

# United States Air Force Research Laboratory



## ASSESSED NEED: AEROMEDICAL TRAINING FOR EMERGING DIRECTED ENERGY

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## EXECUTIVE SUMMARY

This study of a sample population of military healthcare providers characterizes military medics' current awareness of emerging Directed Energy (DE) systems and the implications of those systems for field medical management of real and suspected over-exposures to non-ionizing DE. Using a simple True/False survey instrument the research team found sufficient basis to encourage better education and training of military medics regarding DE systems and the hazards such systems can present. Results of this study help substantiate the need for improved military medical training in DE bioeffects. Cursory DE pertinent information for medics is provided. Recommendations to address the need include improving how the military services share, disseminate, and benefit from military lessons learned (MLL) databases. Furthermore, military medical training institutions are encouraged to integrate MLL tools into their delivery of up-to-date information about DE hazards, injuries, and medical interventions. Subject matter experts, such as those at the Air Force Research Laboratory, Directed Energy Bioeffects Division, must be readily accessible by deployed medics and to the leaders of medical training programs.

## **1.0 INTRODUCTION**

Even a casual observer of military operations will acknowledge the increased presence of Directed Energy (DE) systems on the modern battlefield. Consequently, there are elevated risks to military personnel from intended and accidental exposure to DE beyond established safety standards, the permissible exposure limits (PEL). This study provides an assessment of knowledge levels and medical awareness among healthcare personnel regarding the medical management of real and suspected over-exposures to DE systems and the consequent medical implications.

Such a survey is timely as an assessment of the need to upgrade the quality of training of our military medical personnel regarding DE and the resulting effects upon tissues and behavior. Questionable reports and perceptions on these topics persist in the media and in military healthcare communities. DE technology-precipitated reactions of a few individuals could have a psychological impact on an entire unit if unit members are ill informed about potential DE hazards and health risks. Stress can result from acute anxiety or fear of unknown risks. Distraction from mission priorities may increase risk for other battlefield injuries. Negative attitudes and misperceptions may directly affect injured troops' access to care and their medical care, processing, and disposition with regard to DE exposures. The 21st Century battlefield demands medical personnel be vigilant and committed to documenting issues regarding DE over-exposures and injury observations (Scholl & Moreno, 2002). Emerging DE systems will impact Force Health Protection requirements, delivery of combat medical care, and the conservation of combat manpower. As DE technology advances, so must medical assessments and treatment techniques (U.S. DoD, 1998).

## **2.0 METHODS, ASSUMPTIONS AND PROCEDURES**

This study was intended to capture the need to strengthen medical education and training about DE systems and their bioeffects (Scholl, Peterson, & Moreno, 2003). The method employed was to use a simple survey instrument dealing with DE concepts and administered to a sample of military medical personnel. It was assumed there would be gradations of knowledge about DE concepts among different medical specialists so we chose to construct the survey instrument with items of varying complexity. Our procedure was to obtain authorization to administer the instrument to volunteers, to take advantage of administrative or training events where volunteers could be recruited, and then administer the instrument without disrupting the primary activities of the volunteers' units of assignment.

### **2.1 Subjects**

One hundred and seventy active duty and reserve Army, Navy, and Air Force healthcare personnel volunteered to participate in a 25-question, DE-knowledge survey. Volunteer survey participants were recruited from joint and

deployable environments including the Defense Medical Readiness Training Institute, the Naval Operational Medicine Institute, the Naval Reserve Fleet Hospital Dallas, and the USAF School of Aerospace Medicine. Represented were a broad spectrum of military medical personnel in terms of rank/grade (O-9 to E-3) and specialty area of study. This sample was not necessarily proportionate to the distribution of rank/grade/specialty across the entire military medical population. Survey participants included doctors, nurses, nurse practitioners, physician assistants, corpsmen, and military medics. Participation included some face-to-face volunteers as well as electronic survey volunteer participants.

## 2.2 Survey Instrument

The 25-item survey questionnaire took about 10 minutes to complete. True-False survey questions were randomly distributed. Nine questions were categorized as "basic" level questions, eight were moderately difficult, and eight difficult or advanced. The DE survey questions are presented in Appendix A and the correct responses are in Appendix B. AFRL/HED specialists (both medical and non-medical) in life sciences research with directed energy helped refine the questionnaire.

