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WEAPON SYSTEMS TECHNOLOGY INFORMATION ANALYSIS CENTER

Progress in Directed Energy Weapons

Part II: High Power Microwave Weapons

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Contents

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Introduction

This is the second of a triad of articles on Directed Energy Weapons (DEWs). The first article by Mark Scott covered High Energy Laser (HEL) Weapons (Vol. 4, No.1, Spring 2003). In the current issue, we will review Radio Frequency (RF) DEWs, most often referred to as High Power Microwave (HPM) Weapons, which constitute the second largest R&D effort in the field. Since there are other possible types of DEWs, (such as Relativistic Particle Beams (RPBs), etc.), we will set forth a few definitions that can differentiate between them, especially with respect to their particular applications and target effects, which bound their usefulness to the warfighters and the platforms they must use for the whole battle space. The output parameter limits placed on the various technologies by the operational requirements and environments will, in turn, produce "design drivers" that will define the total integrated RF-DEW, or HPM, Weapon system. The various types of DEWs will be compared and their programs discussed. A subsequent article will review, what to this time may be called the "Achilles heel," of DEWs, i.e., the usually large and heavy Pulsed Power Systems that are necessary to provide the tremendous power and energy requirements of DEW systems, as well as the power conversion and conditioning components and subsystems between the prime power source and ultimate DEW source and radiator, whether it be laser, microwave or other type of DEW.

RF-DEW/HPMW Background

We all now live in a virtual "sea" of electromagnetic (EM) waves, in the frequency spectrum from the very low, such as those emanating from power lines, through higher frequency radio waves and even higher frequency microwaves. Microwaves radiate from our omnipresent wireless communication devices, like cell phones and their new forest of microwave relay towers, to our supermarket door openers, to low power police "radar guns," and finally to the much more powerful airport ground control radars. Everyone is also familiar with the safety concerns that have been in the news about the effects of all this EM radiation on our various electronic appliances (including our computer-controlled vehicles and aircraft), and especially on our very bodies. Such electronic effects of RF or microwaves on our military communications, radars and control systems have also been thought of as weapons and utilized in that mode since the very first radios and radars made their appearance in WW I and II, respectively.

"Jamming" of enemy radios and radars began almost simultaneously with their invention. Early bio-effects were also studied from the very beginning, and described in Buck Rodgers "Ray Gun" terms, leading to "zapping" of people and objects (the latter term rather abhorrent to HPM researchers, since it is still constantly being used by people who have no idea as to what actually happens to targets under such usually non-harmful radiation!). Serious studies of EM effects, however, especially for the military, has unfortunately only followed from serious deleterious effects that led to major accidents, such as explosions and fires onboard an aircraft carrier in the Vietnam War, where it was subsequently found that high power shipboard radars had set off live bomb fuzes loaded on aircraft, and more recent incidents, such as helicopters being affected by flying near microwave towers. The former led to the Navy's "HERO" tests (for "Hazards of Electromagnetic Radiation to Ordnance"), or similar tests, which are now routinely applied to most military and some commercial electronic systems. Such deleterious effects, however, led also to serious consideration of RF or microwaves as a "weapon" system against the whole range of enemy electronic or electronically-controlled systems when, in the late 1960's and early 1970's, huge microwave pulses were produced in university laboratories, initially as a byproduct of Relativistic Electron Beam (REB) research. Such output microwave pulses in the Gigawatt regime (GW = 1billion watts - large, but very short pulse length) naturally led to the assumption, based on the known microwave effects just mentioned, that a new RF/HPM weapon would have to result - at least, if the tremendous size and weight of the laboratory systems could be reduced.

Forty years later, we are still grappling with the "size" problem, but recent trends in the microminiaturization of electronics on target systems, with their consequent large increases in target susceptibility, have reduced output power requirements for RF-DEWs, while, at the same time, many intensive Service R&D programs have made significant improvements in energy and power density of all necessary components, thereby reducing their size and weight enough for their serious consideration for integration on mobile military land, sea and air platforms. Recent military involvement in peacekeeping and "Operations Other Than War" (OOTW) has also led to a great demand for "Nonlethal" (NL) or "Less-Than-Lethal" (LTL) Weapons, for which RF/HPM Weapons, according to a number of NL Wargames, could play a very important part. This is particularly due to the potential "tunability" of their output power for NL and lethal effects, as well as significant standoff ranges for their use in vehicle stopping, crowd control and other NL applications.

RF/HPM Weapon Requirements and Applications

In general, High Energy Lasers or High Power Microwaves cover a wide range of applications - not all of them weapons:

♦ **Military**

• Defensive: air/missile/point/platform defense - tactical /strategic

• Offensive: air/space/ship/combat vehicle-borne precision strike, SEAD, ASAT, C4ISR/IW - tactical/strategic

• Antipersonnel/antimateriel, lethal/nonlethal

• Counter-WMD/Terrorist IEDs/mines

♦ **Law Enforcement**

• Vehicle/individual pursuit management

• Crowd/riot/prison control, nonlethal

• SWAT

♦ **Commercial**

• Energy production

• Communications, radar, weather

• Medical/surgical

• Semiconductor/chemical/industrial materials/waste processing

The DoD on the other hand, as noted in the military summary above, requires improved capabilities in countering artillery fire, ship defense against cruise missiles, aircraft self-protection, suppression of enemy integrated air defense systems (SEAD), space control, security, counter-proliferation, and disruption or destruction of command, control, communication, computer and intelligence (C4I) assets. All of these requirements can be addressed by HPM weapon systems, which upset or damage the electronics within the target. Although sharing many of the features listed below with HELs, the major advantages of HPM Weapons over HEL Weapons are highlighted and offer military commanders the option of:

♦ Speed-of-light, **all-weather** attack of enemy electronic systems.

♦ **Area coverage** of multiple targets with **minimal prior information on threat characteristics**.

♦ Surgical strike (damage, **disrupt, degrade**) at **selected levels** of combat.

♦ **Minimum collateral damage** in politically sensitive environments.

• Deep magazines (only fuel needed for generators/battery chargers) and low operating costs.

• Works against force-multipliers ("smart weapons")

• O&M similar to radar systems

• Normally **nonlethal** to humans

• Hardening against RF-DEW is rare

• Propagation energy limited only by air breakdown

• Downside - lethality is statistical, with variations among apparently identical targets

Some of these applications are illustrated in Figures 1 and 2.

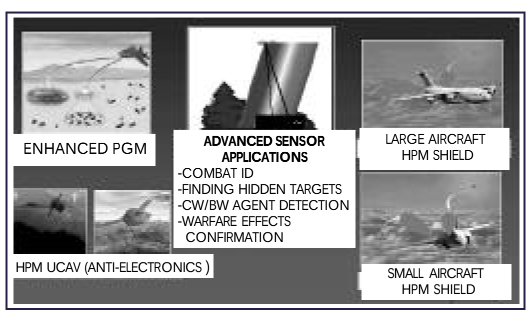


Figure 1. DEW Applications Air Platforms RF-DE/HPM

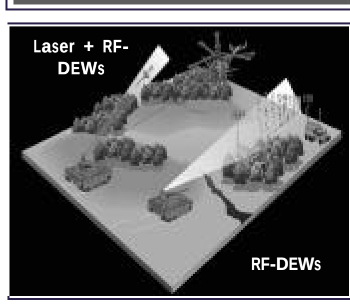


Figure 2. DEW Applications Ground Platforms–Laser & RF

Some Definitions of DEW

So far we have been using the term "Directed Energy" the way most people do - i.e., with only a vague understanding of what it really means, and that mainly through its perceived applications. Some clarification may be had with a few definitions from basic physics, and then perhaps some enlargement of the term:

