100th Communications Squadron (Teresa M. Pumphrey)

Airman from 488th Intelligence Squadron operating field exportable training system

FEATURE

Deconflicting Electronic Warfare in Joint Operations

By ARTHUR F. HUBER, GARY CARLBERG, PRINCE GILLIARD, *and* L. DAVID MARQUET

As in combat involving weapons whose lethal effects can result in friendly casualties, electronic warfare (EW) is no less immune to the deleterious effects of fratricide. While the problem of fratricide involving projectile weapons continues to plague modern armies due to advances in velocity and lethality, it is becoming a growing issue for those who conduct EW. More and more systems—both weapons and purely commercial devices—are vying for their place in an increasingly crowded frequency spectrum. There is growing pressure to transfer previously reserved military frequency bands to the public domain[1] and low tolerance for interference of any kind outside of assigned operating bands. Exacerbating this situation is the rush to field emitters of various kinds without proper vetting through the spectrum certification process. Something must be done soon to manage and deconflict the electromagnetic (EM) spectrum better if EW is to remain a weapon that warfighters can wield with acceptable confidence to yield desired effects.

The "Cocktail of Electromagnetic Confusion"[2]

On one occasion I was on orbit conducting jamming operations, and we knew an EC–130E Commando Solo aircraft was in the area putting out [psychological operations] *broadcasts to Iraqi troops. But we didn't know the frequencies or the times when it was operating. A linguist misidentified a broadcast, we targeted it and we ended up jamming it. We discovered the mistake only after we landed.*

—Chris Bakke, EC–130H Compass Call crewmember in Operation *Desert Storm*[3]

As evidenced in the anecdote above, the problem of EW fratricide is one that exists even in operations involving the most modern equipment and well-trained, professional crews. Although this example comes from Operation *Desert Storm*, the problem has recently become highlighted through the experiences of warfighters in Operations *Enduring Freedom* and *Iraqi Freedom*. According to Lieutenant General Walter Buchanan, former chief of Ninth Air Force and U.S. Central Command Air Forces, "This is the first time that you and I have seen electronic fratricide reach the point that it has. . . . When you take a look at data links and the number of jammers in place and all the radios we have out there, [deconflicting] becomes a very difficult problem."[4]

To help understand the extent and seriousness of this issue, we explore two of the primary characteristics driving current problems: management of the electronic spectrum and emitter proliferation in a dynamic battlespace.

Management of the Spectrum. The EM spectrum stretches from a frequency of 0 for direct electrical current to 1,022 hertz characteristic of cosmic rays. The radio frequency (RF) portion of the spectrum extends from about 3 kilohertz to 300 gigahertz. Those who wish to operate within the RF spectrum must