## 3.0 RESULTS

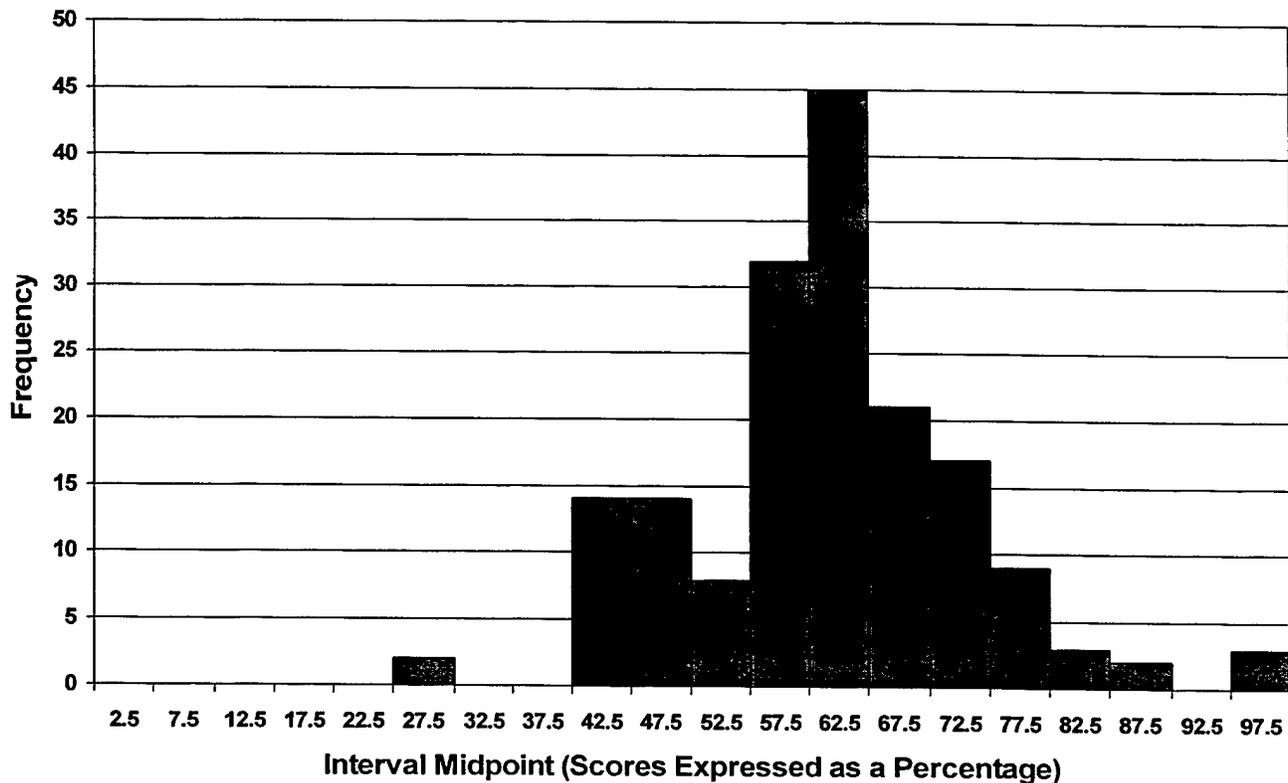
### 3.1 Healthcare Worker Accuracy

Table 1 presents the summary descriptive statistics for the survey results. Number of correct True/False responses could range from 0 to 25. Scores were recast as percentages and participant scores ranged from 28% to 100% correct.

**Table 1. Test Score Statistics**

	Raw	Percentage
Mean	15.25	61.00
Std. Dev.	2.91	11.70
Std. Error	0.22	0.90
Maximum	25	100
Minimum	7	28
Cases	170	170

The frequency distribution of percent correct is shown in Figure 1, which demonstrates a fairly wide range of performance as well as a modal level of performance of around 60% correct.