- ♦Directed
  - To point or move a thing toward a place
  - Aim
- ♦Energy
  - The capacity to do work (force x distance)
- ♦Weapon
  - Any means of attack or defense

Such definitions lead to a broader interpretation than normally thought of DEWs:

- ♦*Present* DEWs normally include only sources that are elec tromagnetic in origin: Laser, Particle Beam and Radio Frequency/High Power Microwave (HPM)
- ♦Directed Energy Weapons (DEWs), however, are devices which destroy/defeat targets using radiated waves *or* beams of microscopic particles
- ♦*Future* DEWs may include other than electromagnetic sources, such as Acoustic Waves (from infra-to-ultrasonic) or other Fluid/Particle structures (such as Vortex Rings)

From the above definitions, further differentiation among DEW types follows:

- ♦High Energy Laser (HEL) weapons - use beams of electro magnetic radiation with wavelengths *usually* in the infrared
- ♦High Power Microwave (HPM) weapons - radiate electro-magnetic energy in the high RF spectrum
- ♦Charged particle beam (CPB) weapons - project energetic charged atomic or sub-atomic particles, *usually* electrons

RF-DEWs and Electromagnetic Warfare

Because "jamming" was mentioned earlier, this would be a good time to compare conventional Electronic Warfare (EW) with RF/HPM-DEW applications. Some more definitions will help to clarify the situation, where it will be seen that RF/HPM and DEWs in general (by military standard) all come under the umbrella of EW:

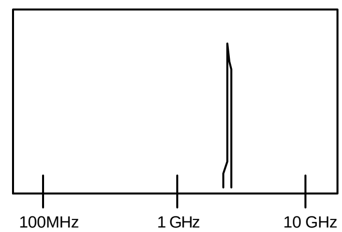
- ♦Electronic Attack (EA) - a subdivision of EW
  - CJCS Memorandum of Policy (MOP) No. 6, Mar 93
  - EW: Any military action involving the use of EM **and** DE to control the EM spectrum or to attack the enemy. Three major divisions within EW are Electronic Attack (EA), Electronic Protection (EP), and Electronic Warfare Support (EWS)
  - EA: That division of EW, involving the use of EM or DE to attack personnel, facilities, or equipment destroying enemy combat capability, includes:

1. Actions taken to prevent or reduce an enemy's effective use of the EM spectrum, such as jamming and EM deception
2. Employment of weapons that use either EM **or** DE as their primary destructive mechanism (lasers, radio frequency (RF) weapons, or particle beams)

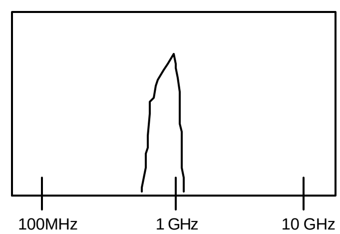
Because of the much higher powers produced by HPM Weapons over EW sources, however, a characteristic set of output radiation parameters for HPM is usually taken to be :

- ♦Peak power levels ≥ 100 MW
- ♦Pulsed energy ≥ 1 joule per pulse
- ♦NB freq. Usually 1 to 35 GHz
  - $\Delta f < 10\ \%\ f0$
- ♦WB/UWB freq. Usually 0.01 to 2 GHz
  - $\Delta f > 10/25\ \%$ of the mean frequency

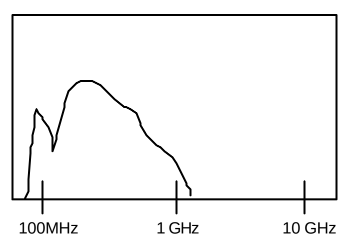
Where NB = Narrowband, WB = Wideband and UWB = Ultra-wideband are defined and illustrated in Figure 3 below:



Narrowband: Traditional RF systems which have a well-defined frequency which is above 300 MHz and below 300 GHz, usually between 1 GHz and 35 GHz, with a frequency



Wideband: RF systems in which the frequency bandwidth is greater than 10% of the carrier frequency.



Ultra-wideband (UWB): RF systems with bandwidth greater than 25% of the mean frequency (e.g., a system which extends from 100 MHz to 1 GHz has 900 MHz bandwidth and 550 MHz mean frequency).

Figure 3.

Wideband or Ultra-wideband RF is of interest (and at one time thought to be the ultimate panacea!) because it is not necessary to know the optimum frequency to attack the threat, since a UWB pulse usually contains at least one narrow frequency band that will couple to the target. However, the power at any given frequency, given that the energy in the pulse is spread over such a broad range, is usually so much less for wideband, that narrowband is much more efficient if a narrow optimum frequency range is known.

The EM Spectrum is shown for convenience in Figure 4 below, so that the various RF weapon regimes can be located relative to the rest of the spectrum:

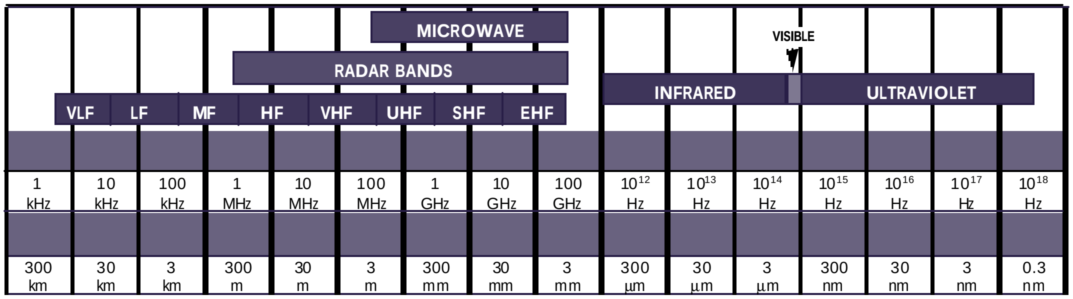


Figure 4.

At this point, we also need to differentiate RF-DE, or HPM, from EMP, or Electromagnetic Pulse, since the terms are quite often used erroneously to mean the same thing. EMP can either be Nuclear or Non-Nuclear generated (NEMP or NNEMP), but:

♦ Phenomenological Differences

- Nuclear EMP is single-shot while HPM, both narrowband and wideband, may be repetitively pulsed.
- Frequency regimes differ so that resonant coupling of ener gy into the target occurs at different characteristic lengths. Some aspects of both nuclear EMP and narrowband HPM, however, also apply to wideband RF.
- Nuclear EMP occurs in the frequency range from DC up to 100 MHz, thus only going *up to* where RF UWB signals *begin* (Figures 3 and 4).

