REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
23-10-2009

2. REPORT TYPE
FINAL

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
The Threat of High Altitude Electromagnetic Pulses: Why it should be keeping Combatant Commanders up at night

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Douglas W. Fletcher, CDR, MSC, USN

Paper Advisor (if Any): Michael E. McGauvran, COL, USAF

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Joint Military Operations Department
Naval War College
686 Cushing Road
Newport, RI 02841-1207

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release

13. SUPPLEMENTARY NOTES A paper submitted to the Naval War College faculty in partial satisfaction of the requirements of the Joint Military Operations Department. The contents of this paper reflect my own personal views and are not necessarily endorsed by the NWC or the Department of the Navy.

14. ABSTRACT

High Altitude Electromagnetic Pulse (HEMP) poses a serious and credible threat to U.S. forces. Research and analysis of current HEMP defenses and contingency planning revealed that U.S. forces are not equipped adequately to survive a HEMP attack and rely too heavily on a vulnerable civilian infrastructure for daily operations. In addition, no process exists for periodic testing of equipment. Further, operational forces do not minimize risk by preparing adequately for post-HEMP attack consequence management. Therefore, Combatant Commanders should assess and wargame OPLANS and develop adequate contingencies for wide spread electronic failure of “non-essential” electronic equipment in the event of a HEMP attack.

15. SUBJECT TERMS
HEMP, Electromagnetic Pulse

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON / 19b. TELEPHONE NUMBER *(include area code)*
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED		25	Chairman, JMO Dept / 401-841-3556

Standard Form 298 (Rev. 8-98)

NAVAL WAR COLLEGE
Newport, R.I.

THE THREAT OF HIGH ALTITUDE ELECTROMAGNETIC PULSES: WHY IT SHOULD BE KEEPING COMBATANT COMMANDERS UP AT NIGHT

by

Douglas W. Fletcher

CDR, MSC, USN

A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Joint Military Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

Signature: ____________________

23 October 2009

Contents

Abstract

High Altitude Electromagnetic Pulse (HEMP) poses a serious and credible threat to U.S. forces. Research and analysis of current HEMP defenses and contingency planning revealed that U.S. forces are not equipped adequately to survive a HEMP attack and rely too heavily on a vulnerable civilian infrastructure for daily operations. In addition, no process exists for periodic testing of equipment. Further, operational forces do not minimize risk by preparing adequately for post-HEMP attack consequence management. Therefore, Combatant Commanders should assess and wargame OPLANS and develop adequate contingencies for wide spread electronic failure of "non-essential" electronic equipment in the event of a HEMP attack.

INTRODUCTION

Another day in paradise is beginning on Guam. Kayakers can be seen paddling around the island, taking in the beautiful vistas. Tourists begin arriving at the many duty free malls that dot the island, and the day is well underway at Naval Station Guam and the other military bases that populate the tropical island. Without warning, the serenity is broken. A giant flash cuts across the sky, blinding many who look directly at it. Chaos quickly engulfs the island. Electrical power outages occur across the island. Hundreds are injured or killed when cars and trucks cease to function and crash on the roads. Radios, televisions and telephones no longer operate. Rioters loot local stores seeking emergency food, water and supplies. Mass hysteria erupts among the population and hospitals are overwhelmed with people seeking care. Police and military are unable to control the situation as their communications and other equipment are inoperable; chaos ensues.

The source of the attack in the above scenario was a nuclear detonation which produced a High Altitude Electromagnetic Pulse (HEMP) that disrupted virtually all electronic equipment on the island. The technology to employ HEMP is readily available and the threat of a HEMP strike on U.S. forces or mainland is a clear and present danger. Experts have envisioned a variation of the above scenario over the years. However, due to a combination of expense and complacency, the warnings of the threat have been largely ignored.

HEMP poses a serious and credible threat to U.S. forces. U.S. forces are not equipped adequately to survive a HEMP attack and rely too heavily on a vulnerable civilian infrastructure for daily operations. Further, operational forces do not minimize risk by preparing adequately for post-HEMP attack consequence management. This paper will propose two possible scenarios in one particular Geographic Combatant Commander's Area of Responsibility (AOR), United States Pacific Command (USPACOM). At present, adversaries within USPACOM's AOR pose the greatest likelihood of attacking the U.S. or its forces with a HEMP attack,[1] but the threat is not limited only to this AOR.

This paper will introduce HEMP and examine the hypothetical consequences and credibility of HEMP attacks against U.S. Forces. It will then examine the ways in which the U.S. currently mitigates the risk of a HEMP attack against its operational forces. Next, it will discuss the operational implications and risk mitigation strategies U.S. operational forces can utilize to prepare for a HEMP attack. It will conclude with recommendations to improve Military HEMP defenses through implementation of robust equipment testing programs and development of substantive post HEMP contingency plans.