**Figure 1. Frequency Distribution of Survey Scores**

### **3.2 Item Analysis**

Using the number of correct answers as the indicator of item difficulty, the following results emerge. Remember, chance would produce 50% correct. The five most difficult items, with percentage of correct answers in parentheses, were: Question 2 (20.0%), Question 13 (20.6%), Question 20 (22.4%), Question 9 (41.2%), and Question 17 (41.8%). The five least difficult items were: Question 7 (80.6%), Question 3 (81.8%), Question 22 (82.9%), Question 14 (84.1%) and Question 18 (91.2%).

### **3.3 Informal Subjective Comments**

Discussion with participants upon completion of the questionnaire reveals high interest in DE concepts and medical implications of these technologies. Some participants relate no prior training, education, or experience with portions of the electromagnetic spectrum used by some emerging DE systems. Some acknowledged that medical readiness training concurrent with deployment of new DE technologies would provide a positive stance for Force Health Protection delivery and continuity of healthcare services.

## **4.0 FINDINGS, RECOMMENDATIONS, INITIAL CORRECTIVE ACTIONS**

The knowledge level about DE, demonstrated by the 170 military medical participants in this study, reveals that military healthcare personnel as a group know very little about this subject. Military medical personnel have insufficient understanding of portions of the electromagnetic spectrum having potential military utility. Military medical personnel are unfamiliar with basic human bioeffects and occupational and environmental exposure risks from emerging DE systems. Military medics must become more familiar with electromagnetic spectrum basics and dosimetry measurements if they are to effectively fulfill their combat support roles. This study provides evidence sufficient to serve as a simple needs assessment regarding military medical personnel training needs regarding DE effects and medical readiness implications. Those training needs should be addressed promptly with immediate attention given to disseminating basic information on DE to medics and also linking the military medical community to information sources for DE Military Lessons Learned (MLL).

### **4.1 Upgrade Medical Readiness Training About DE**

Military medical readiness necessitates development of on-time, DE casualty care policies, protocols, and treatments. Increasing presence of DE systems on the modern battlefield elevates hazards to military personnel from intended and accidental exposure to DE beyond permissible exposure limits (PELs). In the future, should civilian settings experience increased risk for DE injury, pertinent military medical readiness DE knowledge can transfer to civilian agencies. As DE technologies advance so too must assessments and treatment techniques. To ensure medical personnel proficiency some useful features of medical readiness training about DE would include:

- Relevant PELs and parameters of over-exposure
- Key dosimetry concepts and practices
- Differential effects of range, power density, and duration of exposure
- DE interactions with human tissue
- Emergent occupational health hazards and weapons
- Skills to conduct field assessments and treatment
- Access to Air Force Research Laboratory/Human Effectiveness Directorate subject matter experts
- Links to DE knowledge database for known exposure bioeffects
- DE medical risk management plans

Modalities for the training program should take advantage of contemporary training alternatives like computer-based training (CBT), both online and with CD-ROMs. Traditional schoolhouse training blocks are needed for basic and technical level courses for the medical corpsman and technicians of all the services. Similar blocks of instruction should be immediately implemented in service medical professional schools for flight surgeons, dermatologists, and visual system specialties.

## **4.2 Some DE Basics for Medics**

Appendix C contains a visual aid taken from MicroWorlds Web site (2001) to facilitate comprehension of the various regions of the electromagnetic spectrum, the parameters for permissible exposure limits, over-exposure parameters, and DE bioeffects. DE origin and manner of interaction with matter are important to understanding outcome bioeffects. Human bioeffects of DE exposure depend on the frequency, duration, surface area exposed, and the power density. DE bioeffects may be nil, transitory, cumulative, detrimental, irreversible or even fatal (DeFrank, Bryan, Hicks, & Sliney, 1993). The radiofrequency range of the electromagnetic spectrum extends from about 10 kHz to 300 GHz (Durney, Massoudie, & Iskander, 1986). The radiofrequency radiation range includes very low to very high frequency radio waves to microwaves. The frequency interface between millimeter waves and infrared lasers includes emerging DE technologies (Adair, 1999) and will be significant in the assessment of over-exposures and injuries from emerging DE weapons technologies.

