice of the input frequency was converted to baseband where it could be processed. In comparison, the company four years ago put 256 of these in a single FPGA – taking advantage of the FPGA's ability to be configured and then erased later to do something else.

Today the FPGA is the cornerstone of board-level defense products from nearly every company in the embedded business – and beyond. For example, FPGAs are finding their way into hard-core bastions of microwave technology such as the L-3 Communications' Narda Microwave-East division, which is generally associated with the microwave integrated circuits and passive microwave components it has been making for more than 40 years. However, in its latest Integrated Microwave Assemblies (IMAs), the company has redefined what can be accomplished with "mature" microwave integrated circuit (MIC) technology, and it uses FPGAs to do digitally what has always been performed with analog components.

For example, its Model 10512 is a programmable signal source that digitally creates frequency-modulated noise waveforms and applies them to a carrier whose center frequency can be varied +/-50 MHz in less than 100 ns. It can be used as a fast-hopping signal generator, programmable noise source, or arbitrary signal generator. Waveform characteristics such as a video bandwidth, dispersion bandwidth and level can be programmed locally or remotely, The module measures 4 x 4 x 0.6 in., weighs less than 1 oz., consumes 11 W, and meets military requirements for shock and vibration. The FPGA performs an enormous number of functions in the module. If these were implemented using analog circuits, it would be extremely difficult to achieve, make alignment a long and tedious process, increase the size and weight of the module, and require ovens to maintain stability and linearity of its voltage-controlled oscillators (VCOs). Joseph Merenda, vice president of engineering at Narda, explained, "There's just no need to do this with analog components anymore."

The power these devices bring to defense products is accompanied by a commensurate increase in the amount of data that must be processed. "The adoption of FPGAs has helped move the digital domain closer to the antenna," said Scott Hames, director of applications engineering and technical support at GE Intelligent Platforms, "replacing analog processes with digital ones at an IF frequency of about 1 GHz with bandwidth in excess of 500 MHz. One of our customers likened this DSP load as the difference between sipping from a straw and trying to drink from a fire hose. As a result, high-performance FPGA designs now seem to be specifying peripheral memory not by quantity but by IO bandwidth and we've seen requirements for memory IO bandwidths greater than 10 GB/sec."

"With ASICs you could never touch the receiver and had to have something custom between the antenna and ASIC, and it required lot of work to get the ASIC to understand what was happening," said Patrick Stover, vice president of sales at Annapolis Micro Systems. "ASIC speeds also determined your receive rate, because it was single-path device with single entry and exit points, and you cannot shove the data in faster than it can be handled. It can accommodate any kind of signal source from any standard interface. You can think of FPGAs as just electrically defined pins, so I can use them to create multiple paths going in and out, which is where the FPGA's parallelism takes place. I can acquire data through multiple paths, such as 96 LVDS pins, faster than with an ASIC.

"Ten years ago," Stover continued, "we started making ADC daughter cards that plugged into the FPGA cards, and eight years ago we built an interface in the FPGA that could take all signals in at one time, which gave us an instantaneous bandwidth of 1.5 Gb/s. So now we could span a huge amount of spectrum instantaneously without an expensive tuner on the front end and tune anywhere in that 1.5 GHz bandwidth. Today, we have a 5-Gs/s ADC on the front end and a 4-Gs/s DAC on back end, and we're now using a 20-million-gate FPGA sampling at 5 Gb/s. The increase in the amount of processing, tuning, channelization, and FFTs sizes gives us much more EW signal processing power in the same single-slot VME footprint. We're doing 4-million-point FFTs on some operations in real time. Basically, we can process as fast as we can collect, all without touching a bus or an operating system, with no kernel dumps and system service calls."

BENEFITS OF THE FPGA

The FPGA essentially consolidates a huge amount of logic into single device, while providing digital signal processing, general computational functions, and gigabit-level serializer/deserializer (SERDES) interconnectivity. Add this to its ability to be reprogrammed by the customer without making any hardware changes, and a doubling (or more) of logic with each generation, and the popularity of the FPGA becomes obvious.

"With each new generation of FPGAs the capacity of both general-purpose logic and DSP functionality doubles," said Denis Smetana, product marketing manager for FPGA products at Curtiss-Wright Controls Embedded Computing. "With the latest FPGAs, the high count and high speed of Gigabit SERDES on the FPGAs allows vast amounts of data to be received, processed and transmitted. This makes FPGAs ideal at the front end of EW applications for processing huge amounts of data and finding the relevant pieces to hand off to downstream general-purpose processors. In the new 28-nm geometries, enhancements in DSP are enabling more floating point capability inside FPGAs, which changes the line between FPGAs and processors for some applications."

"It's not just about replacing ASICs, but replacing the general-purpose processor as well," said Bill Ceccherini, general manager of the Echotek Product Group at Mercury Computer Systems. "Along with delivering hardware acceleration for functions that were always performed in a general-purpose processor, reprogramming on the fly in order to perform multiple mission sets in one set of hardware is coming, and long awaited."

Charlie Hudnall, director of engineering at Echotek, added, "FPGAs are consuming functions that general-purpose processors and DSPs would perform, as well as fixed-function ASICs. The FPGA can fill all of those roles. There are now so many multipliers in FPGAs and lots of other on-chip features, and FPGA vendors have come a long way in implementing standard bus structures so you can hook up to PCI, PCI Express or serial Rapid IO, as well as integrating small general-purpose processors."

"In the past," Hudnall continued, "functions were implemented using an array of ASICs at the front end – a digital downconverter and somewhat programmable wideband filters pieced together. The data rate could be reduced to something you can process at the back end, which would have been done with DSP chips. Those things have now been replaced with a single FPGA."

TEK Microsystems CEO/CTO Andrew Reddig pointed out that "instead of defense prime contractors charging the program they're working on for an ASIC and a custom board, they can find an FPGA board with the power they need, and eliminate both the board and ASIC. It's almost like FPGAs enable COTS in the EW space, while COTS products were once not powerful or power efficient enough to solve the problem." He added that a reprogrammable system lets you do quick response adaptations and while you would try to design an ASIC with some parameterization, you'd just be guessing what you'd need three years later. "With an FPGA," said Reddig, "a customer can learn of a new scenario and in a couple of weeks have a new algorithm in firmware and get it into the field without having to change hardware. The tempo of EW systems has to be faster in order to respond to today's threats. FPGAs fall right into that and ASICs don't."