BACKGROUND: HEMP AND ITS EFFECTS

Photons from a nuclear detonation quickly interact with the surrounding environment and create an Electromagnetic (EM) field which radiates from the source of the detonation. The strength, duration, and the size of the area affected by an Electromagnetic Pulse (EMP) are highly dependent on the height of burst (HOB) of the nuclear detonation. The strongest fields are created when the burst occurs near the earth's surface, but high altitude detonations are still capable of creating electromagnetic fields which are strong enough to damage or disable electronic equipment. Generally, the EM effects are measured within line of sight of the detonation. Therefore, the higher the height of the detonation, the larger the area of effect.[2]

Any nuclear detonation above a height of 60km above the earth's surface produces EM effects which are termed HEMP. The peak field strength resulting from HEMP is relatively low but is extremely far reaching. These EM fields are large enough to disrupt unprotected computer systems[3] and can be observed as far away as 800 miles from the detonation.[4]

EMP effects vary but are generally classified as short term (E1), middle term (E2), and late term (E3) effects.[5] The E1 component is an EM field with an extremely short time required to generate maximum current (rise time) of a few nanoseconds. This component is capable of disrupting most control and sensor systems as well as disabling many transportation and communication systems. The middle component behaves very similar to lightning and follows closely after the E1 effects. Therefore, electronic systems with lightning protective measures may have some resistance to this component. However, E1 and E2 have a synergistic effect where the E1 component can damage or disable the lightning surge capabilities allowing the E2 component to pass into major electronic circuits and furthering the damage. The late stage component (E3) may last for a minute or more and is similar in nature to the magnetic effects of solar flares. This component can affect electrical systems with long transmission lines and combined with the previous damage caused by E1 and E2, can greatly disrupt these systems.[6]

DISCUSSION/ANALYSIS

Scenarios in PACOM'S AOR

A HEMP attack could be made against the Continental U.S., Alaska, Hawaii, U.S. territories or on U.S. forces. The choice of target will largely depend on the goals and means available to an adversary. In order to show resolve, but limit the probability of an escalatory response by the U.S., an isolated HEMP attack may strike a U.S. carrier strike group, or U.S.

territory away from the continental U.S. In addition, a HEMP attack may occur in order to reduce or eliminate U.S. retaliatory capability facilitating follow-on conventional invasion. Due to the location of potential nuclear adversaries, Guam is a likely target for HEMP attack. Therefore, this paper will illustrate the likely effects resulting from a HEMP attack in the area of Guam as well as possible effects of a strike on a deployed Carrier Strike Group.

Scenario #1: Strike on U.S. territory

Since Guam is a large tourist destination, there is likely to be a number of aircraft in the vicinity of the airports. The exact number of aircraft varies, but at any time there is likely to be dozens flying, with several of the aircraft being large commercial planes. In the event of a HEMP attack, it is likely that some of the aircraft will have catastrophic malfunctions and crash. It is further likely that these crashes will cause widespread injuries and hundreds of personnel casualties. Air Traffic Control radars will likely be non-functional, potentially resulting in further lost aircraft and casualties. In addition, further crashes and casualties will result from the malfunctions of the many buses, trucks, and cars on the road as well as the traffic lights. Maritime traffic will slow as ports react to degraded communications capability. There will be widespread power outages and most, if not all, of Guam will be without power. Mass hysteria may erupt among the population. Hospitals would initiate mass casualty protocols. Depending on the HOB and the time of day, there will likely be multiple cases of flash blindness as well as many cases of "worried well" believing they have been exposed to radiation overwhelming local medical treatment facilities.

Military commands on Guam will likely have greatly degraded capability as well. In particular, communications will be adversely affected. Additionally, the military may be operating with reduced number of personnel. Military personnel will likely be unable to return to their bases due to the fact that transportation will be non-functional. Many of the military vessels which were in the vicinity of Guam will be damaged by the HEMP attack, with some damage being severe enough that they no longer are able to perform their designated mission. Military aircraft and airfields will likely be non-mission capable until repaired.