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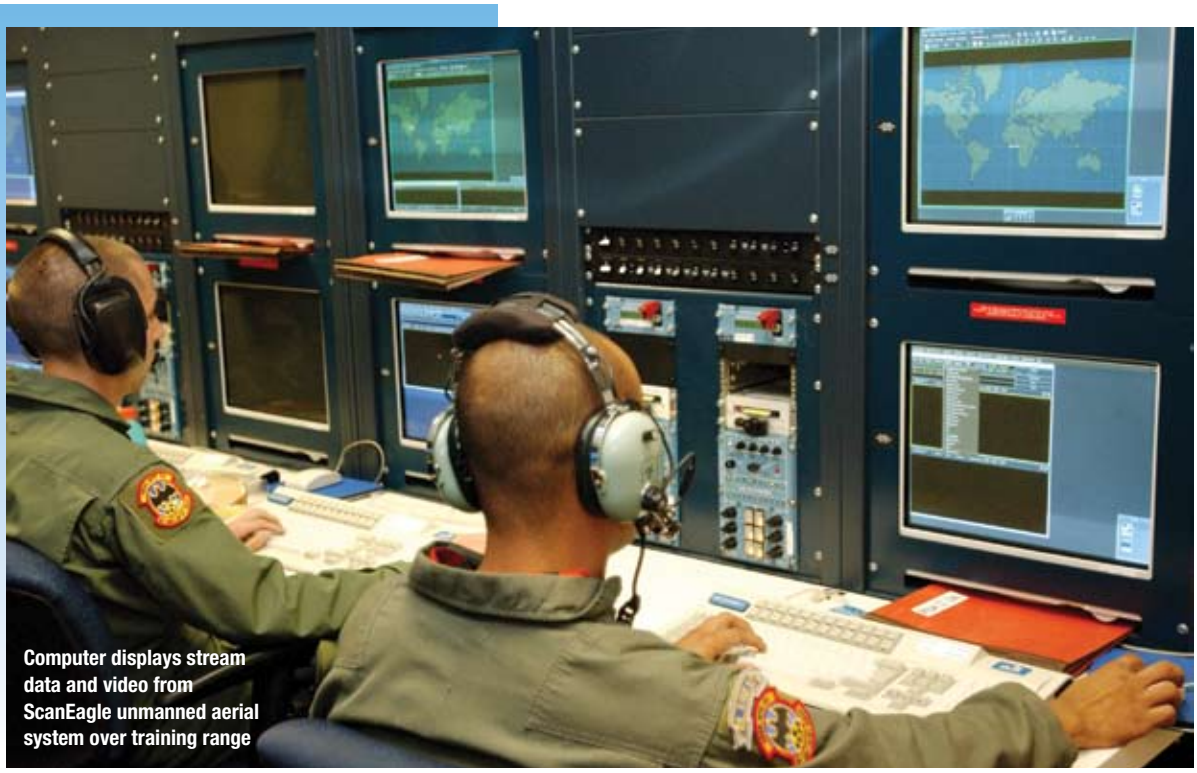
FEATURE

U.S. frequency allocations within the radio frequency spectrum are not necessarily mirrored around the globe



Computer displays stream data and video from ScanEagle unmanned aerial system over training range

U.S. Air Force (Michael P. Snody)

obtain frequency certifications from sanctioned national and international authorities. Unfortunately, when it comes to spectrum allocations and management, "the United States is unique among nations in that it lacks a national spectrum policy." Thus, U.S. interests are not pursued in a coherent and harmonious manner.[5]

Moreover, U.S. frequency allocations within the RF spectrum are not necessarily mirrored around the globe.[6] This has led to many difficulties, including refusal to allow some U.S. systems to operate within foreign national borders.[7] Lastly, while the frequency certification process provides the first line of defense in deconflicting users of the RF spectrum, in the rush to field new systems, it frequently happens that insufficient attention is given to this requirement. This can result in systems that either are incompatible with other systems already fielded or lack the flexibility to permit negotiation in and around a crowded spectrum. This incompatibility manifests itself in inadvertent infringement on authorized users and in restrictions that preclude parallel operations.[8]

Threat Ubiquity and the Dynamic Battlespace. Perhaps no single current circumstance highlights the difficulties of EW deconfliction more than U.S. activities to negate the threat of improvised explosive devices (IEDs). While some IEDs employ triggering mechanisms that do not depend on the RF spectrum, many others do and all have elicited a massive effort on the part of the United States to counter them. This effort was funded at over $3 billion in fiscal year 2006,[9] and approximately $378 million has been spent on the purchase of electronic jammers to counter IEDs since 2003.[10] Despite our best efforts, progress has been limited. The following excerpt from *Newsweek* provides some insight into this problem:

The Warlock is a jamming device used to hunt up and down radio frequencies searching for signals that could detonate a bomb. The Army has worked heroically with the makers to upgrade the short range and limited capability of the Warlock. But in the field, competing technologies kept getting in the way. The Army uses a radio (called SINCGARS) that also hops around frequencies. The radio frequently interfered with the Warlock jammer. Unable to communicate, troops began turning off their jammers—thereby exposing themselves to IEDs.[11]