RF-DEW Effects, Effects Assessments and Operational Capabilities

The main differences between all of the above various EM weapon spectral bands really become evident, however, in the *effects* of EW or DE on their military targets:

♦ Traditional EW or electronic countermeasures (ECM)

- Target effects do **not** persist when the EW system is turned off or directed elsewhere
- EW systems are generally designed to exploit specific tar get system features "in-band," at low power levels (e.g., "fre quency hoppers")
- EW generally requires significant intelligence on detailed design of target system - so that they can bring their very spe cialized signals to bear

♦ DEW (especially RF-DEW) systems produce "burnout"(perma nent) or "upset" interference effects that are less target-spe cific and/or require less target intelligence information

- Upset effects **persist after** the DEW system is turned off
- Target effects may be **either** in-band or "out-of-band"
- Effects are produced by **much higher powers at target**

In actual practice, however, the above parameter ranges vary widely, especially depending on the application and actual target susceptibility values - which, as noted earlier, are decreasing rapidly, due to modern microelectronics being included in target systems (see Figure 5, 6). The target effects are characterized in terms of the following:

♦ Probability of target failure curves (Figure 7)

- Give probability of failure vs range and source parame ters(including antenna gain) for radiated concepts
- Main input parameter is measured fluence vs. frequency

♦ "Footprint" is area of effect for mission kill (Figure 8)

- Footprint depends on slant range for given source level and antenna gain for radiated concepts
- Coverage for Direct Injection (DI)/Induction concepts (i.e., by wires, rather than antennas) are limited to a fixed area of the target

♦ "Time-on-target" depends on level of effects

- Whether effect is "nonlethal" can depend on "on-time"
- Target could be affected only while being illuminated, or for much longer if more serious "upset" occurs

♦ Operational feasibility paramount

- Each basic concept type could have unique uses

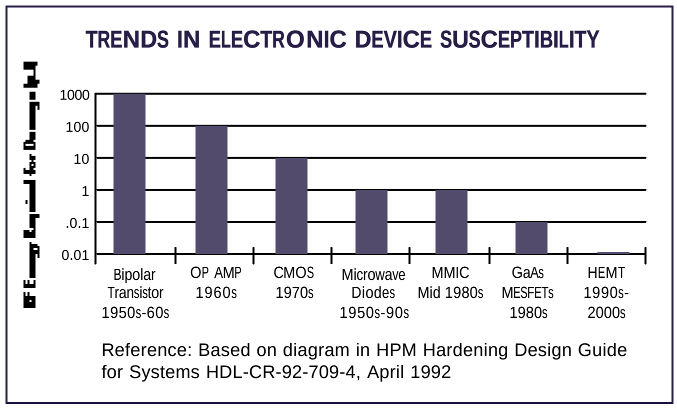


Figure 5

HELICOPTER TEST BED
- MISSION CRITICAL ELECTRONICS -

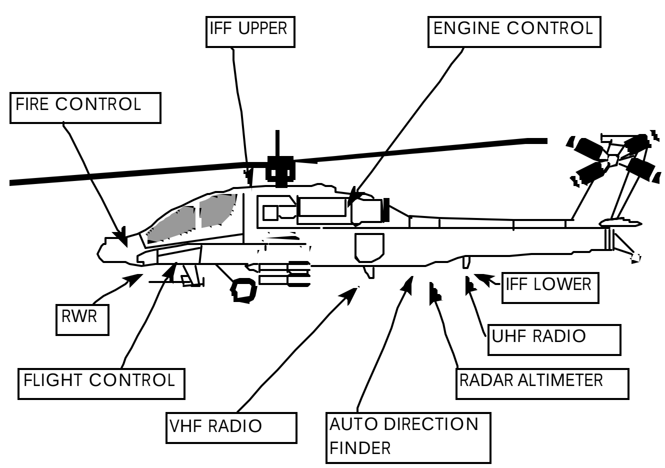


Figure 6

DEW TARGET EFFECTS OPERATIONAL CAPABILITIES

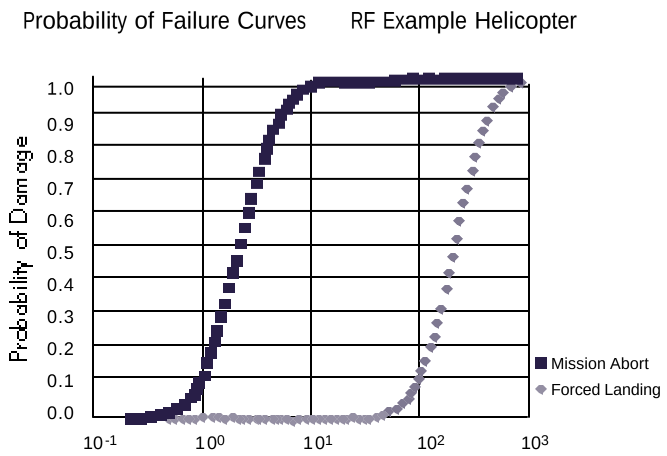


Figure 7

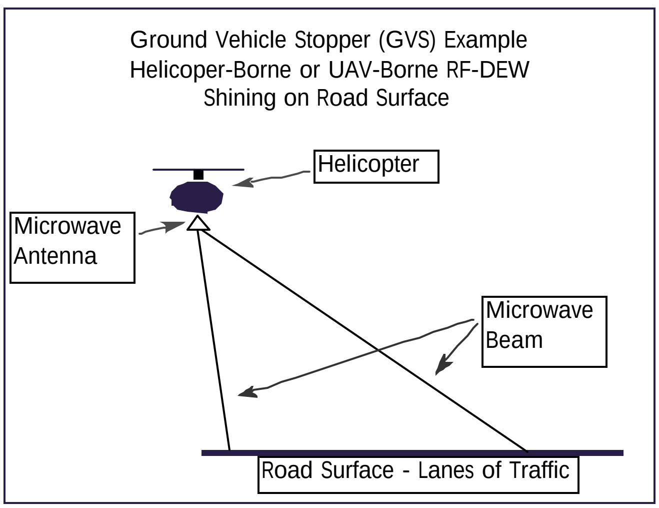


Figure 8.

DEW TARGET EFFECTS

DE SOURCE	WAVELENGTH	ENERGY COUPLING	PROPAGATION SENSITIVITY	LETHALITY
HIGH POWER MICROWAVES	0.1 cm - 3 m	INTERNAL ELECTRONIC COMPONENTS	LOW	ELECTRONIC UPSET, BURNOUT
HIGH ENERGY LASERS	0.27 μ - 10 μ	EXTERNAL MATERIALS	HIGH	THERMO-MECHANICAL STRUCTURAL DAMAGE
PARTICLE BEAMS	PRF	INTERNAL ELECTRONIC COMPONENTS & MATERIALS	VERY HIGH	ELECTRONIC UPSET, BURNOUT, THERMO-MECH-CHEM DAMAGE
ACOUSTIC	0.1 cm - 33 m (0°C@SEA LEVEL)	INTERNAL ORGANS, ELECTRONIC/ MECHANICAL COM-PONENTS	HIGH	PHYSICAL DISCOMFORT/DAMAGE, ELECTRONIC/MECH DIS-RUPTION
VORTEX	PRF	INTERNAL/ EXTERNAL	VERY HIGH	MECH/CHEM/INTERNAL ACOUSTIC

Figure 9.

As noted earlier, target effects experiments determine overall target susceptibilities and ultimately, target vulnerability, via an Assessment Methodology worked out by all three services over many years, which is summarized in Figure 9. From the effects data, one can then work "backwards" to determine RF-DE Weapon output parameters, if one knows the range requirements for the mission application (including the usual EM "one-over-R-squared" beam spread and the atmospheric absorption losses), again, as shown schematically in Figure 10.

RF-DEW LETHALITY METHODOLOGY

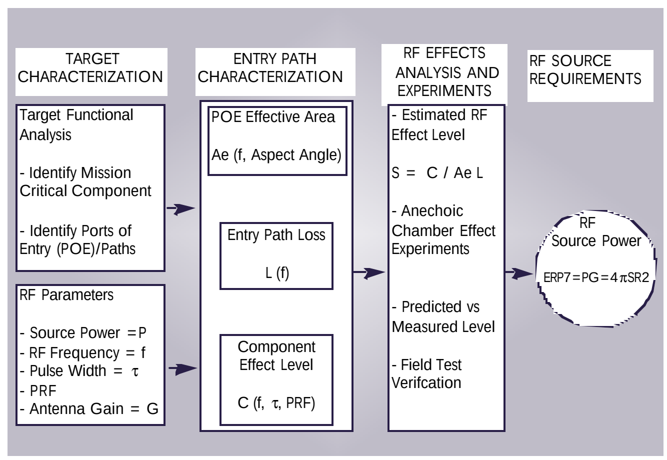


Figure 11.

