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The purpose of this thesis is to increase awareness of the viability of emergent technology weapons and their applicability within the realm of Electronic Warfare. This thesis includes a definition and evolutionary history of EMP weapons. It also discusses how this technology could severely hamper an enemy's ability to wage war without the collateral damage concerns traditionally associated with conventional weapons and do so without the strategic level consequences inherent to the overt use of lethal force. It discusses how incorporation of EMP weapon capabilities into the equipment, training, and doctrine of the armed services could substantially improve a military's effectiveness on the electronic battlefield. Additionally, it analyzes how this capability brings a new type of collateral damage onto the battlefield, and the potential impact of those unwanted side effects heretofore irrelevant to the employ of conventional munitions. Complexities in targeting and applicability in various environments are also reviewed. The thesis concludes that the decision to employ electromagnetic pulse weapons will offer an advantage to armed services in waging Electronic Warfare. Moreover it concludes, due to an EMP weapon's innate potential for extensive unintended collateral damage to unprotected infrastructures, targets must pass through a rigorous approval process prior to employment.

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Executive Summary

Title: Electromagnetic pulse Weapons as an Emergent Technology and Their Place on Battlefields of the Future.

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Thesis: Incorporating EMP weapon capabilities into the equipment, training, and doctrine of the armed services could substantially improve the military's effectiveness on the electronic battlefield.

Discussion: In 1962, miles above a remote atoll in the South Pacific, the United States conducted its last above-ground nuclear test. Beyond the scope of the nuclear detonation itself, the world was exposed to a unique side effect from the gamma rays it released: an electromagnetic pulse. The detonation, though hundreds of miles removed in both range and altitude, caused marked electromagnetic interference as far away as Hawaii. Although researchers anticipated a similar type of wave propagation, they were stunned not only by the amplitude of the wave it created but also by the range at which the interference was detrimental to unhardened circuits. Electromagnetic pulse (EMP) weapons research had begun. With modern technology, EMP can be system generated and directed. This technology allows for the creation of deliverable EMP weapons which can be employed at the tactical level, with devastating results. Moreover, the pulse can be formed without a nuclear detonation. While the utility of this type of weapon is unquestioned, it brings to the operating environment a new type of collateral damage. The physical damage the weapon delivers to the target is limited to the internal electric circuitry, leaving the target's structure otherwise intact. The question then becomes what are the second and third order effects of removing all aspects of electronic support from a 21st century environment. This study does not seek to portray EMP weapons as detrimental to mission success, but rather, while reinforcing their plausibility as a force multiplier, it seeks to examine the nuances involved with their employment.

Conclusion: Electromagnetic pulse weapons will offer the combatant commander a leading edge weapon which may be employed on the battlefield with lethal effects. However, depending on the local electromagnetic environment and overall mission goals, the employment of that weapon will require the development of unique collateral damage estimates to aid in the determination of the weapon's practicality.

DISCLAIMER

THE OPINIONS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE INDIVIDUAL STUDENT AUTHOR AND DO NOT NECESSARILY REPRESENT THE VIEWS OF EITHER THE MARINE CORPS COMMAND AND STAFF COLLEGE OR ANY OTHER GOVERNMENTAL AGENCY. REFERENCES TO THIS STUDY SHOULD INCLUDE THE FOREGOING STATEMENT.

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ABSTRACT

The purpose of this thesis is to increase awareness of the viability of emergent technology weapons and their applicability within the realm of Electronic Warfare. This thesis includes a definition and evolutionary history of EMP weapons. It also discusses how this technology could severely hamper an enemy's ability to wage war without the collateral damage concerns traditionally associated with conventional weapons and do so without the strategic level consequences inherent to the overt use of lethal force. It discusses how incorporation of EMP weapon capabilities into the equipment, training, and doctrine of the armed services could substantially improve a military's effectiveness on the electronic battlefield. Additionally, it analyzes how this capability brings a new type of collateral damage onto the battlefield, and the potential impact of those unwanted side effects heretofore irrelevant to the employ of conventional munitions. Complexities in targeting and applicability in various environments are also reviewed. The thesis concludes that the decision to employ electromagnetic pulse weapons will offer an advantage to armed services in waging Electronic Warfare. Moreover it concludes, due to an EMP weapon's innate potential for extensive unintended collateral damage to unprotected infrastructures, targets must pass through a rigorous approval process prior to employment.

INTRODUCTION

The insurgent forces, well hidden in the terrain, lay in wait of the Coalition's logistical support patrol which transits this pass daily. The guerrilla force is positioned at the preliminary staging points for a complex ambush awaiting a phone call from an observation point outside the nearest Coalition combat outpost. Upon receipt of the call, the group's leader will deploy his team into their firing positions in an effort to remain concealed and out of sight as long as possible. Their leader has fought alongside guerilla forces against conventional militaries for years. Easily replaceable cellular telephones have become his preferred method of controlling complex attacks like this one. His forces have been watching this choke point for weeks, noting the consistent lack of aerial escort and conventional placement and number of gun-trucks escorting the food, water, and fuel his forces need so badly. Theirs will be the second ambush on the logistics patrol that day, as an adjacent group attacked the patrol on the way into the outpost. From his experience, and the unique sounds of the airburst explosions during their attack, he assumed the other force was likely targeted by elements of the Coalition's supporting arms. Regardless, his cellular has not buzzed yet, so he knows at least local coalition attack helicopters must still be on the ground. He knows his brother at the observation point will ring him as soon as they takeoff. Additionally, since they have not yet taken off, he knows his mission is still 'a go.' From their vantage point his men will be able to move safely into position and fight without fear of observation or attack from the air, just as they had done so many times before. The rumble of motors echoed up the canyon walls and he realizes the patrol is already in the pass, but he has not received the planned notification call. No matter, his troops will still have the upper hand. To maintain light discipline and not provide a target indicator from his cellular phone's