Altera, which recently introduced its latest Stratix V family of FPGAs, said that "the ability to move a waveform or algorithm in and out is critical, as is full or partial reconfigurability. Parallel DSP processing reduces latency, and the data rates in FPGAs are so high that it is really the only device that can handle them in real time. So you could argue that without FPGAs, many of these systems would not be here. Response times are in milliseconds, which I think is

impressive. You can recognize a signal as an attack or target, and the entire system can respond in milliseconds. Even decoys have the ability to confuse a missile and emulate signals of aircraft, which is a very complex problem."

ACHILLES HEEL HEALED?

The FPGA's reputation for being difficult to configure is legendary, but in fairness this must be viewed from several perspectives. "Unlike writing software for sequential instruction execution on a relatively simple engine," said Pentek's Hosking, "you are actually building hardware in an FPGA. You have to think like a hardware engineer. With thousands of DSP engines available, megabytes of memory and lots of resources, it's a complex job.

"However, the benefit," Hosking continued, "is that you can make all of this customized hardware do just what you want. Unlike software, you have to be concerned with things like propagation delay, racing, clocking and synchronizing parts of the design. You have to make sure power is allocated across the chip and not bunched up in a corner that the pins to the outside world are connectable with the engine you are putting inside. FPGA design requires a lot of hardware-oriented tasks, so it's not surprising that our best FPGA designers are hardware engineers."

Curtiss-Wright's Denis Smetana added that "partial reconfiguration [reconfiguring only part of an FPGA while the remaining part continues to function as is] has thus far been a challenge, but design tools are now making this more feasible. The wide availability of IP cores has helped as well, and the FPGA vendors have matured their own cores too. However, timing closure is still a challenge, and when pushing for performance over temperature on full designs, a lot of effort is still required." He noted that as the die size of FPGAs increases, routing delay becomes the dominant factor. "It's a bit of art in constraining portions of the design and letting the tools figure out the optimal placement. Doing only one or the other can make the design over-constrained, which limits what the tools need to do, or being under-constrained so the tools struggle to find a good solution."

However, as Marc Couture, director of application engineering at Mercury pointed out, FPGA programming difficulty "depends where your roots are. I get this comment about difficulty from DSP system engineers who know how to program in C and MATLAB and try to tinker with an FPGA. If you're programming 50 percent of the FPGA, it's not all that difficult, but if you want to get 80 or 90 percent from a high-speed FPGA design, you can run into complexities. An FPGA is like a white board, and because there is so much flexibility in it you can hurt yourself."

Annapolis Micro Systems, which has been manufacturing FPGA-based systems for 17 years, has a unique approach to the problem of programming FPGAs: a proprietary, GUI-based software tool called CoreFire dedicated only to their products that eliminates the need to program in VHDL. "We watched all the DARPA efforts and hoped someone would come up with a tool that offered an alternative to using VHDL," said Stover.

“No one did, so we created our own. We built every core and hardware interface to all our boards, all our ADC and storage systems, memory and communication buses, so the customer could just drag and drop from a library.

“CoreFire abstracts you from the hardware level, so you don’t have to worry about clocks, timing diagrams, handshakes or simulation,” Stover continued, “and it includes FFTs, FIR filters, everything needed for compression, Viterbi decoder cores, and handles all types of data. We’re the only company selling FPGA boards and a development package that eliminates the need to use VHDL for end-to-end programming of any magnitude.” The approach has been a big success. “Fifty percent of our customers use CoreFire and 50 percent use VHDL, but 99 percent of our hardware revenue comes from customers using CoreFire, because they’re getting projects done,” said Stover.

Both Xilinx and Altera are out of necessity working hard to make FPGAs more accessible to designers who are not FPGA veterans. “As the devices have grown in capacity, gate density, and resources, we are working more with partners to develop IP and deliver boards,” said Prasanna Sundararajan, staff systems architect, HPC & SEU mitigation solutions at Xilinx. With our Virtex-6 and Spartan-6 families, we launched the Targeted Design Platforms strategy that includes a development kit with a baseboard, IP and reference designs so people can get started rather than being dependent on reference designs from other people. We need to make FPGAs more approachable.”

Ian Land, senior technical marketing manager for Altera’s military business unit, said of the FPGA programming environment that “it may not be like C coding, but our FPGA software has become much easier to use over the last few years. Cordis, our synthesizer and compiler, along with our SignalTap II logic analyzer, lets you debug a design while it is on a platform. I have taken IP off the shelf, plugged it into a device, done the simulation and compilation, programmed the device, and had it running in a couple of days. Our SERDES has also on-chip equalizers and debug interfaces. In addition, prebuilt IP blocks really make things easier because they’ve been verified. You drop in the IP and you should feel comfortable you have a robust core. For EW, we have an interface called DSP Builder, an element that sits between Cordis and MATLAB and Simulink. It lets you do MATLAB system level coding and Simulink can draw from a library in DSP Builder and builds an automatic interface from the system level. So you get a pretty nice system right off the bat.”

A CHALLENGER APPEARS

As every hardcore PC gamer knows, the optimum experience is directly attributable to graphics processing horsepower delivered by the computer’s graphics processing engine. Some of the most elaborate systems look more like defense products than home computers and include multiple graphics cards each with 1 Gbyte of dedicated memory and even liquid cooling to keep the system from melting through the desk. These same GPUs are being eyed by the companies interviewed for this article as a complement to FPGAs in future systems.

"They do some things really well," said Hosking, "like shading for video and even as general-purpose DSP engines." GE has also expressed interest, according to GE's Hames, "since GPUs are starting to offer similar capability without the barrier to entry that FPGA programming presents. They have the potential to turn hardware problems into software problems, which allows a company to use a different set of resources to achieve a desired performance objective."

However, Mercury has already taken the leap, using general-purpose processors as well as a GPU on some boards. "We have Intel Core i7s and a GPU connected to them that has lots of PCI Express lanes," said Hudnall. One system under development has an ADC board with an FPGA feeding the Intel processors that's performing megapoint FFTs in a fraction of the time it used to take because some NVIDIA parts range from half a teraflop to a full teraflop."