## **4.3 Engage & Enhance DE MLL**

Changes to Force Health Protection strategies have occurred as a result of MLL from the Gulf War and recent conflicts. Force Health Protection supports war-fighting commanders with a fit and healthy force (U.S. AMEDD, 2003). Force Health Protection strategies anticipate that emerging technologies will greatly impact all branches of the military services and their war-fighting capabilities. A healthy, fit force requires military medics collaborate with developers of military materiel in order to manage potential health hazards associated with emerging weaponry (Berardocco, 1998).

On-time risk communication of DE threat information is critical (U.S. NEHC, 2003). DE information and education must be readily shared and accessible to frontline medics pre-deployment, while deployed, and post-deployment. MLL programs developed by each of the services collect information and observations about healthcare episodes in operational environments. Some of these programs include a live database documentation format that can lead to changes in medical care, doctrine, organization, training, materiel, leader development, personnel, facilities, and scientific research. Such online resources include links to other applicable information (Freer, n.d.). MLL programs provide structured reporting processes that facilitate documentation and uncover hidden issues in operational environments. An integrated, enhanced MLL database is needed to report DE over-exposures, injuries, and observations (U.S. JFCOM, n.d.). A centralized and integrated joint service communication network for lessons learned could enhance medical protocol and treatment development for DE injuries. Data obtained could provide valuable bioeffects information on energy sources for Force Protection, casualty care, researchers, and weapons developers. Appendix D contains a useful list of links to some MLL Centers.

## 5.0 CONCLUSION

This study identifies areas for strengthening the education and training of joint service medical personnel. Insufficient knowledge about DE effects on humans should be a major concern for delivery of medical care on the 21st Century battlefield. The Defense Medical Readiness Training Institute (DMRTI) is readily positioned to fulfill this unmet medical readiness training need. The Directed Energy Bioeffects Division within the Human Effectiveness Directorate of the Air Force Research Laboratory is manned with subject matter experts to support DMRTI with development of DE medical training programs. The partnership of these two Defense entities and their research and education allies (e.g., USAF School of Aerospace Medicine, Naval Health Research Center Detachment) provides an ideal means to overcome the education and training challenge this study has identified. Objectives for this partnership might include:

- Continuously share data
- Establish and maintain communications/support for medical training
- Provide subject matter experts for consultation
- Establish/support medical management tool for directed energy casualties
- Establish network/liasons with appropriate civilian and military agencies

DE systems are emerging now. Timely threat assessment and risk communication of DE hazards to warfighters' health will support missions across the full spectrum of conflict (U.S. NEPMU, 2004). There is significant potential for a negative impact upon individuals and units from DE over-exposures if medical personnel fail to accurately recognize, assess, provide emergency care, and appropriately refer the injured. Military healthcare personnel need to possess appropriate security clearances to access information on emerging DE technologies. Misdiagnosis of DE casualties can lead to unnecessary attrition of warfighters from a military unit. Therefore, military healthcare providers must know where and how to access subject matter experts on DE systems and effects. On the other hand, accurate diagnosis and management of DE casualties can minimize deleterious effects of exposure on individuals and on the capabilities of military units.

For the foreseeable future, subject matter experts in human bioeffects and medical management of hazards must be incorporated early on into all DE weapon development programs.

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**APPENDICES**

**Appendix A – Directed Energy Concepts for Medical Professionals (Survey)**

## Directed Energy Concepts for Medical Professionals

1. - Peak destructive interference occurs with two waves directly out of phase.  
T F
2. - Ultraviolet radiation is a primary cause of retinal actinic effects in the human eye.  
T F
3. - Nonionizing radiation transmission devices (such as cellular telephones) are not scientifically and reproducibly proved to induce tumors.  
T F
4. - Amplitude of an EM field from multiple sources is dependent upon the wave phases. T F
5. - Electromagnetic radiation is measured by dosimetry.  
T F
6. - Field triage tests for suspected electromagnetic frequency (EMF) (radio &/or laser) injuries includes visual acuity (VA's) and the Amsler Grid.  
T F
7. - Medical management of suspected electromagnetic frequency (EMF) (radio &/or laser) ophthalmic injuries requires field triage and evacuation for physician/PA evaluation and treatment as indicated by the field tests.  
T F
8. - Nuclear streaming is characteristic of both electrical and radiation burns.  
T F
9. - Transmission devices, such as cellular telephones, are scientifically and reproducibly proved hazardous near flammable substances.  
T F
10. - UV and blue-light injuries are predominantly thermal.  
T F
11. - Electromagnetic radiation exhibits either exclusively wavelike or exclusively particle behaviors.  
T F
12. - Monopole antennae radiate in a strictly controlled directional azimuth.  
T F
13. - Retinal burns do not require eye patching.  
T F