The difficulties confronting jamming systems such as the Warlock start with the variety and ubiquity of radio-controlled IEDs. These devices have used command detonation mechanisms adapted from remote control toys, electronic keychains, garage door openers, radios, walkie-talkies, cell phones, satellite phones, and long-range cordless phones.[12] U.S. countermeasures have had some success at neutralizing radio-controlled IEDs by inhibiting detonation or causing premature detonation. The problem is that with so many IEDs employed by the enemy, on occasion these countermeasures inadvertently have been responsible for instances of fratricide resulting in death and injuries to friendly personnel. Additionally, the very proliferation of the jammers themselves has compounded the problem of EW coordination and deconfliction. Systems such as Electronic Jammer Against Bombs developed by Israel and procured for Poland's forces in Iraq further demonstrate that the problem is complicated by the need for interoperability with coalition systems.[13] The introduction of airborne assets, such as the EC–130H Compass Call[14] and EA–6B Prowler,[15] can exacerbate the problem by operating at altitudes where jamming signals are dispersed over wide areas.[16]

In concert with the proliferation of emitters on the battlefield has been the changing dynamics of the battlespace itself. Operations are now more rapid in tempo and nonlinear in nature. Coupled with this acceleration is the fact that combat entails a contest between two thinking entities that adapt to evolving circumstances. The result is a battlespace whose dynamics put a premium on the ability to observe, orient, decide, and act, as portrayed in Colonel John Boyd's classic loop

concept. Deconflicting electronic warfare operations is subject to this premium as much as, if not more than, other systems because its effects are transmitted at the speed of light. To address this reality, a comprehensive EW deconfliction process must be well networked and standardized, operated by well-trained and qualified personnel, and must afford spectrum diagnostic and management capabilities to the tactical level.

Deconfliction by the Book

Having outlined the issues with EW deconfliction, we now move to how warfighters manage it in accordance with doctrine.[17] As described by Joint Publication 3–51, *Joint Doctrine for Electronic Warfare*, frequency management is normally accomplished for a geographic combatant command by a Joint Frequency Management Office (JFMO). Through this office, the supported combatant commander establishes procedures, authorizes frequency use, and controls spectrum resources by military forces under his command. The spectrum management process accomplished by the JFMO staff includes such tasks as developing and distributing spectrum-use plans, preparing and updating the joint restricted frequency list (JRFL), exercising frequency allotment and assignment authority, anticipating and resolving potential or actual spectrum interference and conflicts, and coordinating military spectrum use with international and host-nation authorities.

Doctrinally, EW is categorized as an integral part of information operations (IO), so EW planners are normally assigned to an IO cell. This cell is responsible for developing and implementing strategies that exploit the full value of IO resources when integrated and synchronized properly. The EW officer (EWO) is the principal staff EW planner and is critical to the planning and coordination of the frequency spectrum. Typically assigned to the operations staff or IO cell, the EWO is responsible for planning, synchronizing, coordinating, and deconflicting EW actions. The EWO's influence is primarily exercised through the EW Coordination Center, an ad hoc staff coordination element often formed to facilitate the EW coordination function. Furthermore, as electronic warfare is considered a form of fire (that is, weapons employment), the EWO normally works closely with the fire support coordinator to integrate EW efforts with other supporting fire missions. Additional responsibilities range from supervising EW planning efforts and the preparation of EW appendices in operations plans to monitoring the execution of EW in ongoing activities.

A number of tools and organizational entities have been created to assist the electronic warfare officer, such as databases, planning process aids, and visualization models. In terms of support organizations, the Joint Spectrum Center (JSC) is perhaps the most important insofar as its mission is "to ensure the Department of Defense's. . . effective use of the EM spectrum in support of national security and military objectives." This organization "serves as the [Defense Department] center of excellence for EM spectrum management matters in support of the combatant commands, Military Departments, and Defense agencies in planning, acquisition, training, and operations." In this capacity, the JSC manages the Joint Spectrum Interference Resolution program that addresses those interference incidents that cannot be resolved at the unified, subordinate unified, joint task force (JTF), and component levels.

a national policy for spectrum management would account for both domestic and international environments, as well as government and commercial considerations