However, Hudnall noted that the GPU may support a lot of PCI Express, but an FPGA supports LVDS and SERDES as well. "But the two are incredibly complementary," he said. The company also has VPX modules with an Intel processor and GPU. "NVIDIA and AMD provide a form factor called MXM and we have ruggedized MXM carriers, so since there are new GPUs every nine months, one can be deployed now with the ability to replace it with one that delivers twice the performance in the next generation."

However, as Altera's Land pointed out, "It takes a GPU 100 W of power to do what an FPGA can do using only 15 to 20 W. Another issue is longevity or how long a manufacturer will be willing to support a GPU after its introduction. NVIDIA's core market is the commercial and consumer world where product lifetimes can be measured in months and rarely more than a year, which makes long-term support impractical."

Xilinx and Altera are dealing with the issue of longevity by supporting their FPGAs for a decade or more. Xilinx will support standard devices for 10 years and 16 years for the "Q" series of devices tailored for defense applications. Altera supports a 15-year product life and "will work with our customers to understand their needs as they reach the 15-year mark. Our customer marketing team can extend life as part of our eCOTS program," said Land.

NEWEST FPGAs MAINTAIN THE TRADITION…

The Xilinx Virtex-6 family, introduced early in 2009, is already being employed by a large segment of the embedded world, and Altera's Stratix V announced in July is beginning to appear as well.

The Xilinx Virtex-7, launched in June, actually provides 2 million logic cells, more than twice that of its predecessor. It delivers up to 2.4 Terabits/s of I/O bandwidth and 4.7 TMACS of DSP performance. Xilinx cites a portable radar application in which a single board with three Virtex-7 855T FPGAs can implement a 64-channel beamformer with an 80 percent reduction in board area with 24-channels per device, 60 percent system cost reduction, and 90 percent FPGA power reduction. Fixed-point performance of the device is up to 987 GLFOPS, and security and anti-tamper protection is provided with 256-bit AES and authentication, volatile and non-volatile keying, and on-chip environmental monitoring.

Xilinx has also introduced the Virtex-6Q and low-power Spartan-6Q generation of mil-qualified devices targeted specifically for aerospace and defense applications. The Spartan 6Q is the first of that family to bear the company's "Q" designation for military applications, which specifies ruggedized design and the company's advanced cryptographic capabilities, which were recently accepted by the National Security Agency.

The Altera Stratix V 28-nm FPGA family reduces total power by 30 percent compared to the previous generation and is optimized to support Micron Technology's reduced-latency DRAM (RLDRAM 3) memory. The devices have a core voltage of 0.85 VDC, 14.3 million ASIC gates or up to 1.19 million logic elements, integrated 28-Gb/sec and 12.5-Gb/sec transceivers, up to 6 x 72 DDR3 800 MHz memory interfaces, 1,755 GMACS signal processing performance, and partial re-configuration capability, among other features. The Stratix V family will soon include members designed for radar and EW platforms that require intense DSP processing, gobs of memory and very low latency.

… AND EMBEDDED SYSTEMS GOBBLE THEM UP

Embedded systems manufacturers can be sure in their knowledge that future FPGAs will allow them to pack more horsepower on the board. Curtiss-Wright just announced the CHAMP-FX3 (VPX6-472) card using the Virtex-6 devices, which doubles the capacity of Curtiss-Wright's previous generation and more than doubles the amount of bandwidth it can handle. With support for front-end analog FMCs with low latency LVDS inputs and multi-channel high-speed SERDES to the backplane, it is well suited for EW applications.

Pentek claims the honor of shipping the first product based on the Virtex-6 in its Cobalt V6 XMC module line, within which there are a dozen models. It uses XMC modules, various front-end ADCs and DACs, IP, memory, and options for interfacing, and encompasses five members of Virtex-6 density range. One of the Cobalt products, which will ship before the end of the year, is an L-band tuner using a Maxim 2112 L-band tuner chip with a 1- to 2.1-GHz input frequency and mixes down to a 70-MHz IF, and delivers 40 or 50 dB dynamic range, which makes it suitable for satellite telemetry applications. The module has I and Q outputs and is followed by two 200-MHz ADCs, which then feed the Cobalt infrastructure. The company will also have 3-Gsamples/sec ADC sampler for the Cobalt platform early next year. It will mark the first time a Pentek product will be able to accept signals at these frequencies without the need for an RF tuner from another vendor or the customer.

TEK Microsystems has announced the first platform based on its QuiXilca-V6 architecture using the Virtex-6 FPGA for VME/VXS systems in a 6U form

factor. The baseboard has three of the FPGAs on two module sites with ADCs and DACs ranging from 160 Msamples/sec to 5 Gsamples/sec. The two front-end FPGAs provide a high-speed connection between the ADC, DAC, and FPGA. The third supports additional processing and protocol support for front panel or backplane interfaces. There are six banks of DDR3 memory (up to 5 Gigabytes total), throughput of more than 32 GB/sec, and the back-end FPGA supports two banks of QDR II+ memory. Serial communications is accommodated by 12 full-duplex fiber-optic connections from the front panel and 8 to 12 full-duplex fabric connections through the VPX P0 connector. Total aggregate bandwidth is 18.5 Gb/sec in each direction. The company's next products will use an open VPX base card with Virtex-6 FPGAs.

Referenced earlier for its implementation of GPUs, the Wideband Advanced Spectral Processor (WASP) from Mercury is a signal survey system based on RF, IF and embedded processing solutions and is designed for spectrum monitoring applications. It directly digitizes any IF or baseband with spurious-free dynamic range of up to 95 dBc based on the selected instantaneous bandwidth. It offers a high probability of intercept of signals from 50 KHz to 18 GHz and can be configured for 100 percent probability of intercept of signals with extremely short durations. FFT sizes up to 8 megapoints are supported, and it is available with parallel general-purpose GPUs to support even larger FFT sizes. System scan rate is greater than 600 GHz per second with 10-KHz resolution bandwidth.

CAN THEY KEEP UP THIS PACE?