Scenario #2: Strike on deployed Carrier Strike Group

If a HEMP attack targets a Carrier Strike Group, it will likely be accompanied by numerous air launch decoys in order to overwhelm any Ballistic Missile Defense (BMD) capability possessed by the escort ships of the aircraft carrier.[7] If the nuclear device successfully detonates in the upper atmosphere, the effects on the operations of the carrier and its escorts would be mission crippling. Since any systems which are connected to antennae are extremely vulnerable to the effects of a HEMP strike, it is likely that most if not all of the defensive capabilities of the strike group will be damaged or non-functional. Similarly, the air traffic control capabilities of the carrier itself will likely be nonoperational. Any aircraft which were outside of the skin of the ship will likely have malfunctions or cease to operate. Some of those aircraft in the air at the time of the strike will likely malfunction, lose power and crash into the surrounding sea.

All surface ships within the strike group will likely still be capable of maneuvering, but communications, ship-board power, and computers on board will experience significant degradations and malfunctions. Some will be able to be shut down and restarted without major effect, but many systems will require repair or replacement. The spare parts on board may not be sufficient to regain 100% mission function and may potentially cause a mission kill.

The result is that a successful HEMP strike will likely cause a carrier strike group to at least temporarily be unable to perform its primary mission— carrier based air support. Depending on the extent of the damage to the ships and aircraft, there is a high likelihood that the strike may result in the carrier being unable to support air operations. Thus, it would have to be removed from the operations area to perform necessary repairs.

Credibility of the HEMP threat

Experts have raised concerns over the last decade about the readiness of both the civilian and the military sectors to withstand HEMP attacks. These experts produced several studies assessing various at risk sectors. In 2004, a Congressional Commission reported that HEMP was one of a few threats that could place population at great risk and may cause significant degradation to U.S. military forces.[8] Even as recently as 2009, the report of the Congressional Commission on the Strategic Posture of the United States stated that only limited protective measures have been implemented by the Department of Defense and that no EMP vulnerabilities have been addressed by the Department of Homeland Security.[9]

In addition, proliferation of nuclear technology has further increased the probability of an EMP attack. A.Q. Khan's nuclear technology black market has enabled many countries with nuclear aspirations to acquire this technology while also potentially providing similar technology to non-state actors such as Al Qaeda.[10] Currently, at least eight countries have nuclear weapon technology and the knowledge required to produce and construct HEMP capable nuclear devices.[11] In addition, it is argued that at least two others (Iran and North

Korea) have the requisite knowledge and/or the technology to currently produce these weapons or soon will have the capability to do so.[12,13] Similarly, the missile delivery systems are readily available to any state or non-state actor who is interested in acquiring one.[14] While not simple, it is plausible for a determined group or nation to be able to acquire HEMP capable nuclear weapon technology.

Not all nuclear thresholds are the same; effects matter. In the case of a HEMP attack, the nuclear detonation occurs high in the atmosphere. All of the blast, thermal, and radiation effects remain in the upper atmosphere and do not create the massive widespread casualties or damage normally associated with nuclear detonations. Despite international rhetoric and declaratory policy,[15] it is doubtful that the world would retaliate with full and deadly force against an actor who decides to utilize a weapon in such a way.[16] If an actor desires to demonstrate that they are a "nuclear power" or wishes to perform an escalatory action directed at one of its adversaries, a HEMP strike on the adversary's forces may be a more effective means of communication than a demonstration strike or test blast.

EMP effects on military equipment

Equipment vulnerability to EMP effects remains an ongoing area of concern. There are several ways to study the effects of EMP. The most accurate way is to detonate a nuclear device and evaluate the resultant effects on equipment. Due to the desire for the U.S. to comply with the Comprehensive Nuclear Test Ban Treaty (CTBT), this route of experimentation is closed.[17] However, one can use computational programs to simulate the effect of EMP on electronic components.[18] However, it is extremely complicated to simulate a complex system of components, each of which has a potentially indeterminate contribution to the environment model. Therefore, for most electronic systems, it is nearly impossible to use computer simulations to estimate the effects from EMP with any certainty. Similarly, there are no simulation programs available which calculate the expected EM field strengths of systems within other systems. For example, it is impossible to determine with any confidence what the effects will be to aircraft within the hanger bay of a carrier or within a hanger shelter.

Most large electronic systems require testing and validation to determine EMP survivability, also known as EM or EMP hardening. Systems are tested with either pulse current injection or free field simulators to simulate the EM pulse.[19] Only a few free field simulators exist, and these are not large enough to test large systems. In particular, ships and airplanes cannot be tested using these simulators.[20] In absence of the free field simulation, pulse current injection is used to test larger systems. The largest drawback of this method is that the rise time of the pulse current injection is on the order of ten nanoseconds[21] and does not accurately represent the threat from a HEMP attack. Therefore, one must build full scale, free field simulators to accurately test larger components such as ships and airplanes.