backlighting, under his parka, by 'finger' memory, he calls his supporting element on the far side of the canyon to instruct them to move into position. There is some problem with his speed dial though, because they are not moving. Instead of delaying anymore, he motions his nearside fighters into their positions. Throughout the ensuing engagement his forces suffer heavy losses, on both sides of the canyon, from the attack helicopters he was not expecting to be overhead. The second call from the observation point was to have alerted them of any airborne response, affording his forces ample time to disengage, escape, and re-camouflage before the helicopters came within range. Why had the observer not called to let him know the helicopters had taken off and headed their way? The leader does not know that his brother's early warning call failed because both his cellular phone and pacemaker simultaneously stopped working during the supporting arms barrage in the earlier ambush. Nor does he know that the fuel they have just stolen for their motorcycles to get back to their camp was useless, since the ignition circuitry in the motorcycles had been ruined. Nor would his cell phone ever work again. Confused, frustrated and beaten, his discombobulated forces melt back into the terrain to reconstitute, if they can make the 20 mile trip back to camp on foot. The insurgent leader had just had his first exposure to the new world of electromagnetic interference (EMI) and its invaluable contribution to the Electronic Warfare (EW) battlefield.

BACKGROUND

Although the last above-ground nuclear test conducted by the United States was nearly half a century ago, much learned from those early tests remains viable today. Recent history has seen the threat of outright nuclear conflict replaced by the potential threat of covertly delivered dirty bombs. Today, nuclear testing or even nuclear possession for purposes other than that of self-defense or offensive threat mitigation is considered rogue. As a result, research has shifted

from nuclear weapons themselves to the practical application of theories derived from phenomena observed during those Cold War era tests. Technological advances of the 21st century have made some of the weapons that previously existed in science fiction movies a reality. Today's societies demand of their militaries that maximum effort be made to both mitigate risk posed to friendly forces and minimize the use of excessive force in an attempt to limit collateral damage. This contemporary approach to warfare fosters growth in new age weapons supporting those ends. Electromagnetic interference is one such tool. Incorporating EMP weapon capabilities into the equipment, training, and doctrine of the armed services could substantially improve the military's effectiveness on the electronic battlefield.

HISTORY

The nuclear weapons dropped on Japan aided in bringing World War II to an end, but in doing so it gave birth to a new age of atomic bomb research and development. But it was not until sixteen years later, during the last above-ground test conducted by the United States, that the more subtle side effects of the nuclear explosions were realized. In 1962, the Hawaiian Islands unknowingly suffered some of these side effects. The blast's epicenter was Johnstown Island, an atoll more than 700 miles from Hawaii. The burst altitude was set for approximately 245 miles above the surface.[1] Immediately after the detonation, the Hawaiian Islands were subject to what scientists would later understand to be a type of electromagnetic interference called an electromagnetic pulse. The resultant pulse wrought damage to the Hawaiian Islands, causing severe damage across its electromagnetic grid affecting everything from simple fuses to power lines and streetlights. Shortly after the test, the United States signed the "Limited Test Ban Treaty" which forced all further nuclear testing underground. Although no further tests at

altitude were conducted, scientists had the necessary data to continue with exploitation of this new kind of EMI as a weapon.[2]

WHAT IS AN EMP WEAPON

Today technology has progressed to the point where EMP[3] weapons offer a plausible alternative to the traditional means of target engagement. FMFM 3-3F defines EMP as an intense single phase transient electromagnetic wave that may be generated when a nuclear weapon is detonated, or may be generated by nonnuclear means. This intense wave may damage semiconductor components that are found in receiver front-end or signal processing circuitry.[4] For the purposes of this paper, only nonnuclear-generated EMP's will be discussed. These EMP weapons may be further categorized into either multi- or single-use. Multiuse weapons will also not be discussed in this paper, as these types of stationary high-power directed energy weapons should be pursued in a separate analysis. Specifically in this essay, references to EMP weapons are to single-use weapon associated with a delivery mechanism that allows sufficient standoff from the target area.

FUTURE OPERATING ENVIRONMENTS AND EMP WEAPONS SUITABILITY

Based on the foreseeable operating environment the U.S. will need to be prepared to fight both high and low intensity conflicts and do so in both rural and urban environments. As countries grow and evolve, military-industrial complexes are transitioning to new technologies in an effort to enhance survivability, to maximize performance by streamlining the force, and to decrease the potential for loss of human life. Similarly, the growing affordability of new technologies has also markedly increased electrical dependence within the population at large. Furthermore, most of the projected global population growth will occur in urban areas. With this

technological shift, especially evident in 21st century cities, comes an expanding opportunity for military exploitation on the electronic battlefield. The nature of EMP weapons and their potential to influence the electronic environment in a collateral damage-averse age make them especially suited for just such opportunities.

CONSIDERATIONS

Before fielding EMP weapons, the U.S. military needs to analyze carefully the implications of using these weapons on the battlefield. The four most important considerations are: identification and description of the capability gaps they will fill; assessment of collateral damage pros and cons; a cost benefit analysis; and employment concerns with respect to joint and coalition partners.