With FPGAs growing in performance, shrinking in their geometry, but still maintaining or reducing power levels, the question becomes whether or not the pace of development can be maintained going forward. Both Xilinx and Altera are confident that the FPGA still has a long road ahead. However, Sundararajan from Xilinx provided a broader perspective. "We could begin to find a limit in how big a device can be without becoming overwhelming for the designer. In our Virtex-7 Series 28-nm devices, customers are not demanding more performance but rather lower power, so these devices focus on lower static and dynamic power consumption, which we achieve with innovations in our tools as well as in our silicon." Altera's Land believes that "moving from the current 28 nm to 20 nm, we expect to be on the Moore's law curve and should be able to make gains similar to those in the past."

It's safe to say that without FPGAs to empower them, not only would EW systems today be far behind their current state, but their ability to grow would be immensely hindered in the future. The latter seems a highly unlikely scenario, as shrinking device geometries enable more functionality to be packed in the confines of an FPGA package, and result in lower core voltages and lower power consumption. All this is good news, as there will probably never be a day when there will be fewer threats to detect and identify, and calls from DOD for less performance.

Physics of the Cyber-EMS Prob

Why We Have the Language Wrong

By Ron "Fog" Hahn

For the past four years I have had the privilege of being the Deputy Director for the Joint Electronic Warfare Center (JEWC) at US Strategic Command (USSTRATCOM). Over this period, we have made some significant contributions to the Department of Defense. Many in the electronic warfare (EW) community are familiar with our work on the EW Capabilities-Based Assessment and the EW Initial Capabilities Document (ICD). Both of these efforts have provided groundbreaking work and provided critical analysis on EW and EW-related capability gaps/threats. However, our most important work has focused on elevating the discussion and importance of the electromagnetic spectrum (EMS) and the critical need for an EMS strategy.

Over the past few months we are seeing more and more debate on the terminology of EW, IO, Cyberspace, EMS, EMS Warfare and others. The previous two issues of this magazine have featured – "EW, the EMS Domain and Air Superiority" by Lt Col Jeffrey Fischer in the September *JED* and "A Structural View of EM Spectrum Warfare," by Lt Col (Ret.) Jesse "Judge" Bourque in the October edition. While both are exceptionally well written and thought-provoking articles, I would like to offer an alternative viewpoint on both EMS domain issues and the lexicon argument addressed in these articles.

THE STRATEGIC IMPORTANCE OF THE EMS

The DOD has developed a net-centric environment that is completely dependent on the use of the EMS for all six warfighting functions – intelligence, fires, command and control, maneuver, logistics and force protection – regardless of where we are at in the range of military operations. **Figure 1** is the OV-1 (Operational View-1 High Level Operational Concept Graphic) from the Joint Requirements Oversight Council (JROC)-approved EW ICD. It is something that we (the JEWC) have been extremely proud of, and it is designed to graphically depict this concept.

CYBERSPACE AND THE EMS

Following the development of the EW ICD, the JEWC participated in an EW Organizational Study for USSTRATCOM. Part of this work involved reaching out to leaders in the defense community and

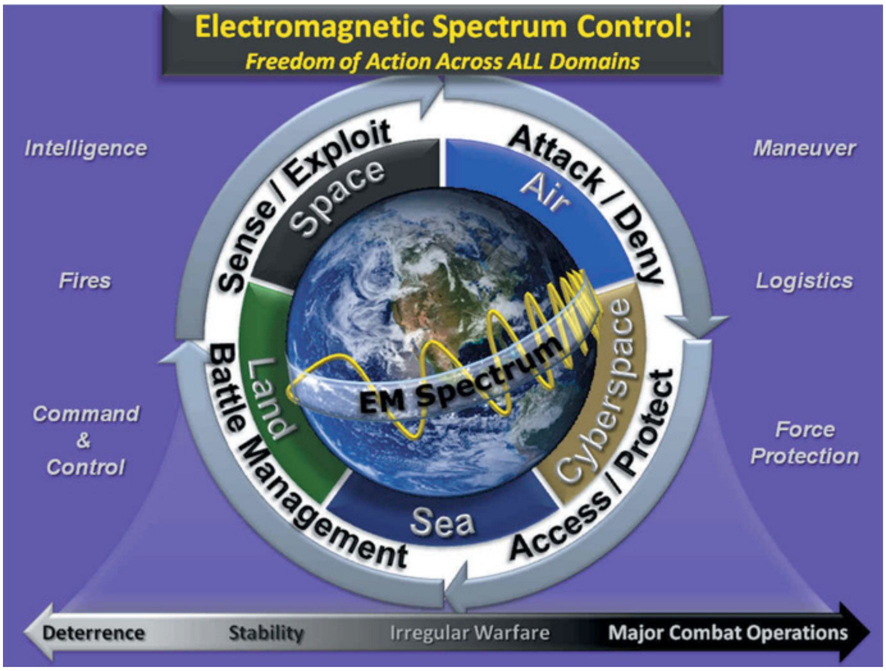

Figure 1 – Electromagnetic Spectrum Control (Source: USSTRATCOM Electronic Warfare Initial Capabilities Document, approved by the Joint Requirements Oversight Council, JROCM 177-09, 30 OCT 2009).

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hearing their ideas on EW and the EMS. During one of these interviews, with Dr. David S. C. Chu and Gen Larry Welch, USAF (Ret.) from the Institute for Defense Analyses (Alexandria, VA), I was provided with an alternative view point to the JEWC's OV-1. They argued that what connects the physical domains (air, land, sea, space) was not the EMS, but rather Cyberspace. Initially, I dismissed this notion as merely more hype on DOD's latest buzzword. But then I began to wonder what is "cyberspace" – not how we have currently defined it, but rather what is it really and how does it relate to EW and more importantly to the EMS? Let's start with a definition for cyberspace. Since all the services have varying definitions, I will use Gen James Cartwright's directed definition for inclusion in JP 1-02 in CM-0363-08:

***Cyberspace**: A global domain within the information environment consisting of the interdependent network of information technology infrastructures, including the internet, telecommunications networks, computer systems and embedded processors and controllers.*

In essence this definition defines Cyberspace as the information telecommunications infrastructure – thus a man-made domain and the only man-made warfighting domain. So, does this adequately describe what Cyberspace is? Well before we can answer that question we must first come to some understanding of what Cyberspace actually is then compare the definition and see if we have a match. So what is Cyberspace, really? Is it actually the computers, processors, and fiber that make up the information telecommunications infrastructure? To answer that, we need to start with what makes Cyberspace *Cyberspace* and how do we know when we are in it?