TRI-SERVICE HPM ASSESSMENT METHODOLOGY

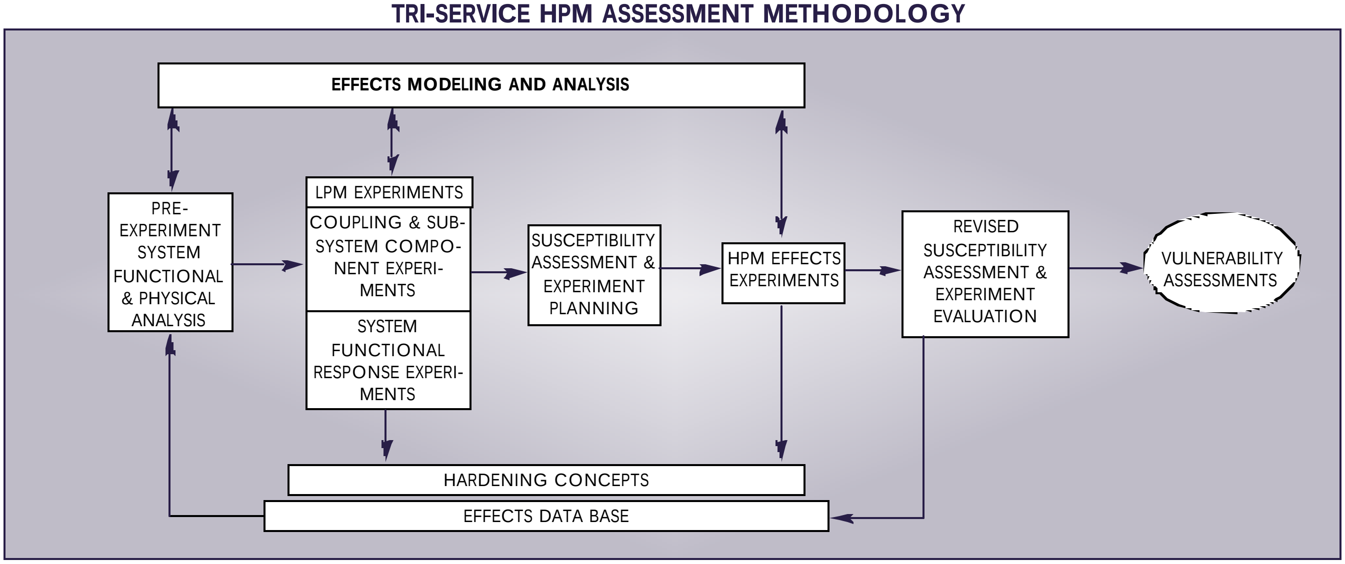


Figure 10.

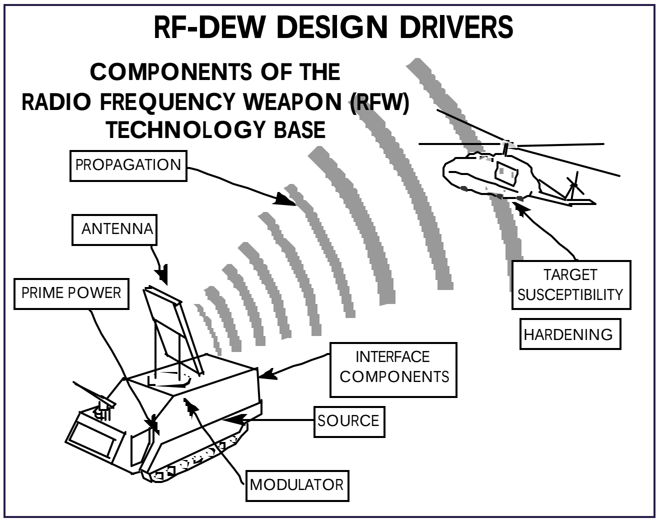


Figure 12.

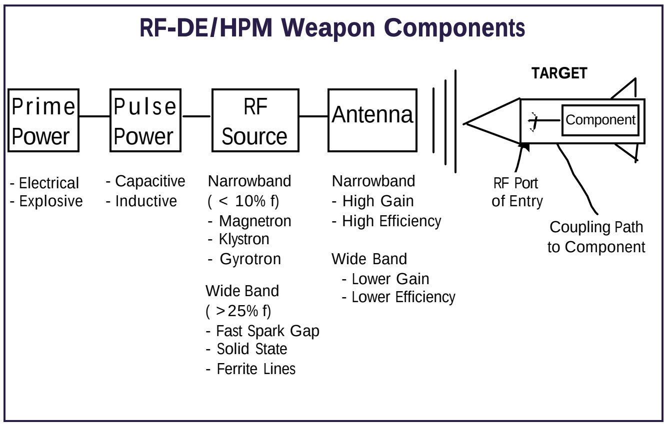


Figure 13.

These RF-DEW Source power, frequency, pulse-length and pulse repetition rate output parameters will then determine prime and pulse power requirements, and hence, how such a system can be integrated onto a military platform. These are the "design drivers" referred to earlier, and which are illustrated schematically in Figure 11, while the RF-DEW/HPMW system building blocks or components are shown in Figure 12.

RF-DEW Components, Systems, "Desirements" and Developments

As shown in Figure 13 above, for RF-DEWs, the antenna is a key technology component that, in large measure, contributes as much to the HPM output pulse as does the HPM source itself. This is illustrated by the Radar Range Equation, which also gives the "1/R^2" range dependence of the power referred to above:

$$P_{target} = \frac{P_{source}\, Gain}{4p\ Range^2}$$

Note the "Gain" provided by the antenna is on an equal footing with the source power in putting power on the target. If the pulse power subsystem was previously called the "Achilles Heel" of DEW systems, then, because antenna gain is directly proportional to its physical area (or square of the diameter), one could also describe the antenna as the "Achilles Nose." This is because physics tells us that, if we want a very compact RF-DEW system, we must come up with alternative ways to provide for large antenna areas on weapons platforms, if we want a narrow, "pencil beam" or long range (high gain) capability. There are many such configurations under investigation, as illustrated in Figure 14, showing how one could reduce the impact of a conventional design antenna with some ingenuity in packaging (14a), or look at alternative configurations (14b), such as trading area for length, as in dielectric rods, or perhaps the ultimate solution, where one uses solid state sources in an array, where they would provide the antenna as well. The latter would allow for conformal mounting to, say, a UAV body and wings, which would also have the very desirable advantage of electronic, rather than mechanical beam steering.

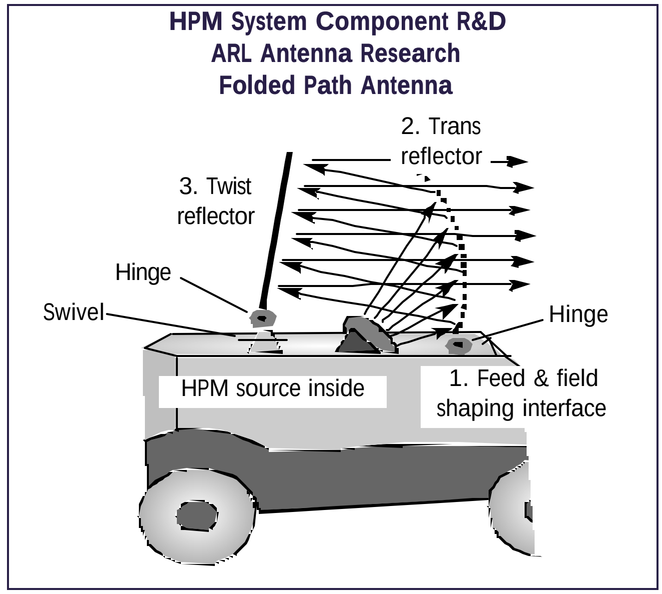


Figure 14a.

