

Operational Evaluation of Electromagnetic Environmental Effects (E3)

New DOT&E Policy Calls for More Systematic Assessment of E3

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Increased dependence of our military forces on the use of information, electronic, and electromagnetic systems has heightened our nation's awareness of military use of the electromagnetic spectrum. For both defense and non-defense applications, spectrum use is increasing, and market forces are steering national policy makers to reallocate exclusive government/military portions of the spectrum to private use. Further, DoD is increasingly aware that the use of more commercial and military electronic systems in tight spaces aboard military ships, aircraft, and vehicles can cause unintended electromagnetic interactions among these systems; such interactions are likely to have adverse impacts on operations.

The discipline of analyzing and managing friendly, unintended adverse electromagnetic interactions and susceptibilities is called electromagnetic environmental effects or E3. A parallel discipline to E3 is spectrum management or SM. SM is the discipline of managing the use of the electromagnetic spectrum to prevent mutual interference among the users.

Many E3/SM incidents already have occurred that have limited mission effectiveness, destroyed systems, and may even have resulted in friendly casualties. For example, in recent operations in the Balkans, a jammer aircraft experienced an engine shutdown when it began to



UH-60 Black Hawk helicopters from the 3-25 Assault Helicopter Battalion take off from the deck of the aircraft carrier, *USS Eisenhower* (CVN-69), bringing the first wave of combat troops ashore in Haiti, Sept. 19, 1994.

Photo by Navy PH1 Martin Maddock

transmit jamming signals. A remotely piloted vehicle for which a payload of electronics was rapidly configured without regard to E3, experienced interference problems that caused dropouts in the downlink. Our own jammer aircraft interfered with an artillery counter-battery radar. In Macedonia, electronic equipment experienced problems when hooked up to the local power grid. In a test flight over a range in the southwest

United States, a Global Hawk Unmanned Aerial Vehicle (UAV) experienced interference from an adjacent test range that was testing auto-termination transmissions on the same frequency. The result was initiation of the self-destruct mechanism in the UAV; the aircraft was destroyed.

A highly memorable incident occurred during the Vietnam War when an ex-

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Fire broke out on the flight deck of *USS Forrestal* (CV 59) as aircraft were being readied for launch over Vietnam. Damage to aircraft and the ship was severe. The final casualty count was 132 dead, two missing, and 62 injured.

U.S. Navy photo



plosion and resulting fire occurred aboard the aircraft carrier *USS Forrestal*, operating off Vietnam. Stray voltage was thought to be a possible cause. A potential source was one of the ship's radars, which may have ignited a rocket on one of the aircraft waiting to be catapulted. A number of lives and aircraft were lost. A more recent incident was the loading of ordnance on Army attack helicopters aboard the carrier *USS Eisenhower* in 1994. The helicopters aboard the *Eisenhower* were bound for Haiti and intended for use in Operation Uphold Democracy. The Navy was concerned that since the Army helicopter ordnance had not been certified for the carrier's electromagnetic environment, a disaster might occur. The ship's radar could not be used, which limited operations.

Department of Defense (DoD) policies for E3 and SM are prescribed in DoD Regulation 5000.2-R.¹ Department of Defense Directive 3222.3² provides further policy detail on E3, and DoD Directive 4650.1³ provides further policy detail on SM. The two directives are currently in revision. Because of the E3/SM incidents cited earlier, along with others, the Director, Operational Test and Evaluation (DOT&E), Philip E. Coyle III has developed a policy on actions his office will take to reduce E3/SM incidents in the future.⁴

What is E3?

Any clear understanding of E3 and SM should start begin with formal definitions from Joint Pub. 1-02.⁵ E3 is defined as:

The impact of the electromagnetic environment upon the operational capability of military forces, equipment, systems, and platforms. It encompasses all electromagnetic disciplines, including electromagnetic compatibility/electromagnetic interference (EMC/EMI); electromagnetic vulnerability (EMV); electromagnetic pulse (EMP); electronic protection (EP); hazards of electromagnetic radiation to personnel (HERP), ordnance (HERO), and volatile materials (HERF); and natural phenomena effects of lightning and p-static (precipitation static).