CAPABILITY GAPS

EMP weapons fill a 'capability void' in the present conventional United States arsenal. The inclusion of EMP weapons will provide a stand-off Electronic Warfare weapon that enables a force commander to negate enemy targets that rely on the use of the electromagnetic spectrum to perform mission functions. Other contemporary supporting arms can achieve the same ends but frequently, in doing so, a large amount of physical damage is usually the result. One example would be electronically-triggered Improvised Explosive Devices (IED). IED's of this type would require large amounts of direct or indirect fire munitions, a dedicated jamming asset, or physical human intervention to disable them. Future EMP weapons could disable the firing circuitry or the command signal device while preserving the integrity of the system for intelligence exploitation. EMP weapons provide a commander with a weapon which can provide

the same resultant but limit physical damage to the internal computer components threat systems require to function.

COLLATERAL DAMAGE

The use of EMP weapons is designed to disrupt or damage all the unprotected electronics in the targeted area. However in doing so, they will affect combatant and non-combatant systems alike. There are advantages and disadvantages to these weapons. One advantage is that, as threat systems are neutralized, so is the electronic infrastructure that supports them. Additionally, if other threat systems are also attached to the shared grid they be exposed to the EMI effects as well. Since all of this damage can be done at a safe distance from the target, EMP weapons may also minimize exposure risks to friendly forces. By targeting one system, multiple systems may potentially become damaged and drop off-line, creating a highly lethal effect with minimal effort. One important disadvantage is the potential for non-combatants, using that same shared electronic grid for non-military purposes, experiencing similar detrimental effects to their electronic systems. The pulse from the weapon will propagate outward from the target area and damage or disrupt all unhardened electronics indiscriminately within its area of influence. In this situation the potential exists, without further design refinements in warhead and fuse mechanisms, for non-combatants, though never specifically targeted, to lose their electronic infrastructure simply due to proximity to a targeted area. Additional collateral damage concerns encompass electronic fratricide inflicted against unhardened friendly joint and coalition forces.

COST-BENEFIT ANALYSIS

EMP weapons provide a cost effective means of processing targets both monetarily and physically. First, from the enemy perspective, hardening against EMP weapons comes down to a

decision of how much they are willing to invest in relation to the perceived threat. The enemy's perception of the threat will also be proportional to how valuable a vulnerable system is to their own mission success. From a design perspective, one source suggested that an average system hardening cost would equate to approximately 10 percent of the total system cost.[5] The study, however, failed to address the ever-increasing cost of an average combat support platform. When costs are frequently measured in the millions of dollars, 10 percent is likely too much for non-state actors to absorb.

Given these additional costs, state actors with established military-industrial complexes will be the most likely candidates to pursue system hardening to counter EMP threats. These countries not only have the most to lose but they also have the resources to support the research, design, and testing that hardening requires. To avoid the associated costs and weight of hardened systems, non-state actors will also likely continue to use readily-available and expendable equipment that can be easily replaced through commercial means. This reliance on commercial Off-the-shelf (OTS) technology provides an opportunity for both targeting and exploitation.

Adverse effects on friendly forces cannot be fully explored without a review of U.S. forces and its hardening against these threats. Contemporary technologies can be hardened against threat EMP systems and fratricide events; however, this hardening will come at a cost. The U.S. military will have to conduct a thorough analysis of its own systems to determine which systems should be hardened based on a metric similar to the enemy's, but also including the likelihood and frequency of exposure events. Additionally, to provide defense in depth against fratricide and threat alike, the U.S. will have to determine how much of its own military-industrial complex needs to be hardened. Frontline units will have the highest priority, but the

intermediate and deep-support structure cannot be overlooked. The consistent success of those leading edge units will, as observed in the past, remain at least in part proportional to the logistic infrastructure and capabilities supporting them.

Additionally, when reviewing cost analysis, production costs of EMP weapons related to similar EW weapons are also relevant. When compared to the cost of a research, design, and production cost of a similar weapon, such as an Anti Radiation Missile (ARM), EMP weapons have considerably lower manufacturing and sustainment costs. This price differential could lead to opportunities for increased stockpile, and ultimately to an enhanced ability to employ saturation-types of target prosecution.[6]

A final subset of cost-benefit analysis is the human factor and risk mitigation in high exposure events such as counter-IED operations. Although an EMP weapon will never replace final requirement for physical removal of an IED or clearing the scene once the bomb is disabled, it will significantly reduce the exposure threat to friendly ground forces by rendering the system inoperable before security teams and bomb technician even approach.

FRIENDLY AND JOINT FORCE CONCERNS

Just as the U.S. will have to identify what portion of the force it wants to harden, like consideration must be given to all the participants in the friendly order of battle. Electronic fratricide problems will increase with the increase and diversity of supporting units and coalition partners. Since all electronic equipment functions under the same laws of physics, detonation of an EMP weapon in close proximity to unhardened friendly forces will damage their systems just as it damages unhardened threat systems.[7] As a result, these weapons will require careful integration throughout all the portions of the friendly forces to avoid exposure events or

potentially electronic fratricide.[8] Since not all military platforms are hardened to withstand EMP weapons, widespread use will also require re-visiting a study in system hardening. As electronics have entered the age of smaller-is-better, circuits by default have become increasingly more compact and, as such, are more vulnerable to EMP weapons.[9] As technology progresses and these smaller more vulnerable systems are integrated into armed services the threat of electronic fratricide also increases.

RECOMMENDATIONS

The trend away from conventional warfare into Irregular Warfare (IW) in the last century provides a plausible venue for the employment of EMP weapons. Coincident with this trend is a parallel trend for enemy forces to utilize readily-available Off-the-Shelf (OTS) technology, the preponderance of which is not hardened against EMP weapons. Most OTS technologies have been mass produced with an emphasis on semiconductors and nanotechnology which lends them to EMP exploitation. Against enemy forces that rely on these OTS items, EMP weapons provide a highly effective conduit for capability interruptions and provide the combatant commander a cost effective force multiplier. To maximize integration and exploit all aspects of EMP weapons on the battlefield will require changes to present U.S. equipment, training, and doctrine.