The EWO responsibility of managing deconfliction extends to consideration of effects on third parties (for example, interagency partners and neutrals). One of the main tools used to manage the spectrum in this regard is the JRFL, and the EWO is normally delegated the responsibility to coordinate preparation of this document. The JRFL is a geographically and time-oriented listing of those functions, networks, and frequencies that must not be jammed or otherwise interfered with by friendly forces. The EWO identifies conflicts between the JRFL and friendly electronic attack operations and requests changes. After sorting out conflicts, the EWO recommends a joint force EW target list through the IO cell to the Joint Targeting Coordination Board, a group formed by the joint force commander to accomplish broad targeting oversight functions.[18]

Freeing Up the Jam

We now consider various ideas to address the EW deconfliction problem. These improvements can be grouped into five major categories:

- developing a national spectrum policy
- applying the joint strategic planning process to spectrum management
- adhering with greater discipline to doctrine and being more creative within its confines
- inserting relevant technological improvements
- holding acquisition efforts accountable for fulfilling frequency certification requirements and conducting proper systems testing.

Develop a National Policy. A national policy for spectrum management would serve foremost to balance U.S. security and safety requirements better with new commercial uses of the frequency spectrum. It would work to ensure that the military's spectrum interests are advanced in order to meet the burgeoning requirements stemming from the imperative to achieve information dominance in modern combat. It would account for both domestic and international environments, as well as government and commercial considerations. Primarily, this will require new mechanisms to promote unity of effort between the Department of State (responsible for international spectrum allocation negotiations), the Commerce Department's National Telecommunications and Information Administration (charged with Federal Government allocations), and the Federal Communications Commission (which administers non–Federal Government and civil/commercial uses). It will also require a single, articulate, and consistent voice at international forums, such as the International Telecommunications Union and World Radiocommunication Conference, that govern international spectrum allocations.

Apply the Joint Planning Process. A critical shortcoming in the U.S. approach to managing spectrum, including its use for

EW, is that we do not treat it as a resource that needs to be subjected to the same extensive planning, direction, and guidance as other constrained resources in our joint strategic planning process. To understand this assertion, we must first describe how spectrum support is provided today. War fighting staffs currently assign frequencies and deconflict operations, relying heavily on spectrum management support provided by the JSC, which resides under the Defense Information Systems Agency. The JSC enjoys an excellent reputation for the support that it provides to warfighters and has a good history of responsiveness to combat needs. In essence, the JSC provides a service analogous to the Defense Logistics Agency insofar as the JSC delivers a commodity—that is, workable frequency assignments—much as the logistics agency provides parts and supplies.

If the military were to change its outlook regarding spectrum management and to view it less as a logistics commodity and more as a force resource, it could improve management by giving spectrum the required priority and visibility. From this perspective, spectrum would be treated not as a spare or consumable but more like equipment and personnel. If the joint strategic planning process embraced spectrum as such, then it could be managed assertively in all types of planning, execution, and across all phases of military efforts. Accordingly, the joint planning system might evolve along the following lines:

- Assign spectrum to the geographic combatant commands for use during peacetime through the "Forces for Unified Commands" memorandum, issued by the Secretary of Defense.
- Apportion spectrum to the geographic combatant commands for use in developing operational plans through the Joint Strategic Capabilities Plan, issued by the Chairman of the Joint Chiefs of Staff.
- Allocate spectrum to the geographic combatant commands for use in actual operations.

To round out this perspective, it is important to note the Services would retain their traditional functions to "organize, train, and equip," so the force planning portion of the strategic planning process would remain essentially the same. However, on the operations planning and force employment sides of the equation, the changes could be profound. Assuming a proper matching of forces to spectrum requirements, some of these changes might include:

- proactive identification of potential and actual theater spectrum conflicts that stem from differing national frequency allocations within a combatant commander's area of responsibility
- preconflict reservation of spectrum blocks for selected systems, thereby motivating other systems to be reprogrammed ahead of time for deconfliction
- detailed planning for spectrum order of battle (in time and space as a function of battlefield evolution and adversary responses)
- institution of a frequency tasking order (FTO) to enable enhanced situational awareness and tracking of spectrum use in order to manage frequency assignments dynamically for individual emitters
- better identification of shortfalls for translation into acquisition requirements by the combatant commanders through their integrated priority lists and mission need statements.