14. - Though wavelength dependent, RFR burns are typically more penetrating than an "ordinary" thermal burn.

T F

15. - The intensity of a source decreases with the square of the distance from the source.

T F

16. - Transmission devices such as "radar guns and forward-looking infrared devices" are proved to induce sterility.

T F

17. - The speed of a given wavelength is independent of the index of refraction of the medium within which it travels.

T F

18. - Absorption of energy is a key mechanism by which electromagnetic radiation affects living cells.

T F

19. - Laser and radio frequency injuries from wavelengths outside the visible spectrum likely can induce psychological stress.

T F

20. - Spontaneous Laser emission occurs when an excited system rises to a higher energy state and emits a photon.

T F

21. - Radio frequency (RF) burns are uniform throughout all tissues in the zone of overload exposure in well thermo regulated mammals.

T F

22. - Regardless of whether or not frank injury is noted, any Radio Frequency (RF) exposures starting at  $>5$  X the Permissible Exposure Limit (PEL) require diagnostic ocular exams within 24 hours.

T F

23. - Energy and power are synonyms.

T F

24. - Lasers are capable of forming "shock waves" within tissue.

T F

25. - The crystalline lens of the human eye is highly resistant to thermal damage.

T F

**Appendix B – Answers for Directed Energy Concepts for Medical Professionals (Survey)**

## Answers for Directed Energy Concepts for Medical Professionals Survey

1. - Peak destructive interference occurs with two waves directly out of phase.

**True**

2. - Ultraviolet radiation is a primary cause of retinal actinic effects in the human eye.

**False**

3. - Nonionizing radiation transmission devices (such as cellular telephones) are not scientifically and reproducibly proved to induce tumors.

**True**

4. - Amplitude of an EM field from multiple sources is dependent upon the wave phases.

**True**

5. - Electromagnetic radiation is measured by dosimetry.

**True**

6. - Field triage tests for suspected electromagnetic frequency (EMF) (radio &/or laser) injuries includes visual acuity (VA's) and the Amsler Grid.

**True**

7. - Medical management of suspected electromagnetic frequency (EMF) (radio &/or laser) ophthalmic injuries requires field triage and evacuation for physician/PA evaluation and treatment as indicated by the field tests.

**True**

8. - Nuclear streaming is characteristic of both electrical and radiation burns.

**False**

9. - Transmission devices, such as cellular telephones, are scientifically and reproducibly proved hazardous near flammable substances.

**False**

10. - UV and blue-light injuries are predominantly thermal.

**False**

11. - Electromagnetic radiation exhibits either exclusively wavelike or exclusively particle behaviors.

**False**

12. - Monopole antennae radiate in a strictly controlled directional azimuth.

**False**

13. - Retinal burns do not require eye patching.

**True**

14. - Though wavelength dependent, RFR burns are typically more penetrating than an "ordinary" thermal burn.

**True**

15. - The intensity of a source decreases with the square of the distance from the source.

**True**

16. - Transmission devices such as "radar guns and forward-looking infrared devices" are proved to induce sterility.

**False**

17. - The speed of a given wavelength is independent of the index of refraction of the medium within which it travels.

**False**

18. - Absorption of energy is a key mechanism by which electromagnetic radiation affects living cells.

**True**

19. - Laser and radio frequency injuries from wavelengths outside the visible spectrum likely can induce psychological stress.

**True**

20. - Spontaneous Laser emission occurs when an excited system rises to a higher energy state and emits a photon.

**False**

21. - Radio frequency (RF) burns are uniform throughout all tissues in the zone of overload exposure in well thermo regulated mammals.