Challenges exist, however, for widespread construction of these facilities. First, the expertise to build and operate such a facility is virtually nonexistent.[22] There are only a few top level designers who have the requisite skill sets to be able to design and build such facilities, and all of these are at or above retirement age. Second, it is expensive to build such facilities and the current fiscal environment does not allow for many new expensive projects. Finally, there are environmental concerns with EM fields in a testing environment which may impact the ability to build facilities of this type.[23] Even though multiple challenges exist, it is imperative that the US continue to research and develop testing facilities in order to ensure future readiness.

The Department of Defense has not been ignoring the need for EM hardening in its requisition process. Standards have been established for mission critical equipment required for war fighting.[24,25] However, these standards are applied to the class of systems and are generally tested immediately after manufacturing and immediately prior to fielding the equipment. In 2004, surveys were conducted and found that routine maintenance, repair and replacement as well as normal aging can impact the nuclear protection capabilities of electronic systems.[26] To complicate the issue, most equipment is routinely upgraded or modified with traditional commercial-off-the-shelf (COTS) components. These components are procured using similar EMP hardening standards. However, the components are typically tested individually and not as part of the entire system.[27] As a result, examples were found of 20 year old systems that met all product specifications when originally purchased, but now fail to meet the same nuclear protection standards.[28]

In addition, it was determined by the Defense Science Board Task Force on Nuclear Weapons Effects Test that the Department of Defense has been neglecting routine testing of nuclear protection systems.[29] In particular, it was found that no surveillance testing was performed on non-strategic systems and little on strategic systems. There is sufficient evidence to believe that many deployed systems are no longer able to meet their originally designed EMP protection.[30] As a result, operational forces are relying on equipment assumed to be hardened to the effects of nuclear detonation and EMP, but may be completely vulnerable.

The case for EM hardening

EM hardening requirements are generally for equipment which is considered "vital" to the mission. As shown previously, the ability to meet these requirements may be lacking. If the operational forces do not have "vital" equipment which will reliably resist the effects of a nuclear detonation or EMP, how many of the "non-essential" secondary systems will likely remain operational after an EMP attack? Will our forces be capable of communicating, but not able to maneuver due to transports being inoperable? Will our forces be able to target the enemy but not engage? These questions should be of great concern to our operational commanders. At present, the technology which is used by our forces is not reliably protected from nuclear effects. The threat of an EMP attack on our operational forces grows each passing year,[31] yet DoD has not adequately minimized the risks.

Military reliance on civilian infrastructure

A critical vulnerability for the military is its dependence on the civilian infrastructure for daily operations. In April 2008, a report was published assessing the civilian infrastructure vulnerabilities to a HEMP attack. The commission extensively examined the condition of the U.S. civilian infrastructure. Virtually all sectors of the civilian critical infrastructure were found to be extremely vulnerable to an EMP attack. Civilian vulnerabilities include power generation and distribution, telecommunications, air, marine and land traffic, food infrastructure, and emergency services.[32] These findings were echoed by the 2009 Congressional Commission on the Strategic Posture of the United States in which recommendations were made to spend $11 Billion to modernize the U.S. power grid.[33]

The status of the civilian critical infrastructure is so precarious that there have been predictions that an EMP attack on the homeland could result in a yearlong blackout.[34]

As stated earlier, military bases are likely to be largely dependent on civilian infrastructure. In particular, the electrical, telecommunications, and water systems are likely to be largely integrated with the surrounding civilian community. As shown previously, these services are very likely to be disrupted if a HEMP attack occurs. Interruptions to the supporting civilian infrastructure will greatly impact operations on these military bases. Military bases generally have some capacity for emergency power generation and other contingencies. However, contingency plans for emergency operations are centered on maintaining mission critical functions. In addition, even those bases which have existing operating plans involving EMP countermeasures may only have an EMP hardened closet or room. Therefore, military bases which are in the vicinity of a HEMP attack will have vast reduction in their capability and will largely be unable to support non-vital functions.

Military assets which are not directly dependent on the civilian infrastructure (i.e. ships, aircraft etc) are generally self-contained in their capability for mission performance. These assets are considered to be more hardened to EMP effects than civilian analogs. However, in the event of a HEMP attack it is likely that there will be some degradation to capability. Depending on the exact electronic systems it is probable that some systems will be unaffected while others experience malfunction or failure. These system failures may result in mission failure and probable personnel casualties. Since exact knowledge of the effects is unknown, more research must occur to ensure adequate hardening of military assets.