Of all the changes noted above, perhaps none gives moment for pause as much as the idea for development of an FTO. Were it actually implemented, it would appear to lend itself to automated frequency conflict identification and possibly a great measure of automated deconfliction as well. The immediate challenge in any such proposal would be addressing the sheer volume of emitters across all force components since it could potentially include multiple systems at the level of the individual Soldier, never mind those embedded in all platforms across the entire battlespace. Furthermore, it would have to address a much more dynamic environment in terms of the number of changes likely required during both planning and operations execution. In principle, these challenges could be overcome, but we recognize a great deal of work must be done to assess all the requirements, develop accompanying compatible processes across a diverse joint force, and design workable solutions that are cost-effective and user-friendly. The multidimensional nature of the requirement (for example, number of emitters, their capabilities, mission cycle times, associated processes at differing echelons) clearly makes development and implementation of the FTO a complex challenge.

Adhere with Discipline and Creativity to Doctrine. The third proposal essentially calls for disciplined adherence to doctrinal precepts for frequency management. Regrettably, the record reflects flawed and inconsistent application of these precepts. Lapses have occurred in the coordination among the entities that implement the frequency management process, from planning phases through frequency assignment and operations. There are instances in which JRFLs were violated or ignored. In some cases, analyses made of the EW environment were incorrect because they relied on incomplete or obsolete data.[19]

Other lapses include neglect of the standup and continued manning of EW

Officers confer about incorporating Joint Integration and Interoperability of Special Operations products in U.S. European Command

U.S. Air Force (Devin Fisher)

Coordination Centers on combatant commander and task force staffs. Sometimes those assigned to conduct EW planning were inadequately trained or lacked sufficient expertise in the EW profession. Rotation policies have also served to aggravate the problem. Short rotation periods have inhibited development of tactical proficiency, while extended tours have burned out personnel. Failures to ensure that replacements were put in place in a timely manner meant that there was no effective hand-off of duties, and as a result spin-up times were lengthened. A classic example of this problem was recently experienced in *Enduring Freedom* by Combined Joint Task Force–76 (CJTF–76). Although the CJTF–76 had developed a highly effective Joint Fires Board (JFB) that was able to deconflict EW, when the EWO rotated out and new counter-IED systems were introduced into the operational area, there was no longer an experienced expert able to engage a process to deconflict EW activities. The unfortunate result was EW fratricide involving Blue Force Tracker systems, vehicle-to-vehicle convoy radios, ground-based and mobile counter-IED equipment, and civilian airport operations.

Of all our proposals, preventing lapses in adherence to proven processes would appear the first order of business. One action would be to ensure the EW Coordination Center is formed and manned prior to and during all phases of a campaign. Furthermore, emphasis should be placed on delineating and training personnel on how the coordination center morphs in character and function as a campaign proceeds. Another role would be to reinforce guidance to combat forces that the JRFL is to be consulted and honored. Training of personnel and manning of geographic combatant command billets for EW and spectrum management functions should also be given higher priority.

Disciplined adherence should not, however, be perceived as precluding other creative actions that innovate within doctrinally based processes. In this vein, the staff at U.S. Central Command has recently published and implemented a concept of operations for EW spectrum management that more precisely delineates objectives and responsibilities including delegation of EW coordination authority to the Combined Forces Air Component Commander. This places the coordination authority role in a single functional commander for the first time. The concept also creates the new staff office of the Combined Theater EW Coordination Cell, which is charged to coordinate with combatant commanders and joint task forces to determine, integrate, and satisfy EW requirements for preplanned operations. The objective of the cell is to develop a coherent and synchronized plan to employ EW assets to achieve theater objectives. Mitigating fratricide issues is explicitly enumerated among its responsibilities.