EQUIPMENT

To minimize overhead cost while maximizing return, EMP's should be incorporated into the weapons platforms that are already fielded. FMFM 3-55 discusses a variety of employment methods, spanning the gamut from supporting arms to UAV's, including cruise missiles. Each of the platforms is designed to deploy the weapon beyond its Minimum Safe Distance, MSD, which would minimize potential adverse effects on friendly forces. If the EMP weapon is

packaged in an already-existing weapons platform like a 1,000 or 2,000 pound bomb, it could be employed by any of the conventional fixed wing aircraft that already delivers those weapons.[10] Additional training would be required for both the ground and air crews and follow the natural progression of weapons through standardized Operational Test and Evaluation processes.[11] Once complete, integration into existing military's war fighting structure would follow the same process as all other conventional munitions. Employment for these types of munitions should be in concert with the combined arms approach to the battlefield mechanics.[12]

Additionally, present EMP technology is not sufficiently advanced to facilitate immediate introduction into the arsenal. Presently, EMP weapons are not target-specific; if non-combatants were intermingled with viable military targets there would be no way for fire support coordinators to neutralize only military targets. The devastating effect of an EMP delivered into a densely populated area would be significant. Even if a commander's goal was to render threat Command and Control (C2) and Air Defense (AD) systems hidden throughout a city inoperable, there would be no way to ensure other largely unhardened civilian infrastructure would not be impacted. Just as the unhardened threat systems would fall victim to the damaging effects of the pulse and cease functioning, so too would all unhardened OTS electrical equipment in the target area.[13]

The two ways around this problem are either not use the weapon at all or pursue research and development (R&D) programs to design a smaller, more surgical weapon that, when interlaced with training and doctrine, make EMP weapons a plausible alternative to conventional weapons even in an urban environment. These R&D programs will support the combination of effective target analysis, reduction in payload, and frequency and modulation adjustments

making EMP technologies a viable option to conventional munitions employment on the battlefield. These advancements will facilitate inclusion into the U.S. arsenal.

TRAINING

EMP weapons cross many boundaries and Military Operational Specialties, and as such require unique training to maximize employment in support of the combined arms mission.[14] Fires employment training for EMP integration will provide the user with effects-based training covering all the components of EW. Training doctrine will have to expand from traditional thoughts on Surface Danger Zones (SDZ's) and evolve and mature to include the local electromagnetic environment (both threat and friendly). Without such training, planners would likely resort to traditional views and means of risk mitigation techniques which are based in meters of separation from a target or thickness of overhead cover; and by doing so, inadvertently cause electronic fratricide. Training in joint and coalition environments will also be revised to encompass EMI vulnerabilities in friendly equipment. Training will address both the kinetic considerations as well as less tangible EW metrics in targeting processes. This broad training approach will ensure when EMP weapons are both effectively and economically employed by maximizing exploitable vulnerabilities in a target with detrimental effect on friendly forces.

COLLATERAL DAMAGE ESTIMATE TRAINING

EMP weapons still cause collateral damage, albeit different from that of conventional munitions, and as such will require specialized training to address those differences properly. Conventional bombs measure damage estimates in impulse-over-time, thermodynamics, over and under pressures, blast radius, fragmentation, or some combination of these and compare these to the material resistance of the target. The extent of the damage realized is also a function

of payload. Simplifying, payload is frequently measured in relation to equivalencies of pounds of TNT. Unlike these conventional munitions an EMP weapon's payload will not be measured in pounds of TNT, but rather in terms of a relationship of target's hardening with respect to the generated electromagnetic pulse strength, electromagnetic atmospherics, and the electronic infrastructure of the selected target. This disparity will require a new type of weaponeering and damage estimates collections training for the proper employment of EMP weapons.

EMI RESISTANCE AND HARDENING ASSESSMENT TRAINING

Additional training to provide 'hardening assessment training' will be required to determine appropriate fusing and payload combinations for EMP weapons. In traditional bombing campaigns the damage that occurs to a target is an immediate the physical destruction of a system or the systems components rendering it inoperable. However, if the targeted system is in defilade, protected behind sufficient cover, providing protection from a conventional bomb, it still may be combat effective post-blast. EMP weapons are not exempt from this rule, but the definition of "cover" is significantly different. In terms of EMP employment "cover" must be viewed in terms of hardening. Hardening, whether by an entire system or by the individual component, is defined in terms of the level necessary to protect that piece of electronic equipment from an EMP.[15] There are various types of hardening ranging from rudimentary grounding or shielding to complete system re-engineering.[16] Although many systems are protected against some types of EMI, such as lightning, they are still vulnerable to EMP weapons, which have a different frequency and amplitude.[17] The extent, to which systems are hardened to increase survivability, is a function of the combination of cost-benefit analysis and probability modeling based on perceived value of the target.[18] Fires cells will require specific training to evaluate and effectively plan for an array of hardening scenarios.

TRAINING FOR SUPPLEMENTAL TARGETING OPPORTUNITIES

If an EMP weapon is employed against an enemy that lacks the ability or desire to harden, he will look to replace the damaged equipment and potentially cause a logistical shift to support those requirements. This large logistical shift provides friendly forces with additional targeting opportunities. By anticipating the enemy's desire to reconstitute his C2 and war fighting capabilities, priorities for collection assets can be adjusted to further exploit the situation to the friendly force's advantage. Hasty expedited movements of mass logistical support equipment may highlight not only previously undiscovered rear area logistic supply points, but also the Lines of Communication (LOC) supporting them. Similarly, if enemy air power was targeted in the EMP attack, since the platforms themselves are not physically damaged, the length of time those platforms will be out of service will be a function of not only the enemy's Combat Service Support (CSS) system but also manpower available to perform the required maintenance to return the aircraft to a flying status. This period of reduced combat effectiveness of threat systems following the employment of an EMP weapon will be referred to as an exploitation period.