**False**

22. - Regardless of whether or not frank injury is noted, any Radio Frequency (RF) exposures starting at >5 X the Permissible Exposure Limit (PEL) require diagnostic ocular exams within 24 hours.

**True**

23. - Energy and power are synonyms.

**False**

24. - Lasers are capable of forming "shock waves" within tissue.

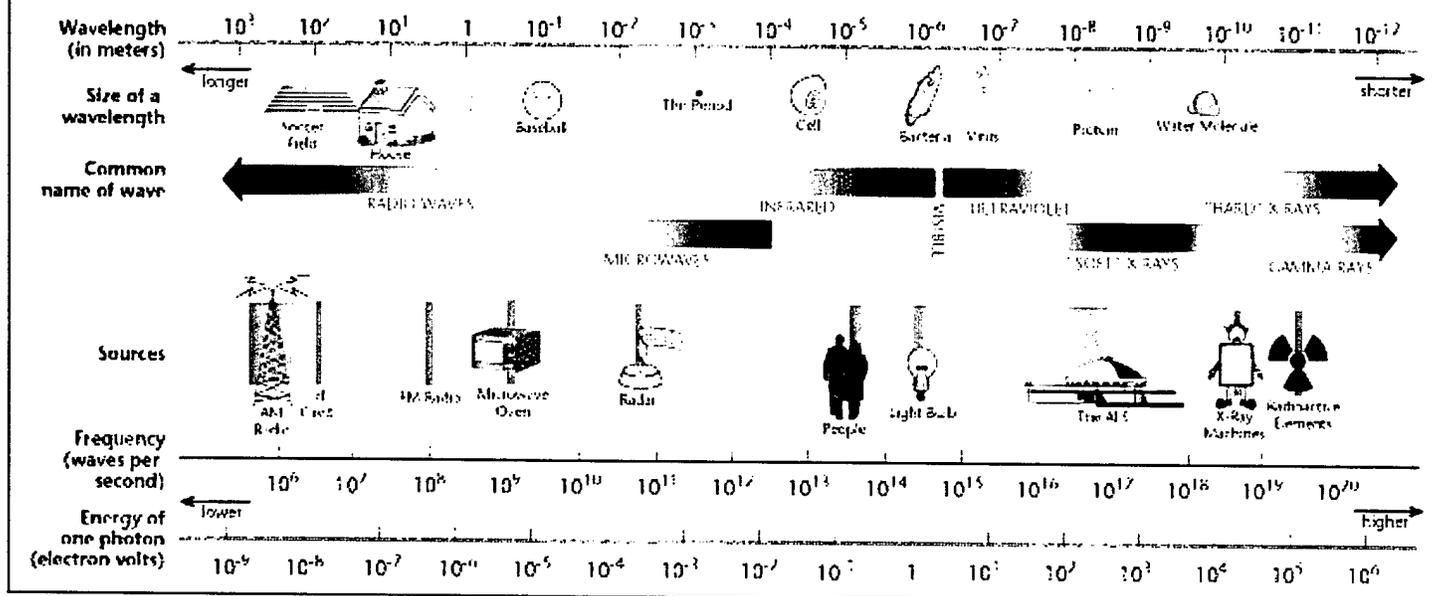
**True**

25. - The crystalline lens of the human eye is highly resistant to thermal damage.

**False**

## Appendix C – Electromagnetic Spectrum

# THE ELECTROMAGNETIC SPECTRUM



**Appendix D – Links to Military Lessons Learned Centers**

DoD Military Lessons Learned  
<http://www.au.af.mil/au/awc/awcgate/awc-lesn.htm>

Navy Lessons Learned  
<http://www.nwdc.navy.mil/NLL/NLL.aspx>

Defense Medical Readiness Training Institute  
<http://www.dmrti.army.mil/home.htm>

Center for Army Lessons Learned  
<http://call.army.mil/>

Air Force Knowledge Now  
<https://afkm.wpafb.af.mil/ASPs/CoP/Entry.asp?>

USMC Combat Development Tracking  
<https://www.cdts.marcorsyscom.usmc.mil/login.nsf/mainlogin?openform>

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