Another creative organizational and process innovation implemented in the USCENTCOM area of responsibility was mentioned earlier: the Joint Fires Board instituted by CJTF–76 in Afghanistan in 2005. The purpose of the JFB is to "ensure unity of effort and synchronize . . . fires within the combined joint operations area."[20] The fire support officer in the Joint Operations Center runs this board to coordinate the efforts of various task force staff offices and cells charged with responsibilities that depend or impinge upon one another. Electronic warfare is given due consideration when fires support and deconfliction are reviewed. The success of this innovation was captured by some of its participants who said:

During the past year, deconfliction of EW missions has gone from being a difficult challenge to a manageable part of the joint fires daily battle rhythm. This is largely due to efforts to increase knowledge of EW at the CJTF level and below as well as regular discussions on EW at the regional command and TF levels.[21]

Reportedly, this JFB success has been noted and was a consideration in the development of the EW concept of operations. Lessons learned will likely be incorporated into future updates of staff EW planning guides.

Insert Technology. Key to the deconfliction process is a suitable characterization of the operating environment. This is an ongoing task that requires rigor and timeliness. The requirement for rigor comes into play with regard to the constant efforts necessary to add new emitters to databases of the frequency environment and to ensure that parametrics properly describe emission characteristics. The requirement for timeliness is perhaps even more relevant in today's circumstances insofar as it may not be a lack of knowledge of the emitter population that inhibits deconfliction, as much as it is knowing who is actually up and transmitting at any given point in space and time. Thus, while it may be possible to know that two types of emitters may interfere with each other, in principle these emitters could be deconflicted in time or space if one knew when and where they are or will be transmitting and then account for the transmission in operational planning and execution. Accordingly, enhancing such databases and associated tools to implement just-in-time deconfliction could assist significantly in avoiding fratricide events.

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Those involved today in the management of the frequency spectrum—including deconfliction processes—rely on a number of standard tools. A key tool is SPECTRUM XXI.[22] While capable, one of the limitations of SPECTRUM XXI is that it does not permit making frequency assignments for time slots shorter than 24 hours. To achieve this capability, EW staff officers and operators need networked access to the global information grid to give them timely information and support analyses to assure deconfliction. While improved spectrum support to crisis planning is required, electronic warfare officers and operators are more concerned with the real-time provision of tactical level data and coordination. Such a requirement implies "spectrum on demand" capability enabling dynamic frequency reassignment.

A replacement for SPECTRUM XXI under consideration is the Global Electromagnetic Spectrum Information System (GEMSIS). This system promises "full integration of network and spectrum management on the global information grid to provide complete spectrum situational awareness."[23] Plans are to assess the potential for this tool in a joint capability technology demonstration entitled the Coalition Joint Spectrum Management Planning Tool.[24] If GEMSIS or a tool

similar to it eventually does become available and is properly networked, it could provide the foundation for a capability to deconflict EW operations in real time.

Advancements in electronic system capabilities—such as expanded transmission bands, frequency agility, programmability, and "precision"—also promise to bolster the ability to deconflict EW operations. A straightforward example is to enable a radio to transmit across a wider range of spectrum to improve the likelihood that a subset of frequencies that it can operate over will be clear and available for assignment. Such approaches are constrained in several respects to include cost, packaging, and spectrum availabilty, so alternatives beyond frequency bandwidth and operating region have become important.

One advanced feature is programmability, both user-selectable and software-based. In the world of radio-controlled IED jammers, for example, the Bombjammer family of systems offers a model permitting operator selection of the desired jamming frequencies, dwell time, frequency windows, and output power. Software reprogramming was once restricted to mission data files that solely reflected the most current intelligence on threat system parametrics, but now enables changing operating frequencies (once fixed by hardware), varying modulation types, and controlling power transmission levels (which affect range). The advent of digitally modulated waveforms permits multi-user access within the same frequency range and channel sharing via multiplexing. "Smart" systems can now "sniff" the spectrum for open frequencies and dynamically control frequency assignment.[25]

Just as precision-guided munitions have helped limit fratricide and collateral damage, precision EW can do likewise. Precision EW takes on several forms to include very "clean" signals (that is, waveforms distinguished by few, if any, unintended spurious characteristics) and transmissions at exact frequencies (that is, with little bleed into adjacent bands). Another form of precision EW has become possible with the introduction of advanced electronically steered arrays possessing transmit antenna patterns exhibiting highly directional "pencil" beams. Such designs enable placing jamming energy precisely where desired (that is, into targeted receivers) with little energy dispersion. Although this puts a premium on geolocation of targeted receivers, it does serve to limit inadvertent interference with other friendly systems.