Effectiveness of the EMP weapon is forecast by superimposing a Collateral Damage estimate over the enemy's order of battle provides the key to determining the exploitation period. Since the damage to the components in most cases will be permanent, the limiting factor is then predominantly based on supply capabilities. If the support materials in logistic supply points were targeted, as well, it could significantly increase the time required for the enemy forces to reconstitute. EMP weapons, although highly efficient, will have an estimable associated exploitation period in which commanders will have to pursue all aspects of the weapons second and third order effects to gain the maximum employment. To maximize these exploitation

periods, in training commanders will include targeting cycles which are time sensitive. This analysis of primary and supplemental targeting opportunities and the resultant increased burden on the threat CSS elements will aid in determining EMP targeting suitability.[19]

DOCTRINE

EMP weapons provide commanders with a true command and control weapon. Although EW doctrine itself easily accepts the new technology within the existing definitions, further modifications to doctrinal targeting cycles, Battle Damage Assessment collections, and employment will be required for EMP weapons integration.

EW DOCTRINE

EMP weapons can be categorized as primary Command and Control weapons. Command and Control Warfare (C2W) denies the enemy the ability to command and control while protecting friendly forces.[20] FMFM 3-55 breaks down C2W into five components: Physical Destruction, Electronic Warfare (EW), Military Deception (MILDEC), Operations Security (OPSEC), and Psychological Operations (PSYOPS) and attributes maximum effectiveness to when at least two of these components are integrated.[21] EMP weapons, when employed in concert with a combined arms approach, meet the criteria of each of the five components of C2W. EMP weapons, by exploitation of the electromagnetic spectrum, are by definition a form of EW. EMP weapons, although themselves do not constitute MILDEC, can be used in support of a MILDEC plan. Additionally, FMFM 3-3F alludes to component damage within radar systems from EMI causing erroneous readings on a radar scopes.[22] In the same manner, by disrupting the enemy's ability for EW/C thereby limiting his visibility of friendly force movements, EMP's can also support an OPSEC role. In terms of PSYOPS, EMP weapons

can be employed to aid in defeating the enemy's morale and confidence in their war fighting systems.[23] As such, EMP weapons demonstrate applicability not only to one or two but all of the components of EW as defined by FMFM 3-3F. These distinctions aide in categorizing EMP weapons as an offensive weapon optimally designed to target vulnerabilities within the electromagnetic spectrum; but with bleed-over into all the components of EW, it also highlights the intrinsic value of the weapon in terms of fringe areas like psychological operations.

DANGER OF DOCTRINAL STAGNATION

One of the peculiarities with EW weapons is time. The FMFM 3-3F makes reference to time and how PSYOPS offenses have a specified time element within which will pass some optimum exploitation opportunity. Similarly, with EMP weapons time is a factor. At first, after a threat system has been targeted the enemy will second guess his equipment and likely become disillusioned with the value of his support network. This PSYOP-like effect will only remain effective until the enemy acknowledges the dysfunctional equipment has been targeted by an EMP weapon and is not just faulty. Following this understanding will be a realization that to return the damaged equipment to a mission ready status, they have to either harden their existing equipment and replace the burned out semi-conductors or replace the equipment with EMP resistant technology. Initially, EMP weapons will have a marked psychological impact on an unprepared enemy, but this impact will diminish over time.

The advantage gained from attacks on threat electronic systems is realized in establishing a "relative advantage over the enemy for a limited period of time."[24] The PSYOPS advantage posed by EMP is similar to the weapon's lethality; it is especially sensitive to time. Over time, a flexible enemy will adapt to the new threat system just as it would against a PSYOP campaign.

This evolution of system development followed by counter-system development is referred to as the Electronic Counter Measures (ECM) and Electronic Counter Counter Measure (ECCM) Ladder.[25] The theory submits, as each ECM system is fielded, over time a counter to that system is fielded by the enemy which drives the development of a counter to the counter and so on. With the ECM ladder as the premise, in spite of EMP weapons evolving as an emergent technology, employing forces need remain wary that the battlefield advantage enjoyed by the deploying entity will be fleeting, as counter measures are developed. Whether that counter measure is in the form of system hardening or simply removing and replacing defective components an adaptive enemy will continually maneuver to regain those lost capabilities.

DOCTRINAL FLEXIBILITY

In situations where collateral damage concerns do not allow the employment of large conventional bombs,[26] EMP weapons may offer a plausible alternative to conventional munitions for targeting. EMP weapons can effectively neutralize or disrupt the functionality of the bunker complex without the concern for physical destruction normally associated with bunker-busters.[27] Tomorrow's fires-planners will have an additional engagement method to consider when determining appropriate weapons-to-target matches.[28] The same weapon could be employed against a single cellular phone at an observation point, and be just as effective against a deeply-buried command and control bunker. The cellular phone, packed with semiconductors, would not work again and have to be replaced. The bunker, sealed with electronic motor driven blast doors and reliant on electrical-based air filtration systems, would become a dark tomb for the personnel locked inside. This comparison, in and of itself, is noteworthy; however, the key takeaway is that neither target suffered the extensive physical or structural damage traditionally associated with large bombs.