DEFINING CYBERSPACE

Over the past 18 months, I have given a brief called, "The Physics of the Problem." I have given this brief to numerous flag-rank officers (up to the four star level), and every time I give this brief I ask them the exact question that I listed above: "what is cyberspace" and how do you know when you are in it? In layman's terms, most come back with a standard answer of the Internet or a networked environment is what makes Cyberspace *Cyberspace*.

Let's look at the Internet first. What makes the Internet? Is it in fact processors, computers and fiber as suggested in the DOD's current Cyberspace definition? The very simple answer is "no." (Remember I am retired Marine so I have to keep it simple.) What makes the Internet the *Internet* is the ability to link computers and processors in mass. Taking that a step further, it's the ability to link these computer systems and processors that defines Cyberspace.

WIRED OR WIRELESS? IT DOESN'T MATTER

So, how do we link systems? I know of two – and only two – ways to connect computers, processors or routers, and that is via either wired or wireless technologies. Most view the wired world as Cyberspace and the wireless world as the EMS. Now this is where it gets interesting. In reality both operate in the EMS. Just because we wrap the electrons in cable or channel the light through fiber-optic cable does not mean they are not operating in the EMS. They are in fact no different than photons operating in free radiated spectrum.

So, let's take this discussion a bit farther. Is a computer or processor that is not linked either via a wired or wireless system still in Cyberspace? Again, the simple answer is, "no." For example, a computer sitting on my desk that cannot connect to another computer system either via a wired or wireless system is no more in Cyberspace than a pad of paper and pencil sitting on the same desk. Let me illustrate this another way. Is an airplane sitting on the runway operating in the Air Domain? Obviously the answer is, "no."

What in fact actually *makes* Cyberspace is the ability to link systems via the physics of EMS, whether wired or wireless. The processors, computers and routers are just examples of the technologies that operate within the domain, much like the airplane is to the Air Domain or the ship is to the Sea Domain.

These technologies will change over time, and it is not the technology that defines the domain but rather the *physics* used by a given technology that defines the domain. To give you a clearer example, let's compare how the DOD currently defines Cyberspace with how we define the Air Domain. If we define the Air Domain in the same manner as we have defined Cyberspace, then the Air Domain would be defined by airplanes, aerostats and helicopters. But the airplane and other flying craft are not what is important.

What is important is the physics of flying (i.e., Bernoulli's Principal, gravity, and other physical characteristics of flight.) Bernoulli's Principal applies equally to the wing of an F-22 or that of a biplane. The bottom line is that the physical laws of aerial flight still apply.

Technologies used in any domain will continue to change at a rapid rate. Therefore, defining a domain by the technology that operates in that domain (as opposed to the physical principals and laws of that domain) is a flawed concept that has created many of the issues that both Lieutenant Colonels Fischer and Bourque's articles discuss.

EMS DEPENDENCE – WHY IT MATTERS

Figure 2 is what I affectionately call the "bowtie." We used it in the JEWC to describe the various warfighting domains' absolute dependence on the EMS and the growing constrictions on this critical maneuver space.

The "bowtie" graphic is not all-inclusive of the EMS, but it is meant to show a couple of important concepts. First the EMS enables, connects and controls modern warfare capabilities across all warfighting domains. Our free and unrestricted access to the EMS has been an assumption that we can no longer make. This incredibly important maneuver space is being constricted by two major forces. One is our adversaries' growing ability to contest our access to the EMS, and the second is the congestion as a result of that exploding use of spectrum-dependent technologies. Each of these forces is driven by the rapid evolution and proliferation of commercial technologies – a trend that will continue for decades.

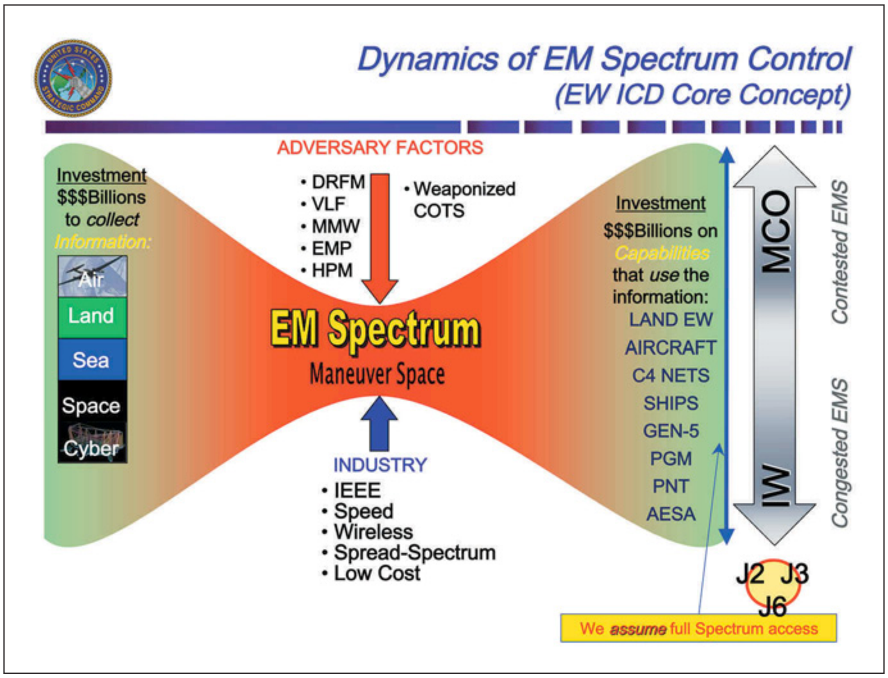

Figure 2 – Electromagnetic Spectrum Control (Source: USSTRATCOM Electronic Warfare Initial Capabilities Document, approved by the Joint Requirements Oversight Council, JROCM 177-09 30 OCT 2009)

The "bowtie" graphic shows how we have traditionally compartmented this maneuver space, with intelligence folks (J2) being responsible for the contested space and spectrum management (J6) being responsible for the congested space; however, responsibility for the EMS must be an operations (J3) function to be successfully integrated on the modern battlefield.