Account for Frequency Certification and Conduct Testing. The fifth and last proposal is another imperative for process discipline. The acquisition enterprise normally follows a prescribed set of steps involving a series of gated reviews and approvals to ensure development programs result in products that meet warfighter needs, are cost-effective, and can be sustained. Unfortunately, the record shows some developmental and upgrade programs fail properly to apply for and receive certification for the frequency bands in which they design their systems to operate—resulting in systems that interfere with those already fielded. For example, a 1998 Defense Inspector General audit report counted almost 90 systems deployed to various theaters without proper frequency certification and host-nation approval.[26] The process that should be followed is one that is dictated by Federal and Defense Department regulations, is facilitated through the Defense Spectrum Office and associated Service agencies, and is overseen by Defense Acquisition Boards and milestone authorities. Negotiating the process can take years depending on a number of factors, including the complexity of the envisioned system, portion of the frequency spectrum desired for operation, and extent of required international coordination. Accordingly, the process must start early in the development phase and be monitored and enforced throughout the acquisition lifecycle, including during test and evaluation as a compliance check.[27]

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Typical examples of this failure in the acquisition process have been products that were developed in an "urgent and compelling" manner to meet immediate combat needs. New counter-IED equipment being developed and introduced by U.S. and coalition forces is a good case in point. In the rush to field urgent capabilities, it is typical for compromises to be made in signal generation precision and for little thought to be given to securing spectrum certification. When the potential for unintended interference is consciously assessed as an acceptable risk, compared to the advantages brought to the fight by the new combat capability, this may be a worthwhile tradeoff. That said, product designers should still anticipate fratricide issues and design the capability to upgrade the system later (for example, through reprogramming) when there is more time to account for all such effects. Furthermore, product testing should strive as much as possible within time constraints to characterize system operation and interference potential so that the system can be fielded with appropriate caveats and warnings.

A Resolute Way Ahead

Since World War II, when electronic warfare first saw widespread use in combat, great strides have been made to infuse EW into the arsenals of contemporary militaries. As recent conflicts have demonstrated, advanced electronic systems have proven themselves as force multipliers on the modern battlefield. However, these benefits have come with a price: the warfighters' growing reliance on these spectrum-dependent systems. Part of the challenge in attaining the full value that EW systems offer is to ensure that we do not introduce interference or confusion within our own operations—hence, the imperative to deconflict.

We have seen in the trends of the last few decades that modern combat is becoming more complex, networked, and integrated through systems of systems. In the arena of electronic warfare, our response has evidenced enough sophistication to recognize these trends and to take measures to address them. We organize ourselves to manage warfighting as efficiently and as presciently as possible. We conceptualize and codify doctrine to guide our planning and execution of combat operations. We push technology to give us better management tools and better performing weapons. But where we often fail is in consistent and universal followthrough.

If we are to slay the demon of EW fratricide—that is, stop being our own electronic enemy—we must not only understand these trends and develop answers to them, but also be ruthless in our followthrough.

When we know from doctrine and experience that instituting a EW Coordination Center or Joint Fires Board enables and optimizes deconfliction, it is not acceptable to allow such entities to be stood down or undermanned when it will put lives and missions at risk. When we have proven through hard lessons learned and creative innovation which processes work and which do not, we cannot fail to institute best practices. When we transform our forces into those that put a premium on the timely prosecution of the kill chain and we do not likewise transform the supporting structures that enable us to manage the very spectrum such a force is founded upon, then we have evidenced a lack of resolution.