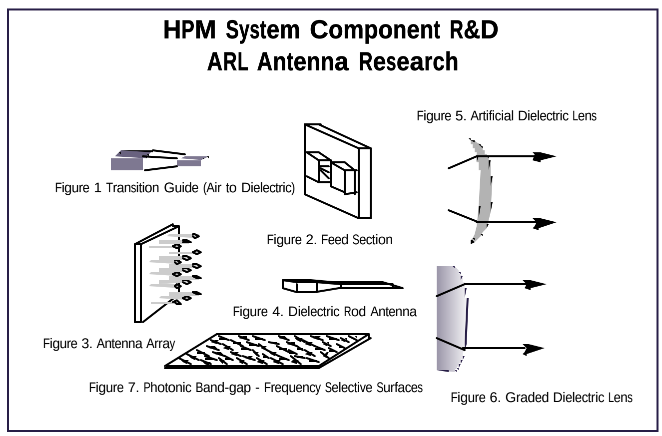


Figure 14b.

Perhaps, in part because of the (at least perceived) intractability of reducing the size of the "Achilles Nose" of the antenna, but most likely because that's where HPM got its start-when GW-level signals were first produced-the HPM *source* has garnered the largest share of the R&D funds of all the components in the whole HPM system. We have discussed the relative merits of both WB, UWB and NB waveforms on various targets. Unfortunately, each type of waveform also requires its own specialized RF/MW source as well, there being no "generic" source that can generate all these waveforms equally well (although the solid state array just discussed may ultimately be able to do just that-giving that all-important "tunability" required for application to all targets). Thus, the "Desirements" for a "best of all worlds" source would have the following features:

Desirable Features for a Hypothetical "HPM" Source

- Frequency tunability
  - Maximizes flexibility, hard to protect against
- High efficiency
  - Minimizes prime power and cooling requirements
- Minimal external component requirements (e.g., cooling, magnetics)
  - Minimizes system weight and volume
- Ability to accommodate complex RF modulations
  - Increases probability of effect at lower power or longer range (but requires more detailed knowledge of target)
- High peak or average power (depends on target susceptibil ity and operational scenario)
  - Increases stand-off range and/or probability of effect
- Relatively low voltage
  - Minimizes power conditioning volume, x-ray production
- Rep-ratable
  - Longer target exposure, higher total energy delivered to tar get

Unfortunately, in the HPM regime of high power, there are virtually no "commercial-off-the-shelf" (COTS) microwave sources, as can be seen in the comparison of the regime of HPM vs. lower power commercial RF sources in Power-Frequency-Pulse Length-Duty Factor space shown in Figure 15 below:

Domains of Application
Single Device Peak Power Performance Limits

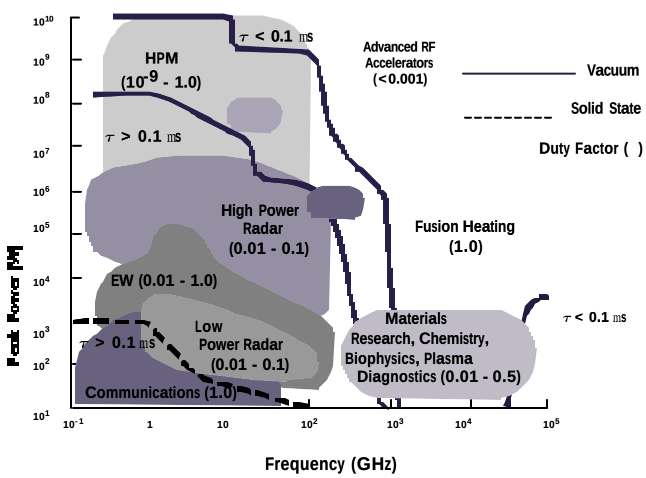


Figure 15.

The reasons why there aren't more COTS, much less even custom made military HPM sources available, are mainly the following:

- Industrial interest in high power military tube development is low due to a perceived lack of high volume sales potential
- - Military applications have unique requirements with few commercial spin-offs
- Inadequate investment in DoD HPM source technology base
- University research waning due to cuts in DOE and DoD funding

Despite the declining industrial base in HPM sources just described (which is a critical problem in many DEW components areas--even in the well funded HEL field), there are still major programs being pursued, with each application requiring its own specialized HPM source (all tubes at this point), each of which, of course, also requires its own separate development program--in order to meet the system specifications requirements. The major applications and their attendant programs (some of which are covered in DoD Defense Technology Objectives (DTOs)) are summarized in Figure 16:

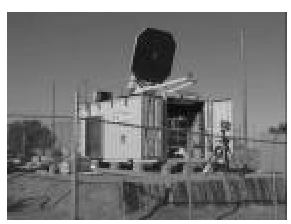
US DEW Development

DEW Type	Laser	HPM	CPB
Beam type	IR photons	RF radiation	Electrons
First deployment	Near term	Near term	Far term
Lethal mechanism	Thermal Deposition	Upset or damage electronics	Initiate explosives
Typical targets	-Missiles -Satelites	-Missiles -Electronics	Explosive material
Typical range	Few km to 1,000s of km	100s of m to 100s of km	Up to few km
Focus of current US development programs	Airborne Laser (ABL) for TMD Ground-Based Laser (GBL) ASAT Multimission Space-Based Laser (SBL) Tactical High Energy Laser (THEL) Aircraft self protect	Command and control warfare; Information warfare (C2W/IW) Suppression of Enemy Air Defense (SEAD) Active denial technology (ADT) Protection of US systems	No current program

Figure 16.

In the list of applications above, several HPM programs that have gotten a lot of attention recently include the "Active Denial Technology" (ADT), "E-Bomb" and Ground Vehicle Stopper (GVS) programs, illustrated in Figures 17-19.

AFRL Active Denial Technology (ADT)



ADT Test Source

ADT Vehicle Mounted Concept

Figure 17.

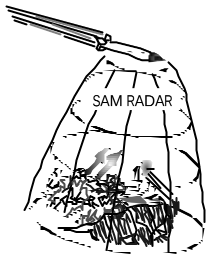


Figure 18.

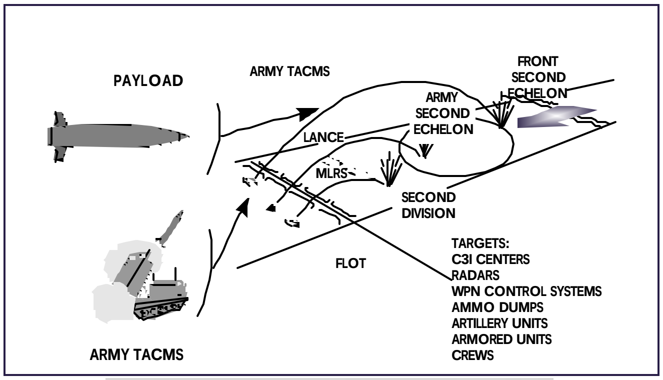


Figure 19.