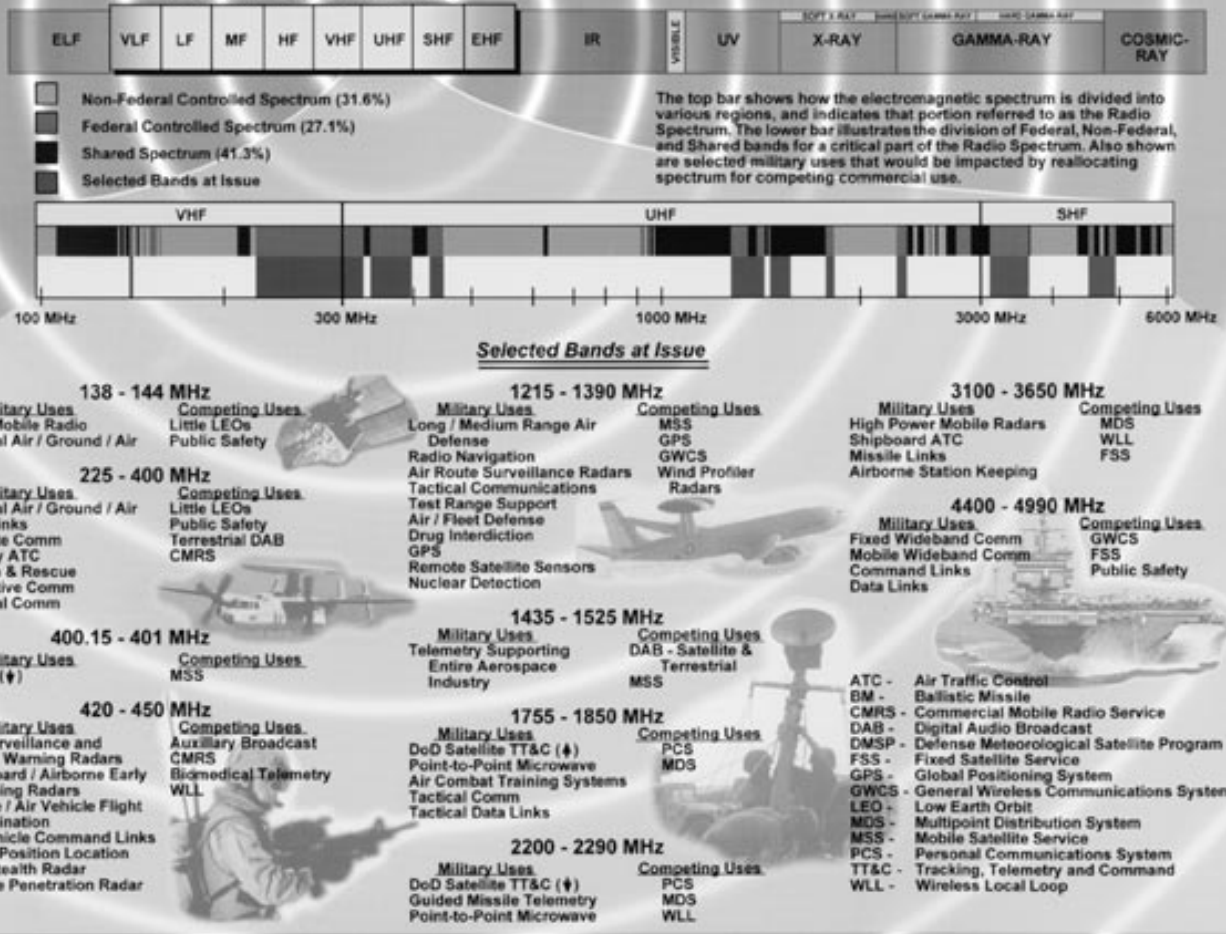


Global Hawk, DoD's newest reconnaissance aircraft, flies over Edwards Air Force Base, Calif., Feb. 28, 1998, during its first flight. Global Hawk is a high-altitude, long-endurance, UAV designed to operate with a range of 13,500 nautical miles, at altitudes up to 65,000 feet, and with an endurance of 40 hours. During a typical reconnaissance mission, the aircraft can fly 3,000 miles to an area of interest, remain on station for 24 hours, survey an area the size of the state of Illinois (40,000 square nautical miles), and then return 3,000 miles to its operating base. Sensors on board the aircraft can provide near real-time imagery of the area of interest to the battlefield commander via worldwide satellite communication links and the system's ground segment.