UNDERSTANDING THE RELATIONSHIP

Why does this all matter? Do we really care if we have defined Cyberspace and its relationship with the EMS correctly? Understanding this relationship and the physics that drive the technology is critical to protecting our ability to conduct modern warfare in a net-centric environment. If we fail to understand this relationship properly, we will not fully understand how EW and computer network operations (CNO) can work together within the EMS. I agree completely with Lt Col Fisher's article there is no doubt that EMS is a domain. However, for the reasons I stated above I believe that there is in fact only one domain that connects the other domains (air, land, sea, and space), and regardless of what we call that domain, it is in fact based on the physics of the EMS. The synergies occur between the EW and CNO technologies and not the EMS and Cyber domains.

Currently we are spending billions of dollars in this thing we call Cyberspace. The problem with this strategy is that we are missing the other half of the equation, which is the EMS. I am not saying that CNO is not important; in fact, quite the contrary. It is very important; however, without EW and our ability to control the EMS, we will never be able to fully defend our networks. We need to look at both sides of the coin. We cannot defend in Cyberspace – even under its current definition – if we cannot control the EMS.

I want to take a moment to clarify a couple of important points. One is the word "control." We introduced the concept of EMS control (or spectrum control) in the STRATCOM EW ICD. What we meant by "EMS control" is that ability to gain the required advantage in the EMS and to enable critical operations in the EMS at a given frequency for a given period of time over a given geographical location. We will never be able to "dominate" this maneuver space, due to the sheer number of signals that move through the EMS each and every second.

Secondly, I also believe we need to look at our current EW lexicon (terms such as electronic warfare, electronic support and electronic protect) and see if it fully articulates the effects we need to achieve in the EMS. Although the Joint lexicon of EW (as currently defined in JP 1-02) already covers all aspects of the EMS, including directed energy, infrared and electromagnetic pulse, I am not sure it adequately covers the breath and depth of skill sets required to control the EMS.

It is important that we develop an effective strategy for the EMS. New EMS management approaches, such as dynamic spectrum allocation, are being championed by industry, and they will impact how the DOD uses spectrum. In addition, Internet Protocol Version 6 (IPv6) will basically allow for an infinite number of IP addresses for software defined radios and radars, as well as consumer electronics. Not only will this drive increased military, government and civilian EMS traffic, it and will further enable network-centric capabilities in all nations. In the midst of these developments, EW and CNO – although two very different skill sets – must be able to work together in order for us to be able to control the EMS, defend our networks and allow us to conduct warfare across all domains.

Ronald "Fog" Hahn served 20 years in the United States Marine Corps, retiring as lieutenant colonel in August 2005. He flew EA-6Bs, accruing more than 2,000 flight hours in the Prowler, and deployed in support of operations including operations NORTHERN WATCH, DENY FLIGHT, SOUTHERN WATCH, ALLIED FORCE, JOINT ENDEAVOR, ENDURING FREEDOM, and IRAQI FREEDOM. While serving at the Joint Information Operations Warfare Command (JIOWC), he served as the Command Electronic Warfare Officer for USCENTCOM during Operation ENDURING FREEDOM and Special Operations Team Chief for USSOCOM, deploying in support of both Operation ENDURING FREEDOM and IRAQI FREEDOM. In the summer of 2006, he assumed the duties of Deputy Director of the Joint Electronic Warfare Center (JEWC) and, in April 2008, was promoted to GG-15. Last month, he received the AOC's Gold Medal Award. He recently was named VP for Strategic Business Development at URS Corp.

EW Against Modern Radars – Part 13

Pulse Doppler Radar *continued*

AMBIGUITIES

As discussed in the August 2000 "EW 101," the maximum unambiguous range of a radar is the distance for which a transmitted pulse can make a round-trip at the speed of light before the next pulse is transmitted (see **Figure 1**).

$$R_U = (PRI/2) \times c$$

Where: R_U is the unambiguous range in meters
PRI is the pulse repetition interval in seconds
c is the speed of light (3×10^8 m/sec)

For example, if the PRI is 100 µsec, the unambiguous range is 15 km. The higher the pulse repetition frequency (PRF), the shorter the PRI, hence the shorter the unambiguous range. If the PRF is quite high, there will be many range ambiguities.

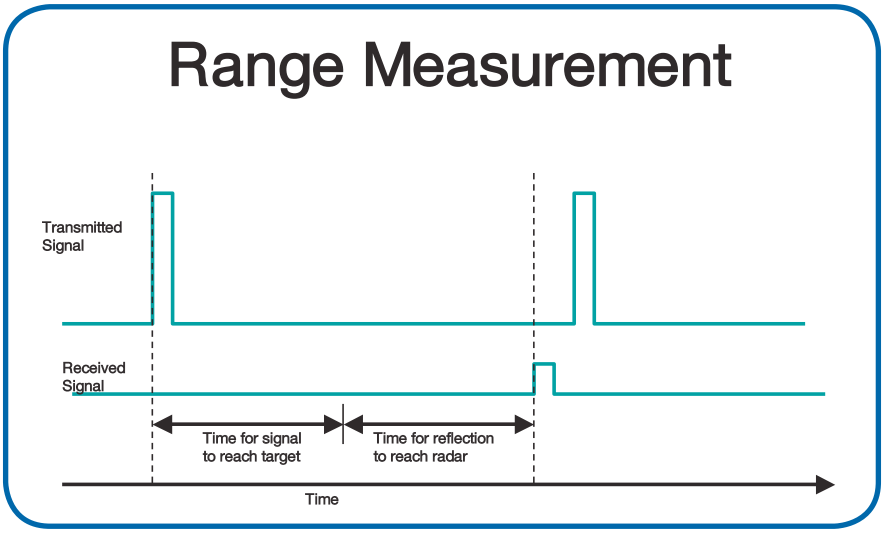

Figure 1: The maximum unambiguous range is the range at which the radar pulse can make a round-trip to the target at the speed of light before another pulse is transmitted.

The Doppler shifted frequency of the return signal falls into a Doppler filter in the pulse Doppler (PD) radar's processor.