Active Denial Technology (ADT) refers to the use of HPM in the millimeter-wave (mmw) region of the microwave spectrum in an anti-personnel role. All of our previous discussion so far has centered on the use of HPM in its most common application as a counter electronics weapon - while still pointing out its "nonlethal" aspects; i.e., as normally safe for humans - both operators and those in the target area of effects (or "footprint" as defined earlier). In the case of ADT, however, mmw are used specifically to interact with human targets in a deterrence - but still to be emphasized - *nonlethal* role, for use in single individual or crowd-control applications.

The reason ADT utilizes mmw signals is because of their limited penetration power on the subject's surface skin area. This is a use of the electromagnetic (EM) term "skin effect" in the true sense of the word: in EM theory, the term refers to the penetration depth of EM waves through the surface area of an electrical conductor, the "skin depth" being inversely proportional to the square root of the frequency and the conductivity of the target surface. Thus, high frequencies (or short wavelengths), such as mmw, penetrate very little (about a 64th of an inch) into a conducting surface like human skin. The impinging EM wave then induces surface currents in this very thin conducting layer, which in turn heats the surface, as determined by Ohm's law of electrical resistance. Because of the high power of the mmw pulses in this case; the heating is very rapid - exciting the nerve endings that are just at that depth - eliciting the "hot stove" response from the human subject. However, because the pulses are very short and delivered in a similarly short pulse "burst," there is no permanent injury (worst case being similar to a mild sunburn), as long as the subject does not stay in the mmw beam for long periods. This, he will be seriously disinclined to do - hopefully, thereby eliciting the desired response by the operator, such as dropping a weapon or ceasing otherwise threatening behavior, or running away, or probably all of these things at once.

The second HPM application receiving a lot of press lately is sometimes referred to (at least in the press) as the "E-Bomb" (see the references at the end of the article). In our recent "TV wars," the public at large has gotten used to very few or zero casualties, and a "perfect" weapon would go that one better and not even harm civilian infrastructure, such as buildings, bridges, etc., leaving them intact as well. This is the promise of an explosive-driven HPM or RF "Hybrid" Warhead (RFW) that can be placed on a bomb, artillery shell or missile that would explode high above the target, and only affect the target's internal electronics, such as those mentioned in the target sets in Figures 16 and 18.

Several advantages accrue from the use of a remotely delivered RFW, including:

- Fratricide avoidance (delivers HPM radiation close to the target and away from friendly, electronics-rich US systems)
- Explosive pulse generators providing the prime power can be very compact (witness the size of the artillery/bomb/missile platform in this case)
- Hybrid (explosive/RF) effects are possible (i.e., conventional explosives may not totally take out certain targets - e.g., antennas on an enemy missile command and control (C2) site can be hit by anti-radiation missiles (ARM), but the C2 station itself often escapes damage, since it is remote from the antenna - but the C2 can be damaged by the HPM effects on its internal electronics)
- Downside is that most RFWs are single-shot, i.e., allowing only one HPM "pulse-burst" on the target, whereas conventional HPM effects data show a much greater probability of target lethality with repetitive pulses

The third HPM program mentioned above, the Ground Vehicle Stopper (GVS - see Figure 19), initially began as a nonlethal pursuit management technique for law enforcement agencies (LEAs - see the National Pursuit Management Task Force Report in the references at the end). Normally, one thinks of nonlethally or nondestructively ending high speed chases, which very often ended in crashes and fatalities of innocent bystanders, but one could also envision stopping *low speed* chases as well (recall the long, drawn-out O.J. Simpson live broadcast pursuit). A more immediate military application of this technology is the urgent need to utilize the long-range capabilities of the technique to stop potential suicide car bombers, who may have run through a conventional checkpoint, at sufficient standoff to allow a safe detonation of the subject in a controlled area. It is indeed unfortunate that an existing, demonstrated technological solution has been available for some time, and has not been used to save soldier's lives in our current foreign theaters of conflict.

The GVS technique works by utilizing the HPM susceptibilities of modern Electronic Engine Controls (EECs), which already have to be shielded against the "sea" of microwaves in our environment mentioned earlier, but also to protect itself from its own engine EM interference (EMI) emissions from spark plug wires, etc. It has been demonstrated by a number of investigators that properly

continued on page 10

Director's Corner

by Mr. Gary J. Gray

Ladies and Gentlemen:

Welcome to my second newsletter as Director. Let me first admit that I did not deliver on my promise last month to solicit your feedback to better serve you. I underestimated the time it would take to develop the questions and set up a web-based application. We are trying to make it as easy as possible while taking the minimum amount of your valuable time. We are hoping to get it done in the next newsletter, which we plan to get out early in the next calendar year.

There is one specific area of concern to the Department of Defense that cannot wait. That is in the area of Improvised Explosive Devices (IED). These devices are causing casualties in Iraq. We should be pulling out all the stops to prevent these attacks. It is a difficult problem, especially in an urban environment. However, we should be putting all our brightest minds together to develop countermeasures to identify and defeat these devices long before they have a chance to do anymore harm.

Our chief Scientist, Dr. Ed Scannell, provided some promising ideas to defeat these threats using Directed Energy weapons and concepts. Dr. Scannell's article in this newsletter focuses on the basics of RF-Directed Energy (RF-DEW), usually called High Power Microwave (HPM) Weapons for a number of applications, including IED's, and he has formal submissions based on his previous efforts as Chief of the Army Research Lab's Directed Energy & Power Generation Division, to provide a solution to this important problem. To date, the interest in DE has been increasing, but at this point there is no formal specific effort ongoing to use this technology to solve the problem. We will continue to work this as well as other solutions.

WSTIAC does not own the market on brainpower. We need your help to collaborate on solutions to this very difficult problem. Please provide any ideas you may have to help solve this current life and death issue. Provide your answers via email to my Deputy, Ms. Vakare Valaitis at vvalaitis@wstiac.mil or snail mail at 1901 North Beauregard Street, Alexandria, VA 22311. Classified concepts must be sent via snail mail and will be handled accordingly. Please do not be bashful, even if you are unsure your idea has any promise.

All ideas will get a reasonable consideration. We will forward the ideas to the appropriate individuals within the Department and publish a synopsis of your ideas, where security limitations allow.

Thank you for your consideration and look forward to talking to you in our next quarterly.

Sincerely,

Gary J. Gray
Director

designed microwave signals can perform this duty well within ANSI/OSHA safety standards for human irradiation.

This brings us again to safety standards and safe use of HPM in any environment where either operators or non-intended targets are in either source-field or target footprint HPM fluence areas, respectively. The main issues and conclusions are summarized in the following:

Safety, Policy & Legal Issues

- All system parameters must be designed for safety at opera tor as well as target ends
  - Initial tests show target effect levels below normal safety standards
  - Initial calculations also indicate operator & platform levels can be made to be below safety and EMC stan dards, respectively, with proper shielding techniques
- "Fratricide" effects workable with proper ops
- Public acceptance may be hardest issue
  - "R" word hardest to overcome in public perception, even though legally below all international safety stan dards
  - Policy would have to mandate exposure levels to safe ty standards, with perhaps built-in auto-limiters and fail-safe modes
- Previous legal reviews found no unique liability