DoD Photo

Electromagnetic Spectrum

THE RADIO SPECTRUM



Spectrum Management is defined as:

Planning, coordinating, and managing joint use of the electromagnetic spectrum through operational, engineering, and administrative procedures, with the objective of enabling electronic systems to perform their functions in the intended environment without causing or suffering unacceptable interference.

Electromagnetic environmental effects comprise a number of electromagnetic disciplines, as indicated in the definition. The definitions of these disciplines, also defined in Joint Pub. 1-02, are presented in Figure 1.

From the perspective of the developer and the user, spectrum management has

two major components: *spectrum certification* and *frequency assignment*.

SPECTRUM CERTIFICATION

Spectrum certification is of concern to the developer (i.e., the program manager). It is the process (called the J/F-12 process by the spectrum managers) whereby a new spectrum-dependent system is certified to operate in a portion of the spectrum. This is not permission for the user to operate the system—it is permission for the developer to design and build the system to operate in the approved portion of the spectrum.

The vehicle for initiating the spectrum certification process is DD Form 1494.⁶ Updated continuously throughout the acquisition process, this form is filed with the Military Communications-Electronics Board directly or through a local

frequency manager. The J/F-12 process is extremely important because the spectrum is tightly controlled by international agreements via a global table of allocations whereby portions of the spectrum are allocated for various functions and system spectral characteristics. The approval process consists of the U.S. spectrum managers finding the best “fit” for the new system to minimize potential EMC/EMI with other systems operating in the same or adjacent portions of the spectrum. This process normally involves coordination with international organizations.

To obtain approval (certification) with nations in which the system is intended to operate, the Host Nation Coordination (HNC) section in DD Form 1494 must be completed. Host nation approval is needed because there are vari-

ations in the global table of spectrum allocations, depending on the region of the world (there are three regions). Each sovereign nation controls the spectrum within its borders. A particular function or service, such as cellular telephone service, may be allocated one frequency band in one country and another frequency band in another country. A frequent mistake made by purchasers of commercial equipment (such as a cell phone) in the United States for use overseas is the belief that overseas use of equipment is allowed without proper certification by the host country.

FREQUENCY ASSIGNMENT

The second major component of spectrum management is the frequency assignment process, which gives the user (warfighter) the authority to operate a fielded, spectrum-dependent system. To prevent EMI, coordination among all spectrum users within a frequency band and geographic region must occur. The regional frequency manager provides this coordination. DoD Area Frequency Coordinators are available at the major test ranges in the United States. For overseas operations, frequency management for U.S. forces is handled by the Joint Frequency Management Office of the Commander in Chief or Joint Task Force, working in conjunction with the host nation frequency management authorities.

The seriousness of a military conflict does not necessarily permit U.S. military forces unrestricted use of the spectrum. Local region commerce, public safety, and public service operations are expected to continue, to the extent possible, even in a conflict. This is especially true if the conflict is of limited intensity (e.g., peacekeeping operations), or of limited geographic scope (i.e., the conflict

is in a small nation surrounded by border nations that are not involved in the conflict but are affected by electromagnetic transmissions in the conflict area). The ease with which U.S. forces can gain the necessary authorization from regional governments will generally depend on the extent to which commerce will be disrupted or whether anyone's national sovereignty is actually threatened.

fectiveness and the safety of the warfighter will be adversely affected if these effects are not understood. E3 is complex; program managers and their teams need time to analyze effects and design prevention into the system, or at least accurately document the limitations and vulnerabilities for the warfighter.

Policy Specifics

DOT&E is placing greater emphasis on E3 matters with early involvement in the acquisition process to prevent problems from reaching the field. Certainly, analyzing E3 problems and designing preventative measures in the development phase is more cost effective than being forced to create fixes in the field, especially after becoming aware of the problem only after suffering loss of life and property.

DOT&E's new E3/SM policy more clearly defines the role of Operational Test and Evaluation (OT&E) in identifying potentially adverse E3 and spectrum availability situations. The policy is intended to make pro-

gram managers and Operational Test Agencies aware that DOT&E plans to assess this area more systematically. It is not intended to replace or add to any existing DoD directives or regulations, but to ensure that current required practices are applied and leveraged to the fullest extent in evaluations of system operational effectiveness. Figure 2 lists specific actions to be carried out by the responsible organizations.