Operational implications

An adversary will likely strike U.S. forces with a HEMP attack as a precursor to a follow-on action. In the case of the scenarios provided earlier, the HEMP attack on Guam or the deployed carrier could be launched prior to an adversary invading U.S. allies in the PACOM area. As discussed previously, the most effective way of neutralizing a HEMP threat is to procure equipment which is proven to be HEMP survivable. U.S. forces are among the most technologically advanced in the world. This reliance on technology creates a critical vulnerability which can be exploited through a HEMP attack. Since it is impractical to ensure every piece of vital and non-vital electronic equipment is HEMP survivable,[35] operational commanders need to develop risk mitigation strategies to prepare U.S. forces in the event of a HEMP attack.

In the event that a state or non-state actor successfully detonates a nuclear weapon in high altitude, an operational commander has very little options for a measured, proportional response. Due to various treaties and presidential initiatives, the non-strategic nuclear forces have been drastically reduced.[36] Further, the United States' strategy is to utilize its advanced conventional capability to respond to low-escalatory nuclear actions[37] and all nuclear capabilities are centrally commanded by USSTRATCOM and require Presidential authorization for use. Therefore, the operational commander's organic retaliatory option is limited to conventional weaponry.

Several difficulties arise in the decision process for the operational commander. First, a successful HEMP strike can affect an area from several miles to several hundred miles depending on HOB. If the target of the HEMP strike was the operational forces, many of the operational commander's assets are likely to be located within the vast affected area. As described previously, any offensive or defensive capability will be greatly diminished. Therefore, if the commander wished to respond with conventional force, he will have to call upon functional forces outside of the affected area.

In addition, the operational commander will then have to recommend to higher authorities whether use of advanced conventional force is a measured and proportional response for an attack that caused no widespread personnel casualties and targeted technology only. If his calculus determines that a retaliatory HEMP strike is warranted vice an advanced conventional response, the commander has no such capability within the forces assigned to his Area of Responsibility (AOR) and would have to recommend use of strategic nuclear assets to higher authority. If higher authority determines that a retaliatory HEMP strike is warranted and it is not already preplanned, it is likely that USSTRATCOM targeteers will have to initiate an adaptive targeting process[38] which would allow for a HEMP strike at the location of interest. This process is time and labor intensive, requiring at least several hours to several days to complete. As a result, the operational commander's desired response may not be available in a timeframe beneficial to the ongoing conflict.

Experts are divided as to the immediacy of the threat of EMP,[39] but there is general agreement that it constitutes a grave threat.[40] In fact, HEMP is not even considered a Weapon of Mass Destruction (WMD) by itself, and is only considered as a byproduct of another WMD device (nuclear detonation).[41] Since there is debate about the probability of an attack, little is done to minimize risks of a HEMP attack on our forces. HEMP is given little attention in Joint Publication (JP) 3-11 which addresses operations in Chemical, Biological, Radiological, and Nuclear Environments. This document mentions HEMP only a few times in passing and erroneously states that the major impact HEMP will have is disruptions in communications.[42] No other joint doctrine exists which address preparing for or reacting to HEMP strikes. Therefore, there is little of value in this document for an operational planner attempting to prepare for HEMP contingencies. Some service or command-specific procedures exist that are to be activated upon the notification of an imminent HEMP attack. Many of these plans are classified and are unable to be addressed specifically in this paper. However, open source procedures consist of turning the power off on all electronics for the duration of the HEMP attack.[43] Additionally, there is no guidance in JP 3-11 which discusses any potential logistics or sustainment issues arising from the use of HEMP strikes against U.S. or allied forces. Without strong joint guidance, US forces will not be able to adequately minimize risks against a HEMP strike contingency.

In particular, contingency planners should assess and wargame appropriate Operational Plans (OPLAN) and develop adequate contingencies for wide spread electronic failure of "non-essential" electronic equipment as well as some, if not all, "vital" equipment. This should include assessing any reliance on surrounding infrastructure. In this way, the operational commanders will be able to envision the scope of the challenges their forces may be facing.

The DoD appears to be believe that by simply using equipment EMP hardness standards for the procurement of primary military systems, no other planning is required. Perhaps this passive defense is adequate, but at present this assumption can be not proven until a HEMP attack occurs. Since force capabilities cannot be reliably proven to be HEMP survivable, the DoD should develop robust plans to operate in a post-HEMP environment.

Counterarguments

Those who do not view HEMP attacks on U.S. forces as a valid, imminent threat use three arguments to attempt to prove their point. First, doctrines exist which prescribe that military equipment is EM hardened and if the equipment is hardened to lightning, it will survive a HEMP strike. As shown previously, determination of vital electronic equipment is performed with approximations or simulations of a HEMP environment and experts are uncertain as to the accuracy of these approximations.