Summary and Conclusions

A last area that has not been discussed so far is that of *counter-measures* to HPM (and DEWs in general). Much has been made earlier of the fact that, since the US is becoming more and more heavily dependent on microelectronics, that that also makes us the most vulnerable, especially to RF-DEW attack. A counterpoint to such statements is that, say, unlike KEWs, wherein armor protection is losing the battle to armor-penetration munitions (witness our vulnerability to even simple RPGs in our present overseas theaters of engagement), HPM shielding should be easy, since it can be extremely thin and yet provide very good protection (the term "Reynolds Wrap" is often used). Although there is some truth to the latter statement, i.e., that shielding material does not have to be thick, it is also true that the proper *employment* of such shielding is *not simple*, and even minimal treatments are very often not sufficient nor adequately utilized in actual practice (how often have field supervisors found communication vans, and other radios, radar and C2 facilities, operating with their doors open!). The RF-DEW operator even depends on the fact that most of their targets have had their EM shields corrupted by poor field maintenance procedures, thereby reducing their target defeat thresholds by as much as 20-30 dB. It would seem that these vulnerabilities to RF-DEW threat signals could, however, be countered by proper field operational and maintenance practices, and, while true, even if this is the case, even environmental degradation (e.g., mine RF gaskets) will still allow for eventual RF-DEW susceptibility. Also, proper RF-DEW design certainly allows for these variations in protection, and hence, tries to increase his weapon's lethality by having his source parameters with as large a "kill" margin built in as possible. Although there is not the space to discuss countermeasures in great detail here, a general summary of the usual suspects is given below:

Countermeasures to DEWs - General

- HEL DEWs:
  -Spectral filters
  -Ablative coatings
- RF DEWS:
  -In-band limiters, filters
  - Out-of-band EM shielding
- CPB DEWs:
  - High density materials
- Acoustic DEWs:
  - Acousto-absorbers/reflectors
- Vortex DEWs:
  -Fluid-dynamic jets

To summarize our final "Desirements" for the ideal DEW of any type, it should have the following qualities:

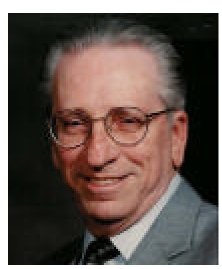
Future Concepts and Directions DEW System Desirements

- DEW systems that are compact, mobile, efficient, reliable, maintainable and affordable
- DEW target effects that are consistent and predictable
- DEW systems that have "rheostatic" capabilities - i.e., variable from antimateriel to antipersonnel, lethal to nonlethal

Major obstacles to the attainment of these "Desirements" for HPM include the following technical challenges that must be met before this technology will make it into our warfighter's arsenal:

- Compact, high peak power and/or high average power HPM sources
- Compact, high gain, narrowband and ultra-wideband (UWB) antennas
- Compact, efficient, high power, pulse power drivers
- Predictive models for HPM effects and lethality
- Low impact hardening of systems against hostile and self-induced EMI/HPM
- Reliable and affordable system integration meeting military platform requirements. ♦

About the Author:



Directed Energy Weapons Course

Instructor: Dr. Edward Scannell, WSTIAC

Location: Huntsville, Alabama
TBD

Course Description:
This one day classified short course provides an introduction to the basic principles and techniques of Directed Energy Weapons (DEWs). The technologies behind each type of DEW will be examined, and the critical path components will be identified and explored with respect to their effect on future DEW development. In addition, advantages that can be achieved by employing DEWs will be discussed, as well as the status of U.S. and foreign DE developments and deployments. The key DEW programs in High Energy Lasers and RF-DEWs or High Power Microwaves will be fully described.

This short course will be of great benefit to people who need to understand the basic concepts, technologies, design requirements and practical applications of DEWs, including program and business managers, political decision makers, engineers, scientific researchers and military personnel. An undergraduate technical degree is recommended. Mathematics is kept to a minimum, but important formulas are introduced.

Questions to be examined include:

- What is Directed Energy and what are the different types of Directed Energy Weapons?
- What are the advantages and disadvantages of each type of DEW and what are their target effects and tactical and strategic capabilities?
- How do DEWs work and what are the critical technologies that must be developed for their eventual use in practical systems?
- How may threat DEW effects be countered and how can we protect our own systems?
- What are the major U.S. and international DEW programs that are being pursued?
- What is the prognosis for future DEW development?

About the Instructor:
Dr. Edward Scannell is the Manager of the Tactical Systems Division, acting Director of WSTIAC, and formerly Chief of the Directed Energy and Power Generation Division of the U.S. Army Research Laboratory. He has 30 years of experience in technical areas related to DEWs, including: plasma physics; conventional and alternative energy sources, electromagnetic (EM) guns, particle beam, laser, high power microwave (HPM), and pulse power physics.

Security Classification:
The information presented is kept at the unclassified level, but is designated FOR OFFICIAL USE ONLY (FOUO) and is export controlled. The security classification of this course is SECRET (U.S. citizens only) to facilitate discussions.

Training at Your Location:
WSTIAC can conduct this course at your location to reduce your travel time and cost. Please call Mrs. Kelly Hopkins to discuss.

Fee:
$700.00 for government personnel; $800.00 for government contractors.

Handout Material:
Each student will receive a comprehensive set of course notes covering the material presented.

For additional information, contact:
Mrs. Kelly Hopkins, Seminar Administrator,
at (256) 382-4747, or by e-mail khopkins@iitri.org

Notice: WSTIAC reserves the right to cancel and/or change the course schedule and/or instructor for any reason. In the event of a schedule change or cancellation, registered participants will be individually informed.

Introduction to Sensors and Seekers for Smart Munitions and Weapons Course

Instructor: Mr Paul Kisatsky, WSTIAC

Location: Huntsville, Alabama

TBD

Course Description:

This 3-day short course provides an introduction to the most commonly used sensors and seekers employed in smart munitions and weapons (projectiles, missiles and wide area mines). It is oriented to managers, engineers, and scientists who are engaged in smart weapons program development and who desire to obtain a deeper understanding of the sensors they must deal with, but who do not need to personally design or analyze them in depth. An undergraduate technical degree is recommended. Mathematics is kept to a minimum, but important formulas are introduced. This course also provides an excellent foundation for those scientists and engineers who desire to pursue this discipline to intermediate and advanced levels.

The course covers:

- Classification of seekers and sensors
- Fundamentals of waves and propagation
- Fundamentals of noise and clutter
- Fundamentals of search footprints
- Introduction to infrared
- Introduction to radar
- Introduction to ladar
- Introduction to visionics
- Introduction to acoustics
- Future projections and interactive brainstorming

Noise and clutter, the predominant obstacles to success in autonomous seekers, are given emphasis. The major sensor types are classified and each is discussed. In particular, infrared, radar, optical laser radar (ladar), imaging and non-imaging, and acoustic sensors are individually covered. Of special interest is the discussion on human visionics versus machine recognition, since this concept is of central importance to understanding autonomous versus man-in-the-loop sensing systems. The implications of "artificial intelligence", "data fusion", and "multi-mode" sensors are also briefly discussed. System constraints, which force tradeoffs in sensor design and in ultimate performance, are also covered. Time permitting, a projection of future trends in the role of sensors for smart munitions will be presented, followed by a "brain-storming" session to solicit student views.

About the Instructor:

Mr. Paul Kisatsky is a Senior Physical Scientist. He is a nationally recognized expert on sensors and seekers for smart munitions and weapons and has more than 30 years of hands-on experience developing sensors and seekers fielded in modern smart munitions and weapons.

Security Classification:

This course is unclassified.

Training at Your Location:

WSTIAC can conduct this course at your location to reduce your travel time and cost. Please call Mrs. Kelly Hopkins to discuss.

Fee:

The registration fee for this 3-day course is $950 for U.S. government personnel and $1150 for government contractors. Contractor teams of 3 or more, registered at the same time, are charged $950 per person.