The employment of EMP weapons will also facilitate intelligence gathering. The neutralized equipment, although nonfunctional, would remain intact. Once recovered, the threat systems require only an electrician replace the damaged circuits to return the device to working order. These types of weapons are especially appealing to environments in areas commonly encountered in 'Full Spectrum Warfare' where physical collateral damage is frequently a limiting factor. Also in these types of operations, the cost of reconstruction is usually subsidized by the U.S., so we would be the ones that have to repair the infrastructure our weapons damaged. The innate targeting flexibility EMP weapons offer a combatant commander is a substantial force multiplier on the 21st century battlefield.

Established as a force multiplier, the bigger question of applicability still remains. As survivability in Irregular Warfare drags combatants into more and more built-up and urban areas and away from the less populated rural regions do EMP weapons remain a plausible alternative to conventional munitions? For employment in more densely populated areas where combatants and non-combatants are intertwined, the real concern becomes collateral damage. This concern highlights the absolute necessity for extensive target analysis and a thorough understanding of the Surface Danger Zone (SDZ) unique to EMP weapons and how that SDZ relates to the targeted zone. Instead of a point target, the engagement area becomes a zone of influence, or geographic area. Unlike conventional munitions, the area is necessarily defined by the unique electric infrastructure and the conduction potential within the targeted area rather than the metric increments (meters) traditionally used to measure Circular Errors of Probability (CEP). Target areas will have to undergo a new type of extensive infrastructure analysis specifically designed to evaluate conduction potential prior to any detailed planning for delivery. Failure to do so could result in unwanted interruption of electric support infrastructure miles from the targeted

area. As EMP technology progresses, more precise fusing and payload combinations will lead to an ability to target smaller areas. This progression is when the real benefit of EMP technology will be realized. The progression towards precision targeting, through frequency and modulation, adjustments will lead targeting cells to isolate adverse effects to the immediate area of the blast. The hurdle will then become ensuring a balance is maintained between payloads large enough to reduce targeted systems' capabilities while keeping collateral damage to a minimum.[29]

EMPLOYMENT OPTIONS

EMP weapons can be employed with devastating effect against both frontline and rear echelon support elements. In a conventional force-on-force conflict the same effects illustrated in the aforementioned urban scenario could be employed with devastating impact to the enemy's military support infrastructure.[30] In cities, bombing industrial complexes may not be a viable conventional targeting option due to proximity to non-combatants or a protected site, like shrines or religious sites deemed national treasures. Rules of Engagement (ROE) and No Fire Areas (NFA) are established to protect these sites and help ensure strategic mission success. If the fragmentary effects of high explosive bombs targeting these complexes could damage the structures within the NFA's, requests for inclusion on a conventional targeting list would likely be denied. In these instances an EMP weapons provide a plausible target prosecution options. Here, an EMP weapon could be employed in the vicinity of both the complex and the protected site with no fear of physical damage to either while simultaneously rendering the production capabilities of the industrial site dysfunctional. Additionally, any of the completed electrical military support equipment, if not stored in a hardened facility, would also be rendered useless. After an EMP attack, this equipment, if not inspected, may still be thought operable. If

transported to the enemy combatants without obvious external physical damage, an unknowing enemy may still continue with shipping operations. This illustrates how the use of an EMP weapon can have unanticipated 2nd or 3rd order effects on the battlefield when warfighting material is shipped from a previously targeted rear area and unknowingly inoperable equipment is transported to the front lines. Here additional time delays for re-screening completed components or faulty component transportation translates into additional burdens incurred by the enemy's Combat Service and Support (CSS) elements. These supplemental factors further retard the enemy's overall war effort. Moreover, these effects, extending well beyond the tactical scope, demonstrate an operational value of EMP weapons.

CONCLUSION

Since 1962, the world has learned much from the study of nuclear detonations. A rudimentary understanding of the phenomenon, which caused those first recorded errant side effects disrupting the Hawaiian electrical infrastructure, has matured and flourished in contemporary research fields. Today, with existing technology, weapons which exploit those electromagnetic theories could be developed for use on the battlefield. The employment would have an immediate combat multiplying affect for the targeting force in the Electromagnetic Warfare arena. Even though the true damage to the afflicted systems may not be easily observed, it is nonetheless lethal for unprotected electrical systems.

On today's irregular battlefield, where lines between friend and foe are not clearly delineated, the practicality of the weapon will have to be analyzed prior to employment. Traditional views of mission accomplishment will have to grow in scope to include the unique long term employment effects of EMP weapons. With EMP weapons, the commander's now

simple answer, to render threat systems inoperable, becomes complicated by new environmental considerations, previously of minimal or no concern. The same will be true even for those already familiar with nuances of Electronic Warfare. In EW today, when a jamming system is turned off or a chaff cloud dissipates the targeted equipment still functions. When EMP weapons are employed, the affected systems will either never recover or do so only after extensive electronic maintenance. On a sterile battlefield, in which non-combatants and their electronic support networks are absent, more conventional approaches to employment may still be viable. But in a scenario with an urban-based counter insurgency where the potential for overwhelming collateral damage exists, determining practicality becomes much more complex and can only be answered by extensive pre-mission target analysis and electromagnetic spectrum weaponeering.

While the utility of this type of weapon is unquestioned, it brings to the operating environment a new type of collateral damage.[31] The vast spectrum of targets and extent to which they can be affected by EMP weapons does not detract from their potential role on electromagnetic battlefield. If anything, it proves the weapon will be all the more desirable on a new age battlefield.

EMP weapons provide a cost effective fill for an existing capability gap in the U.S. arsenal, offer new option for threat and risk mitigation, and can with through coordination provide a joint force or coalition commander a viable target prosecution option without excessive force or damage to targeted areas. For successful integration into the U.S. armed service modifications must be made to the equipment, training, and doctrine before employment. If these adjustments are implemented in conjunction with continued research and advancement in emergent technologies, incorporating EMP weapon capabilities into the equipment, training, and

doctrine of the armed services will substantially improve the military's effectiveness on the electronic battlefield.