Signed on Oct. 25, 1999, the new DOT&E policy applies to all DOT&E oversight programs. It applies to programs at Milestone 0 at the time of approval. Programs between Milestone 0 and Milestone III are to incorporate this approach during their next Test & Evaluation Master Plan approval cycle.

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From the perspective of the program manager, the importance of E3 and SM in acquisition lies in two areas:

- First, the PM needs to be concerned with obtaining spectrum certification for the new spectrum-dependent system under development. Without this, the system cannot be operated, and thus would be of no use to the warfighter. The J/F-12 process for approval takes time, especially if HNC is needed to operate the system in areas outside of the United States. For this reason, it is important to start the process (filing form DD 1494) early in the acquisition program at, or soon after, Milestone 0.
- Second, E3 needs to be addressed as early as possible because mission ef-

FIGURE 1. **Definitions of the Electromagnetic Disciplines Covered by E3**

Discipline	Definition (Joint Pub. 1-02)	Discipline	Definition (Joint Pub. 1-02)
EMC	The ability of systems, equipment, and devices that utilizes the electromagnetic spectrum to operate in their intended operational environments without suffering unacceptable degradation or causing unintentional degradation because of electromagnetic radiation or response. It involves the application of sound electromagnetic spectrum management; system, equipment, and device design configurations that ensure interference-free operation; and clear concepts and doctrines that maximize operational effectiveness.		electrons from photons scattered in the materials of the nuclear device or in a surrounding medium. The resulting electric and magnetic fields may couple with electrical/electronic systems to produce damaging current and voltage surges (pulses). May also be caused by non-nuclear means.
EMI	Any electromagnetic disturbance that interrupts, obstructs, or otherwise degrades or limits the effective performance of electronics/electrical equipment. It can be induced intentionally, as in some forms of electronic warfare, or unintentionally, as a result of spurious emissions and responses, intermodulation products, and the like.	EP	That division of electronic warfare involving actions taken to protect personnel, facilities, and equipment from any effects of friendly or enemy employment of electronic warfare that degrade, neutralize, or destroy friendly combat capability.
EMV	The characteristics of a system that cause it to suffer a definite degradation (incapable of performing the designated mission) as a result of being subjected to a certain level of electromagnetic environmental effects.	HERO, HERP, HERF	HERO is the danger of accidental actuation of electro-explosive devices or otherwise electrically activating ordnance because of radio frequency (RF) electromagnetic fields. This unintended actuation could have safety (premature firing) or reliability (dud-ding) consequences. HERP (not specifically defined in Pub. 1-02) refers to the danger of RF electromagnetic fields to the health of personnel. HERF (not specifically defined in Pub. 1-02) refers to the danger of RF electromagnetic fields accidentally igniting volatile materials (fuels).
EMP	The electromagnetic radiation from a nuclear explosion caused by Compton-recoil electrons and photo-		

FIGURE 2. **Policy Actions**

Organization	Actions	Organization	Actions
DOT&E	<ul style="list-style-type: none"> Review Service Test and Evaluation Master Plans (TEMP), System Threat Assessment Reports, Operational Requirements Documents, test plans, test concept briefings, and test reports to determine the adequacy of E3 testing. Ensure that E3 issues are satisfactorily reviewed by program acquisition Integrated Product Teams (IPT). Review Services' evaluation approaches, including modeling and simulation, small-scale tests, and appropriate chamber and laboratory tests. Leverage the evaluation of E3 impacts during large-scale field training exercises. Review Services' early assessments to identify and understand those situations where E3 and spectrum limitations would likely affect mission accomplishment. The results and projected impacts should be reviewed in the appropriate IPT forum and used in the design and scoping of full-scale operational tests. Review the DD Form 1494 and J/F-12 process and share the data with the OTAs. Review E3 engineering assessments and qualification test plans and reports. Report the status of E3 issues for each program in the DOT&E Annual Report, and report specific program findings as part of Beyond Low Rate Initial Pro- 		<p>duction reports to the Secretary of Defense and the Congress.</p> <ul style="list-style-type: none"> As E3 issues related to fielded systems arise during operational tests (OT) or during large-scale training exercises used to complement OTs, report these issues to the appropriate agencies for resolution.
		OTAs	<ul style="list-style-type: none"> Work in conjunction with the Joint Spectrum Center, the Defense Intelligence Agency, the system user, and others as appropriate to conduct early independent analyses of potential E3 issues, and review the program manager's resolution of these issues. Conduct early operational assessments that consider the intended operational environment, including storage, training, transportation, staging, and conduct of the battle in single Service, joint, and international deployments. (Avoid relying solely on developer-planned E3 analyses or evaluations.) Include E3 and spectrum availability assessment issues as a standard presentation at Operational Test Readiness Reviews. These assessments should include the operational impact of any waivers and results of analyses normally accomplished as part of the DD-1494 or J/F-12 review process.
		PMS	<ul style="list-style-type: none"> Ensure that E3 test and evaluation receives adequate funding and is sufficiently addressed in system