The second argument is that there is no need for additional protocols for post HEMP operations. U.S. forces train, equip, organize and plan for a wide variety of consequence management scenarios. These scenarios range from loss of electrical power to operations in a radiological environment. While it is true the military does plan for a wide variety of operating environments and contingencies, no plans or doctrine exist for the potential of every electronic component malfunctioning over an area with a several hundred mile radius. Most contingency operation designs rely on having a cache of spare parts in case of malfunction. These are typically stored near the associated equipment in order to be accessible when parts become inoperable.[44] In the event of a HEMP strike, it is likely that many, if not all, of these spare parts will also be damaged or disabled. The effects from a single HEMP strike could damage or disable all spare parts to any particular piece of equipment that may reside within the theater of operations. Therefore, every contingency operation plan which relies on any piece of electronic equipment is suspect and it is unlikely that any military planner has prepared for this type of worst case scenario.

Another argument is that BMD capabilities will be able to defend U.S. forces from a missile bound for a high altitude detonation. While the idea of a BMD shield for U.S. forces and the homeland has been in existence for several decades, it is only in the last few years where technology advanced to the stage where it can successfully target and destroy a ballistic missile on any stage of its flight. There are still significant shortcomings to the BMD systems. In particular, BMD can be easily overwhelmed by coordinated, massed attacks.[45] While BMD systems will be capable of defending deployed troops and U.S. homeland from the threat of a single or a few missiles, technology is not advanced enough to ensure reliable defense from a concerted multiple missile attack from a determined adversary.

CONCLUSION

The use of a HEMP strike on U.S. forces or mainland is a credible threat. Currently, there are several state actors which have the capability to deliver HEMP. Therefore, it is imperative that the U.S. be proactive in preparing for the eventuality of an attack. U.S. forces are utilizing equipment which is assumed to be EMP resistant. However, much of the equipment is not tested for EMP vulnerability and even the equipment designated as critical is only tested once prior to fielding. No process exists for periodic testing of equipment. Further, there is no substantive joint doctrine pertaining to operating in post HEMP environments. In the area of HEMP strike survivability, the DoD is operating on invalid assumptions. These assumptions need to be reassessed, so that U.S. forces are not caught unaware and unprepared when a HEMP strike occurs.

RECOMMENDATIONS

1. Initiate an in depth review of all electronic equipment required to perform mission functions. Forces should focus on secondary and tertiary effects resulting from inoperable "non-vital" equipment to decide which systems should be HEMP survivable.

2. Implement robust periodic testing programs on all equipment procured using HEMP protective standards. Initially, this will require using pulse-current injection testing and can be augmented with different testing modalities as other recommendations are implemented.

3. Reassess the requirement for large scale free-field EMP simulators and renew testing on large equipment with multiple electronic systems in it (i.e. aircraft). Concurrently, reassess the need to develop better computer simulations to validate the requirement of large scale testing.

4. Implement periodic testing programs for equipment designated as "non-essential" for HEMP survivability. This will provide situational awareness for contingency planners as to the extent of equipment failure U.S. operational forces may experience as a result of a HEMP attack.

5. JP 3-11 should be updated to include substantive guidance on operating in a post-HEMP environment to include wide spread electronic failure of "non-essential" electronic equipment.

6. Combatant Commanders should assess and wargame OPLANS and develop adequate contingencies for wide spread electronic failure of "non-essential" electronic equipment.