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Endnotes

[1] Carlo Kopp, "The electromagnetic bomb-a weapon of electrical mass destruction," (Thesis, Monash University of Australia. Melbourne, Australia, 1996) 1-3.

[2] William Schilling, *"Nontraditional warfare : Twenty-first-century threats and responses*. 1st ed. (Washington, D.C.: Brassey's., 2002), 291. and Steven McGrath, "The Electromagnetic Pulse Environment and Its Influence on Tactical Electronic and Communications Equipment," (Masters Thesis, Naval Post Graduate School, Monterey, California, 1992), 1-2.

[3] Electromagnetic pulses can be generated through both nuclear and non-nuclear processes. Detonation of nuclear devices causes propagation of gamma and X-rays, which induces a directional current flow from Compton Scattering and an ensuing magnetic pulse. Non-nuclear EMP's generate magnetic pulses through an internal process. Though the generation methods are different, the same physical laws apply to both weapons. In both cases, the effectiveness of the resultant pulse is restricted by coupling. FMFM 3-3F defines coupling as the means by which an interference source is coupled to the victim equipment. It goes on to describe the three main modes of coupling: direct radiation, indirect coupling, and conduction. Direct radiation occurs when the EMI enters the equipment through normal means like an antenna or a device developed to collect radiated energy and direct it into the system. Indirect coupling occurs when high voltage currents run parallel to cables controlling electrical circuits and causes interference in the system receiving energy from an errant source. Lastly, conduction occurs when errant energy affects one side of a circuit then continues through the connected devices to affect some other portion of that same circuit. In discussion regarding MAGTF vulnerabilities, FMFM 3-55 refers to these modes respectively as "Front Door" and "Back Door." Front Door EMI enters the system via normal input channels and "Back Door" is EMI entering the system in any other way. EMP weapons exploit all three modes of coupling to affect electronic circuits by essentially saturating circuits with large amounts of radiated energy and rendering those systems inoperable.[FMFM 3-3F].

[4] FMFM 3-3F, 1987, 3-1.

[5]William Schilling, *"Nontraditional warfare : Twenty-first-century threats and responses*. 1st ed. (Washington, D.C.: Brassey's., 2002), 298.

[6] Carlo Kopp, "The electromagnetic bomb-a weapon of electrical mass destruction," (Thesis, Monash University of Australia. Melbourne, Australia, 1996) 17.

[7] Susceptibility of unhardened systems must be considered as in these systems one microjoule of errant energy is enough to burn out a solid state element. Large EMP weapons could deliver one millin times that amount to the locally radiated area. [Kopp 18]

[8] Carlo Kopp, "The electromagnetic bomb-a weapon of electrical mass destruction," (Thesis, Monash University of Australia. Melbourne, Australia, 1996) 1.

[9] Carlo Kopp, "The electromagnetic bomb-a weapon of electrical mass destruction," (Thesis, Monash University of Australia. Melbourne, Australia, 1996) 19.

[10] Carlo Kopp, "The electromagnetic bomb-a weapon of electrical mass destruction," (Thesis, Monash University of Australia. Melbourne, Australia, 1996) 8,13.

[11] FMFM 3-55, 1993, 4-4.

[12] FMFM 3-55, 1993, 1002.

[13] In this instance, the extent of the collateral damage is not restricted to an errant cellular phone or a man with a pacemaker. All the unprotected electronics simultaneously cease to function. The surgical support equipment in a hospital, its primary and secondary electrical systems would all be rendered inoperable. Nor is the damage limited to a single hospital. Rather, every hospital in the targeted area and, in this case, the entire city was damaged. Every ambulance and every fuel pump would be useless. Potentially most importantly in a city, the power supply

to the water pumps that feed the inhabitants with fresh water is also damaged. Collateral damage of this magnitude has the potential to severely hamper the operational and strategic goals of friendly forces. Essentially the city is transformed from a sprawling 21st century city into the 1800's instantaneously. The implications of the improper employment of EMP weapons in densely populated urban areas are sobering. For the 21st century commander who simultaneously fights both a local war on the ground and a worldwide public relations war, such a decision could prove devastating to strategic mission.

[14] FMFM 3-55 1993, 1-6.

[15]Steven McGrath, "The Electromagnetic Pulse Environment and Its Influence on Tactical Electronic and Communications Equipment," (Masters Thesis, Naval Post Graduate School, Monterey, California, 1992), 40.

[16]Steven McGrath, "The Electromagnetic Pulse Environment and Its Influence on Tactical Electronic and Communications Equipment," (Masters Thesis, Naval Post Graduate School, Monterey, California, 1992), 47-54,60.

[17]Steven McGrath, "The Electromagnetic Pulse Environment and Its Influence on Tactical Electronic and Communications Equipment," (Masters Thesis, Naval Post Graduate School, Monterey, California, 1992), 40.

[18]Steven McGrath, "The Electromagnetic Pulse Environment and Its Influence on Tactical Electronic and Communications Equipment," (Masters Thesis, Naval Post Graduate School, Monterey, California, 1992), 72.

[19] Although EMP weapons provide a force multiplier in the tactical sense, application is not limited to those targets alone. Unprotected frontline threat systems remain the primary targets for immediate exploitation while intermediate and rear areas deep within the military-industrial support complex provide secondary targets. In an ideal situation, the two groups are simultaneously targeted to maximize the EMP's exploitation period. Coincident to the systems on the Forward Edge of the Battle Area (FEBA) becoming inoperable, the parts required to fix them, often deep within the rear areas, are also rendered useless. Therefore, functionality of coordinated attacks both in the near and deep battle zones with minimal 'traditional' collateral damage make EMP weapons uniquely suited for use in both irregular and conventional conflicts.