The maximum Doppler frequency shift is:

$$\Delta F = (v_R/c) \times 2F$$

Where: ΔF is the Doppler shift in kHz
v_R is the rate of change of range in m/sec
F is the radar operating frequency in kHz

For example, if a 10-GHz radar were designed to handle an engagement with a maximum range rate of 500 meters/second (a little over mach 1.5):

$\Delta F = (500 \text{ m/sec} / 3 \times 10^8 \text{ m/sec}) \times 2 \times 10^7 \text{ kHz} = 33.3 \text{ kHz}$

The spectrum of a pulsed signal has spectral lines spaced at frequency increments equal to the PRF as shown in **Figure 2**. If the PRF is low, for example 1000 pulses per second (pps), the spectral lines are only 1 kHz apart. If the PRF is high, for example 300 kpps, the spectral lines are 300 kHz apart. Each of these lines will also be Doppler shifted, and will cause frequency responses in the processing matrix (i.e., frequency ambiguities) if they are less than the maximum Doppler frequency shift for the design engagement. The lower the PRF, the greater the frequency ambiguity. A PRF of 1000 pps will have many ambiguous responses less than 33.3 kHz, while a PRF of 300 kpps will be totally unambiguous within the frequency range of the processing matrix.

As shown in **Figure 3**, the range is ambiguous if the PRI is less than the round-trip time to the maximum target range of the processing matrix, and the frequency is ambiguous if the PRF is less than the maximum Doppler shift in the matrix (i.e., the frequency of the highest Doppler filter).

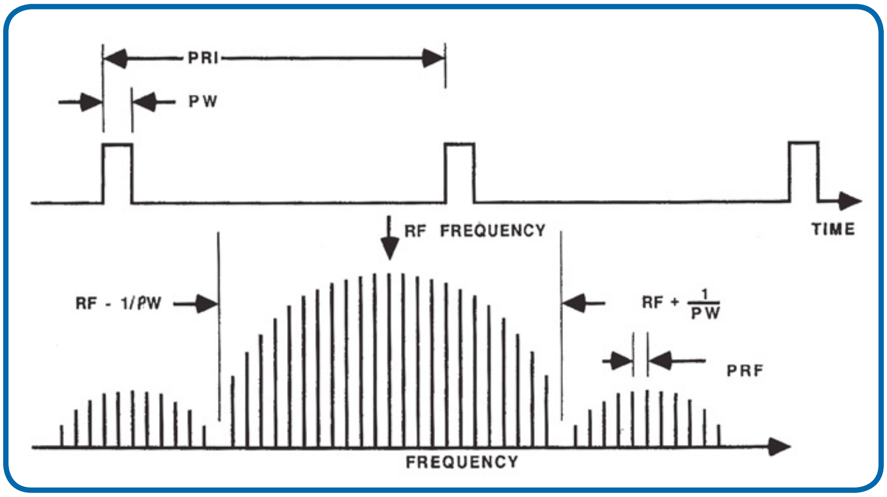

Figure 2: In the frequency domain, a pulse signal has spectral lines separated by a frequency equal to the PRF.

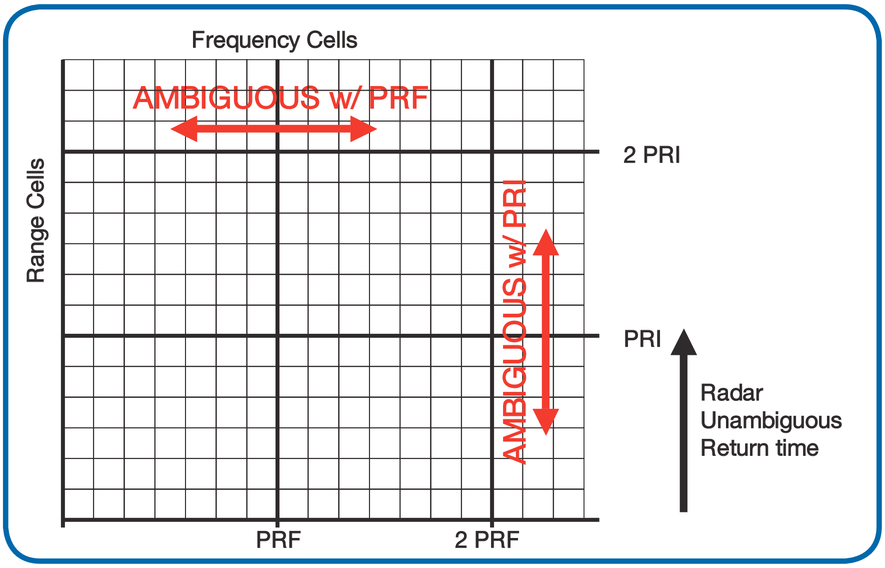

Figure 3: The PD radar can be ambiguous in range as a function of its pulse repetition interval and in frequency as a function of its pulse repetition rate.

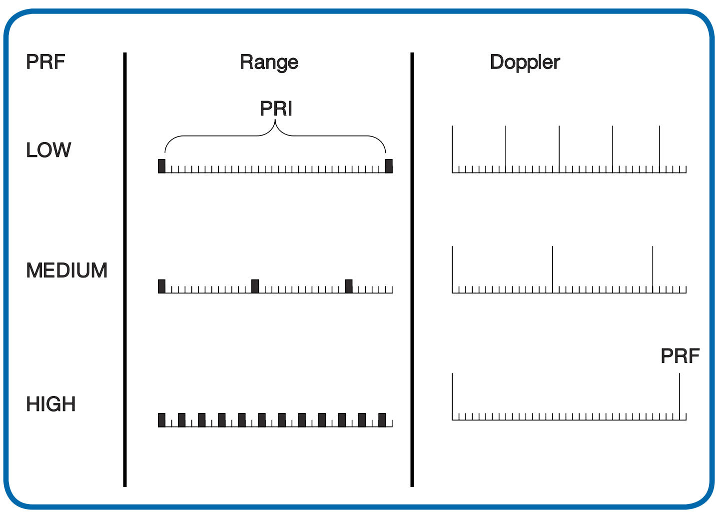

Figure 4: Range and frequency cells in Low, Medium and High PRF Doppler radars.