ENDNOTES

[1] Collin R. Miller, "Electromagnetic Pulse Threats in 2010" (research paper, Maxwell AFB, AB: U.S. Air War College, Air University, Center for Strategy and Technology, 2005), 394-397.
[2] Samuel Glasstone and Philip J. Dolan, *The Effects of Nuclear Weapons,* Third Ed. (Washington DC: U.S. Government Printing Office, 1977), 514.
[3] Federation of American Scientists, "Nuclear Weapon EMP Effects," http://www.fas.org/nuke/intro/nuke/emp.htm (accessed 9 Sep 2009).
[4] Glasstone, 523.
[5] John S. Foster, Jr et al, *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack: Critical National Infrastructures* (Washington, DC: U.S. Congress, April 2008), 34, http://empcommission.org/docs/A2473-EMP_Commission-7MB.pdf (assessed 16 Oct 2009).
[6] Foster et al, *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack: Critical National Infrastructures*, 35.
[7] Miller, 395.
[8] John S. Foster, et al., *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack*, Volume 1: Executive Summary (Washington DC.: U.S. Congress, 2004), 47-48.
[9] William J. Perry et al., *America's Strategic Posture: The Final Report of the Congressional Commission on the Strategic Posture of the United States* (Washington, DC: United States Institute of Peace Press, 2009), 91.
[10] David Albright and Corey Hinderstein, " Unraveling the A.Q. Khan and Future Proliferation networks." *The Washington Quarterly* 28, no. 2 (Spring 2005): 111.
[11] Federation of American Scientists, "Status of World Nuclear Forces," http://www.fas.org/programs/ssp/nukes/nuclearweapons/nukestatus.html (assessed 16 Oct 2009).
[12] National Intelligence Council. *National Intelligence Estimate—Iran: Nuclear Intentions and Capabilities* (Washington, DC: National Intelligence Council, November 2007) http://www.dni.gov/press_releases/20071203_release.pdf (assessed 16 Oct 2009).
[13] Joel S. Wit, Daniel B. Poneman, and Robert L. Gallucci, *Going Critical: The First North Korean Nuclear Crisis* (Washington, DC. : Brookings Institutional Press, paperback edition, 2005).
[14] Thomas C. Riddle, "Nuclear High Altitude Electromagnetic Pulse- Implications for Homeland Security and Homeland Defense" (Strategy Research Project, Carlisle Barracks, PA: U.S. Army War College, 2004), 9-10.
[15] Perry et al., 35-37.
[16] Clay Wilson*, High Altitude Electromagnetic Pulse (HEMP) and High Power Microwave (HPM) Devices: Threat Assessments* (Washington, DC: Congressional Research Service, 2004), 15.
[17] "Comprehensive Nuclear Test Ban Treaty," 10 September 1996 http://www.state.gov/www/global/arms/treaties/ctb.html (accessed 15 Oct 2009).

[18] Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, *Report of the Defense Science Board Task Force on Nuclear Weapons Effects Test, Evaluation, and Simulation* (Washington, DC, 2005) 38.
[19] Ibid.
[20] *Report of the Defense Science Board Task Force on Nuclear Weapons Effects Test, Evaluation, and Simulation* (Washington, DC, 2005), 39.
[21] Federation of American Scientists, "Nuclear Weapon EMP Effects", http://www.fas.org/nuke/intro/nuke/emp.htm (accessed 9 Sep 2009).
[22] *Report of the Defense Science Board Task Force on Nuclear Weapons Effects Test*, *Evaluation, and Simulation*, 39.
[23] Ibid.
[24] Brent B. Bredehoft, "Commercial Off-The-Shelf Equipment Survivability in High Altitude Electromagnetic Pulse Environments," *NBC Report* (Spring-Summer 1999): 16.
[25] John Keller, "Nuclear Proliferation raises the specter of EMP attack," *Military & Aerospace Electronic*s 24, no.2 (February 2009): 28.
[26] *Report of the Defense Science Board Task Force on Nuclear Weapons Effects Test, Evaluation, and Simulation*, 42.
[27] Bredehoft, 19.
[28] *Report of the Defense Science Board Task Force on Nuclear Weapons Effects Test, Evaluation, and Simulation*, 42.
[29] Ibid.
[30] Ibid.
[31] Foster et al., *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack*, 47.
[32] Foster et al., *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack: Critical National Infrastructures*.
[33] Perry et al., 93.
[34] Keller, 24-29.
[35] Foster et al., 47.
[36] Hans M. Kristensen, Robert S. Norris, and Ivan Oelrich, *From Counterforce to Minimal Deterrence: A New Nuclear Policy on the Path Toward Eliminating Nuclear Weapons* (Washington, DC: Federation of American Scientists and the National Resources Defense Council, April 2009), 6-13.
[37] Keith B. Payne, *The Great American Gamble: Deterrence Theory and Practice from the Cold War to the Twenty-First Century* (Fairfax, VA: National Institute Press, 2008), 234.
[38] Barbara Starr, "Analysis Targeting Rethink May Lead to Non-Nuclear STRATCOM Role", *Jane's Defense Weekly*, 22 May 1993, 19.
[39] Perry et al., 90.
[40] Miller, 394.
[41] *Use of Weapons of Mass Destruction*, U.S. Code, vol. 28, sec. 2332a (2007).
[42] Chairman, U.S. Joint Chiefs of Staff, *Operations in Chemical, Biological, Radiological and Nuclear (CBRN) Environments,* Joint Publication (JP) 3-11 (Washington, DC: CJCS, 26 Aug 2008).
[43] Warren Dixon, "Survivability of Army Personnel and Materiel," *NBC Report* (Spring-Summer, 1999), 20.