[20] FMFM 3-55, 1993, 1-3.

[21] FMFM 3-55, 1993, 1-3.

[22] FMFM 3-F, 1987, 4-2.

[23] FMFM 3-55 1993, 1-5.

[24]Richard E. Fitts, and Robert W. Burton, *The strategy of electromagnetic conflict*, (Los Altos, Calif.: Peninsula Pub., 1980), 54.

[25]Richard E. Fitts, and Robert W. Burton, *The strategy of electromagnetic conflict*, (Los Altos, Calif.: Peninsula Pub., 1980), 38.

26 Traditionally, bunker-type targets require large specialized penetrator bombs. First, the bombs have to pierce the overhead earthen cover. Then, they have to maintain enough energy to penetrate the hardened ceilings before they get to the bunker's soft interior. As a result, to neutralize such a target, either a thermobaric or large (1,000 or 2,000 pound) bomb is usually required. It naturally follows that the damage inflicted on the target area is proportional to the payload of one of these large bombs. Employment of these types of weapons in densely populated areas is generally restricted due to collateral damage concerns.

[27] How could an EMP affect an underground bunker? If a bunker has any unhardened wires or cables that lead from the exterior of the facility to the interior, the entire bunker is susceptible to EMP effects via coupling. Conduction takes over once the pulse couples with the exposed unhardened wire and the pulse then propagates through all the unprotected components within the network. This amplifies the flexibility of EMP weapons with respect to targeting.

[28]Effective targeting will require continued advancements in the EMP technology, research, and design so that commanders may employ a weapon with a realistic forecast of what the beaten zone will look like post-blast. Over time, as the size of the payload is matched directly to the intended target, commanders will have a reasonable expectation they can use an EMP in one part of the country and not worry about destroying the national power grid in another part of the country. Also with increased study, future payloads would go through a weapon-to-target match process fitting specific bombs and fuses to specific threat systems and exploit frequency and modulation windows. To maximize the effectiveness of the attack, individual targets will be prosecuted in concert

with other supporting elements. [McGrath 37] Unlike conventional munitions, fire support coordinators are not encumbered with triangulating each target's exact positions for an EMP attack. EMP weapons can be used in proximity to threats and still achieved desired effect. Additionally, EMP weapons will influence buried cables and, render the components on both ends damaged or completely dysfunctional without so much as disturbing the ground in which they are buried.[28] As a result, EMP weapons would also be highly effective against deep belowground bunkers and as such, provide additional flexibility to the targeting process.[FMFM 3-55 3-4]

[29] Accurately assessing post-employment Battle Damage Estimates (BDA) poses a unique problem in realm of EMP weapons. Quantifying the extent of the damage will require enhancing contemporary Early Warning and Cueing (EW/C) devices designated to capture subtle target indicators. Traditionally, the effectiveness of EW weapons is determined by assessing whether a target is still emitting. Arguably, if a targeted system is not turned back on, it would be difficult to determine if the EW weapon employed had the desired effects or not. Since electronic lethality is difficult to assess, although not the preferred method the use of decoys may play a role in this type of intelligence collection. By coaxing the enemy into energizing those previously targeted circuits and may at some point "resemble a cat-and-mouse game."[Fitts and Burton 65] Limited or no EM response would indicate the EMP weapon was employed effectively. These approaches would be considered a type of EW reconnaissance or probing. The development of a passive long range magnetic field detection system is the preferred method. The system would essentially be designed to detect electrically induced magnetic fields and utilize those fields as target indicators. The development of such a system would also greatly enhance the initial targeting process.

[30]William Schilling, *"Nontraditional warfare : Twenty-first-century threats and responses*. 1st ed. (Washington, D.C.: Brassey's., 2002), 298.

[31] Is there a moral component associated with the employment of EMP weapons? At the tactical level, provided the planning, target analysis, and employment fall within the given theater's Rules of Engagement and internal steps are taken to mitigate fratricide, EMP weapons may initially appear to be a perfect 21st century weapon. Due to the unique SDZ associated with EMP weapons, the notion of morality becomes inexplicable linked to targeting. In the earlier examples, it is fairly simple to review a near-sterile battlefield where the line is clearly drawn between friendly and enemy forces. A battlefield in which belligerents are operating in sparsely populated areas lacking the complex infrastructure common in urban areas of highly industrialized nations. In these situations, the electromagnetic environment is multifaceted and in many cases interdependent. Here targeting analysis becomes marked more complex and needs to encompass neighboring population centers which may be codependent on power or water supplies. Simply, it is not only a morality an issue as discussed above. But lack of proper target analysis could lead to employment a highly susceptible area, like a city. And that employment in such a region could shatter the delicate support structure in an urban area. So much so that devastation over a time period as small as a month could have an absolutely disastrous outcome. In this case the resultant could potential breakdown of the local society. The question becomes which is more acceptable, the conventional explosion which could extensive collateral damage outright or an EMP? How is there relationship here at all? At first glance, it may seem absurd to consider an EMP a weapon of mass destruction. If improperly employed even a tactical EMP could have a severe negative impact in densely populated urban areas. Although lacking the massive physical destructive power of a conventional 1,000 pound bomb, or even smaller, an EMP's power is measured in its effectiveness against electric circuits. As time progresses and societies evolve, further into electrical dependency, their susceptibility to EMP weapons increases.