Handout Material:

Each student will receive a comprehensive set of course notes covering the material presented.

For additional information, contact:

Mrs. Kelly Hopkins, Seminar Administrator,
at (256) 382-4747, or by e-mail khopkins@iitri.org

Notice: WSTIAC reserves the right to cancel and/or change the course schedule and/or instructor for any reason. In the event of a schedule change or cancellation, registered participants will be individually informed.

Weaponeering Course

Instructor: Professor Morris Driels, US Naval Postgraduate School

Location: Picatinny Arsenal, NJ
TBD

Course Description:
This 2½-day short course is based on a very successful graduate-level weaponeering course developed by Professor Driels and taught at the Naval Postgraduate School(NPS), Monterey, CA. The course will provide an overview of the fundamentals of the weaponeering process and its application to air-to-surface and surface-to-surface engagements. The course explains the analytical basis of current weaponeering tools known as the Joint Munitions Effectiveness Manuals (JMEMs) produced by the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME). The JMEMs are used by all Services to plan offensive missions and allow the planners to predict the effectiveness of selected weapon systems against a variety of targets.

The short course is divided into three parts.

Part I covers the basic tools and methods used in weaponeering:

- The weaponeering process
- Elementary statistical methods
- Weapon trajectory
- Delivery accuracy of guided and unguided munitions
- Target vulnerability assessment

Part II covers the weaponeering process for air-launched weapons against ground targets:

- Single weapons directed against point and area targets
- Stick deliveries (point and area targets)
- Projectiles (guns and rockets)
- Cluster munitions
- Weaponeering for specific targets: bridges, buildings, etc.)
- Collateral damage modeling

Part III covers the weaponeering process for ground engagements:

- Indirect fire systems - artillery and mortars.
- Direct fire systems - infantry and armored vehicles.
- Mines - land and sea.

About the Instructor:
Professor Driels is a Professor of Mechanical Engineering at the U.S. Naval Postgraduate School in Monterey, California. He has worked with the JTCG/ME on a variety of topics in support of the JMEMs for a number of years. He has taught a quarter-long weaponeering course at NPS for three years and is preparing a text book on the subject.

Security Classification:
The security classification of this course is SECRET (U.S. citizens only) to facilitate discussions.

Training at Your Location:
WSTIAC can conduct this course at your location to reduce your travel time and cost. Please call Mrs. Kelly Hopkins to discuss.

Fee:
The registration fee for this 2½-day course is $950 for U.S. government personnel and $1150 for government contractors. Contractor teams of 3 or more, registered at the same time, are charged $950 per person.

Handout Material:
Each student will receive a comprehensive set of course notes covering the material presented.

For additional information, contact:
Mrs. Kelly Hopkins, Seminar Administrator,
at (256) 382-4747, or by e-mail khopkins@iitri.org

Notice: WSTIAC reserves the right to cancel and/or change the course schedule for any reason. In the event of a schedule change or cancellation, registered participants will be individually informed.

Smart / Precision Weapons Course

Instructors: Mr. Hunter Chockley and Mr. Mark Scott, WSTIAC

Location: Huntsville, Alabama

TBD

Course Description:
This 2½-day short course provides a comprehensive understanding of smart weapons and related technologies. This course is aimed at providing general knowledge about smart weapons technology and a source of current information on selected U.S. and foreign smart weapons, to include system description, concept of employment, performance characteristics, effectiveness and program status.

A variety of ground, sea and air smart/precision weapon systems are discussed, to include fielded and/or developmental U.S. systems such as Joint Direct Attack Munition (JDAM), Joint Air-to-Surface Standoff Missile (JASSM), Small Diameter Bomb, Javelin, Line-of-Sight Anti-Tank (LOSAT), XM982 Excaliber, Extended Range Guided Munition (ERGM), Common Missile, Tomahawk, Standoff Land Attack Missile - Expanded Response (SLAM-ER), Cluster Bomb Munitions and Airborne Laser, among others, as well as representative foreign smart/precision weapons.

The objective of this course is to inform materiel and combat developers, systems analysts, scientists, engineers, managers and business developers about smart/precision weapons, to include:

- State-of-the-art of representative U.S. and foreign smart weapons systems;
- Employment concepts
- Smart weapons related systems, subsystems, and technologies; and
- Technology trends.

About the Instructors:
Mr. Mark Scott and Mr. Hunter Chockley are Science Advisors. Each instructor has more than 25 years of experience with weapons technology and/or smart/precision weapons.

Security Classification:
The information presented is kept at the unclassified level, but is designated FOR OFFICIAL USE ONLY (FOUO) and is export controlled. The security classification of this course is SECRET (U.S. citizens only) to facilitate discussions.

Training at Your Location:
WSTIAC can conduct this course at your location to reduce your travel time and cost. Please call Mrs. Kelly Hopkins to discuss.

Fee:
The registration fee for this 2½-day course is $950 for U.S. government personnel and $1150 for government contractors. Contractor teams of 3 or more, registered at the same time, are charged $950 per person.

Handout Material:
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Calendar of Events

January 2004

20-22 January 2004
Network Centric Warfare 2004
Arlington, VA.
For additional information
800 882 8684
E-mail: info@idga.org
http://www.ncw2004.com

28-30 January 2004
Tactical Power Sources 2004
Arlington, VA.
For additional information
973 812 5165
E-mail: info@idga.org
http://www.idga.org

February 2004

3-5 February 2004
Strategic and Tactical Missile Systems Conference
Naval Postgraduate School
Monterey, CA
For additional information
http://www.aiaa.org/calendar/index.hfm?cal=5&luMeetingid=971

4-6 February 2004
15th Annual NDIA SO/LIC Symposium & Exhibition
Washington, DC
For additional information
Email:asaliski@ndia.org
http://register.ndia.org/interview/register.ndia?PID=Brochure&SID=_1310Q2D6T&MID=4880

10-11 February 2004
AIAA DEFENSE 2004
Defense Excellence: Moving to Meet the Needs of Joint War Fighting Requirements
Washington, DC
For additional information
http://www.aiaa.org/calendar/index.hfm?cal=5&luMeetingid=1063

17-19 February 2004
Munitions Executive Summit
Tampa, FL
For additional information
Email: cohara@ndia.org
http://register.ndia.org/interview/register.ndia?PID=Brochure&SID=_1310Q2D6T&MID=4650

25-26 February 2004
AFCEA Homeland Security Conference
Washington, DC
"Homeland Security - Breaking Down the Walls"
For additional information call Tina Schaefer at (800) 336-4583 ext. 6250
E-mail: tschaefer@afcea.org.
http://www.afcea.org

March 2004

15-18 March 2004
2004 Joint Undersea Warfare Technology Spring Conference
"Understanding the Littoral Undersea Warfare Challenges"
SECRET/NOFORN
Naval Postgraduate School
Monterey, CA
For additional information
Email: kwilliams@ndia.org
http://register.ndia.org/interview/register.ndia?PID=Brochure&SID=_1400KR1FM&MID=4260

22-25 March 2004
2004 Interoperability and Systems Integration Conference
Denver, CO
For additional information
Email: pedmonson@ndia.org
http://register.ndia.org/interview/register.ndia?PID=Brochure&SID=_1400KR1FM&MID=4120

The WSTIAC Newsletter is the current awareness publication of the Weapon Systems Technology Information Analysis Center (WSTIAC). WSTIAC, a Department of Defense (DoD) Information Analysis Center (IAC), is administratively managed by the Defense Information Systems Agency (DISA), Defense Technical Information Center (DTIC) under the DoD IAC Program.

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