Implementation

To assist program managers in E3/SM matters concerning their programs, DOT&E, together with the OTAs and with the assistance of the Defense Information Systems Agency Joint Spectrum Center (JSC), is in the process of developing guidance for implementing the policy. A guidance document for program managers is in preparation and will be distributed when available.

DOT&E is following a philosophy of identifying and enabling units to fix E3 and SM problems early in the acquisition program to the maximum extent possible without "breaking the bank" before operational testing and fielding occurs. E3 problems are highly scenario-dependent, and it may not be possible to identify and solve them using the models/simulation, test and evaluation process for all possible scenario configurations. In such cases, the models/simulation, test and evaluation process is intended to document specific limitations and vulnerabilities and inform the

warfighter. Adjustments can then be made in tactics, techniques, and procedures to accommodate the limitations.

The JSC has considerable expertise in E3 and SM matters. This organization can provide advice and carry out E3 test and analyses in the field or in the laboratory. At its disposal are a multitude of Electromagnetic Compatibility databases and models. The JSC can also assist in the completion of DD Form 1494 and provide guidance in the J/F-12 process.

Editor's Note: The point of contact at the JSC is the E3 Engineering Division Chief, Bill Lenzi, at (410) 293-4958 or J5@jsc.mil. Lenzi can also provide an educational video on CD-ROM called "E3 and SC (Spectrum Certification) for Acquisition Managers."

REFERENCES

1. Department of Defense Regulation 5000.2-R (Change 4), *Mandatory Procedures for Major Defense Acquisition Pro-*

grams (MDAPs) and Major Automated Information System (MAIS) Acquisition Programs, May 11, 1999.

2. Department of Defense Directive 3222.3, *Department of Defense Electromagnetic Compatibility Program (EMCP)*, Aug. 20, 1990.

3. Department of Defense Directive 4650.1, *Management and Use of the Radio Frequency Spectrum*, June 24, 1987.

4. Director, Operational Test and Evaluation Memorandum, "Policy on Operational Test and Evaluation of Electromagnetic Environmental Effects and Spectrum Management," Oct. 25, 1999.

5. Joint Publication 1-02, *Department of Defense Dictionary of Military and Associated Terms*, March 23, 1994 (as amended through Feb. 10, 1999).

6. Form DD 1494, *Application for Equipment Frequency Allocation*, August 1996.

From DSMC Protégé to MDW Award-Winning Photojournalist



Photo by Collie Johnson

Laura Bonner, a former layout artist for *Program Manager* magazine, receives the Keith L. Ware Award for Photojournalism in a ceremony at Fort Belvoir, Va., March 31. Presenting the award is Army Maj. Gen. Robert R. Ivany, Commanding General, U.S. Army Military District of Washington. Bonner came to DSMC in 1998 at the journeyman level under the mentorship of Paula Croisetiere, DSMC Chief of Design. *Program Manager* magazine was Bonner's first assignment upon entering the communications media career field. Currently, she is the designer for the Military District of Washington Pentagram.

The Keith L. Ware Competition, recognizing journalistic excellence in several categories, is named in memory of Army Maj. Gen. Keith L. Ware, former Army Chief of Public Affairs. Gen. Ware received the Medal of Honor in World War II and was killed while commanding the 1st Infantry Division in Vietnam in 1968.