[44] Charles H. Davidson, "Hemp Survivability: Exposing the Myths," *NBC Report* (Spring-Summer 1999), 3.
[45] James D. Cox, "Theater Ballistic Missile Defense needs Command and Control, It needs assets, and it needs it today" (research paper, Newport, RI: U.S. Naval War College, Joint Military Operations Department, 2007), 10.

BIBLIOGRAPHY

Albright, David and Corey Hinderstein. "Unraveling the A.Q. Khan and Future Proliferation Networks." *The Washington Quarterly* 28, no. 2 (Spring 2005): 111.

Bredehoft, Brent B. "Commercial Off-The-Shelf Equipment Survivability in High Altitude Electromagnetic Pulse Environments." *NBC Report* (Spring-Summer 1999): 16-19.

Cox, James D. "Theater Ballistic Missile Defense needs Command and Control, It needs assets, and it needs it today." Research paper. Newport, RI: U.S. Naval War College, Joint Military Operations Department, 2007.

"Comprehensive Nuclear Test Ban Treaty." 10 September 1996. http://www.state.gov/www/global/arms/treaties/ctb.html (accessed 15 Oct 2009).

Davidson, Charles H. "Hemp Survivability: Exposing the Myths." *NBC Report* (Spring-Summer 1999): 2-3.

Dixon, Warren. "Survivability of Army Personnel and Materiel." *NBC Report* (Spring-Summer, 1999): 20-21.

Federation of American Scientists. "Nuclear Weapon EMP Effects." http://www.fas.org/nuke/intro/nuke/emp.htm (accessed 9 Sep 2009).

———. "Status of World Nuclear Forces." http://www.fas.org/programs/ssp/nukes/nuclearweapons/nukestatus.html (assessed 16 Oct 2009).

Foster, John S, et al. *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack*, Volume 1: Executive Summary. Washington DC: U.S. Congress, 2004.

———. *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack: Critical National Infrastructures*. Washington, DC: U.S. Congress, 2008.

Glasstone, Samuel and Philip J. Dolan. *The Effects of Nuclear Weapons,* Third Ed. Washington, DC: U.S. Government Printing Office, 1977.

Keller, John. "Nuclear Proliferation raises the specter of EMP attack." *Military & Aerospace Electronic*s 24, no.2 (February 2009): 28.

Kristensen, Hans M., Robert S. Norris, and Ivan Oelrich. *From Counterforce to Minimal Deterrence: A New Nuclear Policy on the Path Toward Eliminating Nuclear Weapons*. Washington, DC: Federation of American Scientists and the National Resources Defense Council, April 2009.

Miller, Collin R. "Electromagnetic Pulse Threats in 2010" Research Paper. Maxwell AFB, AB: U.S. Air War College, Air University Center for Strategy and Technology, 2005.

Payne, Keith B. *The Great American Gamble: Deterrence Theory and Practice from the Cold War to the Twenty-First Century*. Fairfax, VA: National Institute Press, 2008.

Perry, William J. et al. *America's Strategic Posture: The Final Report of the Congressional Commission on the Strategic Posture of the United States.* Washington, DC: United Sates Institute of Peace Press, 2009.

Riddle, Thomas C. "Nuclear High Altitude Electromagnetic Pulse- Implications for Homeland Security and Homeland Defense." Strategy Research Project. U.S. Army War College, 2004, 9-10.

Starr, Barbara. "Analysis Targeting Rethink May Lead to Non-Nuclear STRATCOM Role." *Jane's Defense Weekly*, 22 May 1993, 19.

Use of Weapons of Mass Destruction. U.S. Code. Vol. 28, sec. 2332a (2007).

U.S. National Intelligence Council. National *Intelligence Estimate—Iran: Nuclear Intentions and Capabilities.* Washington, DC: National Intelligence Council, November 2007.

U.S. Office of the Chairman and the Joint Chiefs of Staff. *Operations in Chemical, Biological, Radiological and Nuclear (CBRN) Environments.* Joint Publication (JP) 3-11. Washington, DC: CJCS, 26 Aug 2008.

U.S. Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, *Report of the Defense Science Board Task Force on Nuclear Weapons Effects Test, Evaluation, and Simulation*. Washington, DC, 2005.

Wilson*, Clay. High Altitude Electromagnetic Pulse (HEMP) and High Power Microwave (HPM) Devices: Threat Assessments.* Washington, DC: Congressional Research Service, 2004.

Wit, Joel S., Daniel B. Poneman, and Robert L. Gallucci. *Going Critical: The First North Korean Nuclear Crisis.* Washington, DC: Brookings Institutional Press, paperback edition, 2005.