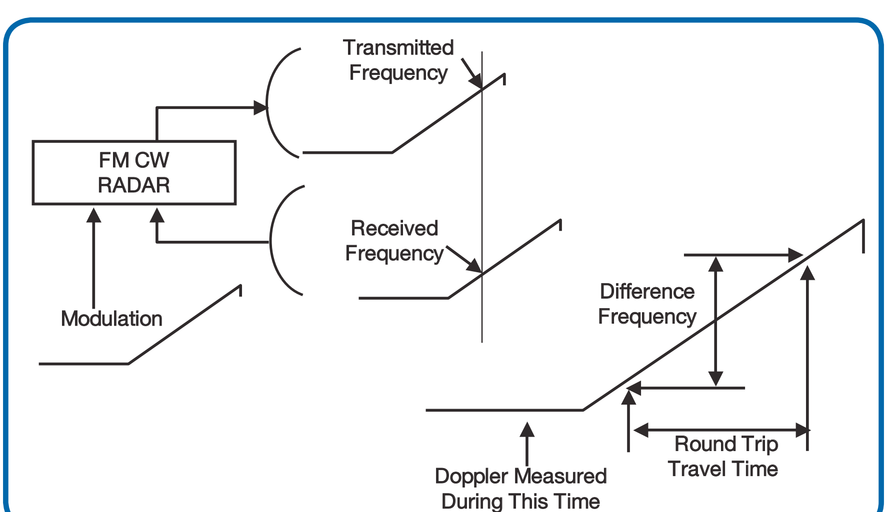

Figure 5: If an FM modulation (as shown) is placed on a radar signal, the difference between the transmitted and received signals will be from the Doppler shift during the linear part and also from the propagation delay (proportional to range) during the ramped part.

LOW, HIGH AND MEDIUM PRF PD RADAR

There are three types of pulse Doppler radars, differentiated by PRF. These are illustrated in **Figure 4**.

Low PRF radar is unambiguous in range out to a significant target range because of its large PRI, thus it is very useful for target acquisition. However, its low PRF creates a highly ambiguous Doppler frequency determination. This means that the target radial velocity determination is ambiguous, limiting the radar's ability to make useful range rate/velocity correlation determinations, making it vulnerable to range-gate-pull-off and range-gate-pull-in jamming.

High PRF radar is unambiguous in Doppler frequency out to quite high range rates, making it ideal for use in a high-speed, head-on engagement with a target. Large Doppler frequencies are highly desirable because the target returns are far away from ground returns and internal noise interference. However, the high PRF causes a low PRI, so the high PRF pulse Doppler radar is highly ambiguous in range. This radar may be used in a velocity-only mode, or range can be determined by imposing a frequency modulation on the signal, as described for CW radars in the October 2000 "EW 101" column and shown in **Figure 5**. Note that a tail-chase engagement is characterized by low range rate, so Doppler frequency shifts are much lower than for head-on engagements. This makes the high PRF PD radar less advantageous.

Medium PRF radar is ambiguous in both range and velocity. It was developed to enhance tail-chase engagements. The medium PRF PD radar uses several PRFs, each of which creates ambiguity zones in the range/velocity matrix. In processing, it can be determined that some of the PRFs are not ambiguous at the range and velocity of the target being tracked.

DETECTION OF JAMMING

Because a PD radar can detect jamming, in will allow any missile system which has a home-on-jam capability to select the home-on-jam operating mode, as discussed next month.

WHAT'S NEXT

Next month, we will conclude our discussion on radar EP techniques, with frequency agility, PRF Jitter, home-on-jam and burn-through modes. For your comments and suggestions, Dave Adamy can be reached at dave@lynxpub.com.

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association news

CALL FOR NOMINATIONS: AOC 2011 ANNUAL ELECTION

Each year the AOC membership helps determine the future direction of the AOC by electing representatives to its Board of Directors. Nominations for the 2010 election are now being accepted effective November 1, 2010.

This year's election slate will include the position of President, who will serve as Vice President in 2012 and as President in 2013. The AOC President appoints the Association's Secretary and Treasurer, presides over the Board of Directors and Executive Committee and appoints committee chairs. The President is also the AOC's primary spokesperson, visiting AOC chapters across the world and meeting with leaders in the Electronic Warfare community. This is a personally rewarding but significant commitment.

The 2011 election slate will also include three At Large Director positions. At Large Directors serve a three-year term. In addition, three Regional Directors will be elected for three-year terms from the Southern, Mountain-West and Northeast Regions.

Nomination forms are available on the AOC website at www.crows.org or by contacting Carole Vann at the AOC at vann@crows.org. Nominations must be submitted to Ms. Vann by close of business on February 1, 2011.

For any questions or assistance, please contact:
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Office: (703) 549-1600
Fax: (703) 549-3279
E-mail: vann@crows.org

CALL FOR PAPERS: DIXIE CROW SYMPOSIUM 36

The Dixie Crow Chapter of the AOC will host its 36th annual Regional Technical Symposium March 20-24, 2011. This year's theme, "Electronic Warfare – Shaping America's Defense," illustrates our commitment to providing "State of the Art" EW. Electronic Warfare is defense that works. It prepares the battlefield as we attack and defends our forces. It is the key to America's protection at home and force projection abroad. We must continue to shape the leading edge of Electronic Warfare if we are to protect the nation.

Papers to support this theme should include issues relating to how well Electronic Warfare works, how it is needed for attack, how it helps to defend our forces and our homeland, and ways it must be improved to keep our tactics and products viable for the future.

Papers may be classified or unclassified. Briefing sessions will separated into classified US ONLY; NON RELEASABLE - EXPORT CONTROLLED information; and US, UK, CN, AS, releasable. There will be significant representation from our Foreign Military Sales allies, and there will be sessions that are appropriately releasable. Thus, in preparing your papers, please consider and advise us on their applicability, export control restriction and releasability to US ONLY, US/UK/CN/AS, or all.

Presentations will be targeted for 20 minutes. Please let us know if you are interested in presenting a paper. Abstracts (unclassified) may be submitted electronically any time before February 1, 2011 and should be less than 200 words. Presenters will be notified by February 15, 2011, if accepted.

Please ensure all abstracts are unclassified. Along with the abstracts, please provide the classification/releasability guidance for the presentation along with speaker's short bio. E-mail abstracts, bios and releasability document to any member of the Technical session's committee:
Doug Nation, (478) 926-9835, harold.nation@robins.af.mil
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