The problem of electronic warfare fratricide is a growing issue. Proliferating systems, rapidly procured and fielded, are making for an increasingly crowded spectrum. Our freedom to operate is jeopardized. As our adversaries learn to get the most from their asymmetric strategies and close the gap with us technologically, our edge in combat will increasingly rely on our singular competencies in integration and operational excellence. We have the tools in hand or in development to maintain these trump cards as asymmetries of our own. Let us not prove wanting in our willingness and resolution to take advantage of them. **JFQ**

NOTES

[1] Katherine McIntire Peters, "The Battle for Spectrum," *Government Executive* 33, no. 10 (August 2001), 56, accessed at <www.govexec.com/features/0801/0801s5s1.htm>.

[2] David A. Fulghum, a writer with *Aviation Week & Space Technology*, coined this phrase.

[3] Alfred Price, *The History of U.S. Electronic Warfare, Volume III,* Rolling Thunder *through* Allied Force (Alexandria, VA: The Association of Old Crows, 2000), 432.

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[5] Report of the Defense Science Board (DSB) Task Force on Department of Defense Frequency Spectrum Issues, "Coping with Change: Managing RF Spectrum to Meet DoD Needs," November 2000, slide 24, accessed at <www.gao.gov/new.items/d03617r.pdf>.

[6] Peters, 56.

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[8] Captain Mike Murphy, USN, Joint Spectrum Center briefing, "Spectrum: Critical to the Warfighter," May 24, 2006, slide 12.

[9] Michael Goldfarb, "Improvised Explosive Disaster," *The Weekly Standard*, May 4, 2006, accessed at <www.weeklystandard.com/Content/Public/Articles/000/000/012/178fjedi.asp?pg=1>.

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[13] Michael Fiszer, "Polish Troops in Iraq Getting Counter-IED Devices," *Journal of Electronic Defense* 29, no. 3 (March 2006), 18.

[14] David Pugliese, "The Hidden Enemy," *The Ottawa Citizen*, February 18, 2006, B1.

[15] Michael Sirak, "U.S. 'Needs to Do Better' with EW Assets," *Jane's Defense Weekly* 42, no. 44 (November 2, 2005), 11.

[16] Fulghum, 32.

[17] The following discussion is a summary of salient points and includes passages from Joint Publication 3–51, *Joint Doctrine for Electronic Warfare*, available at <www.dtic.mil/doctrine/jel/new_pubs/jp3_51.pdf>.

[18] Joint Publication 3–09, *Doctrine for Joint Fire Support*, May 12, 1998, GL–8, available at <www.dtic.mil/doctrine/jel/new_pubs/jp3_09.pdf>.

[19] "Spectrum Planning in EW," slides 8, 23, 25.

[20] Daniel C. DiNicola, Leo F. Brennan III, and Bruce J. Carter, "Afghanistan: CJTF–76 Joint Fires Board in OEF 04–06," *Field Artillery*, March-April 2006 (HQDA PB6–06–2), 35, available at <http://sill-www.army.mil/famag/2006/MAR_APR_2006/MAR_APR_06_PAGES_34_37.pdf>.

[21] Ibid., 37.

[22] Joint Publication 3–51, B–7.

[23] Alion Science & Technology, *2004 Annual Report*, 10, available at <www.alionscience.com/uploads/docs/AboutAnnual_2004.pdf#search=%22alion%20GEMSIS%22>.

[24] Office of the Secretary of Defense, Research, Development, Testing, and Evaluation Budget Project Justification (R2a Exhibit) PE 0603648D8Z—Joint Capability Technology Demonstration, February 2006; Murphy, slides 15, 16.

[25] Report of the DSB Task Force, slides 18, 20, 21.

[26] Department of Defense, Office of the Inspector General, "Coordination of Electromagnetic Frequency Spectrum and International Telecommunications Agreements," Report No. 99–009, October 9, 1998.

[27] Report of the DSB Task Force, slides 5, 7, 9, 43, 44.

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Strategic Forum 225

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