EMP impact study bottom line…

This study looks at economic output and does not attempt to estimate the costs associated with infrastructure damage, replacement costs, or secondary effects due to the loss of infrastructure (such as the cost due to the inability of a community to put out fires). For this and many other reasons, the financial impacts reported here are conservative and do not reflect the full financial impact of an EMP. That being said, an EMP impacting the Baltimore-Washington-Richmond region could be expected to result in a loss of economic activity between $34 billion and $770 billion.

While affirming the validity of the EMP Commission's dire warnings, this study also produced some very good news. Businesses and local governments can substantially reduce the threat of an EMP event by protecting approximately ten percent of their most mission critical infrastructure and facilities. The benefits would be far greater than a corresponding ten percent reduction in losses. **The three city metro area between Richmond, VA, Washington, DC and Baltimore, MD could save $25B to $185B in losses if they were to take steps to protect their most critical communications and power infrastructure. The East Coast as a whole would save ten times as much.**

Policymakers can proactively limit damage and expedite recovery times through shielding activities that protect key communications and energy-related infrastructures, water supply, and key emergency response functions.

Exhibit 6 summarizes the changes in the percentage of economic capacity damaged with and without shielding

Initial Economic Assessment of Electromagnetic Pulse (EMP) Impact upon the Baltimore-Washington-Richmond Region

by

The Sage Policy Group

With an introduction by Instant Access Networks, LLC who commissioned the report, and

A foreword by Congressman Roscoe Bartlett of Maryland -- author of the provision that established the U.S. Congress' blue ribbon "Commission to Assess the Threat to the United States from EMP Attack" in 2001, and

A preface from Dr. Alan Shark, Executive Director of Public Technology Institute

Washington D.C., Baltimore, MD, Frostburg, MD

Preface

This study is certainly an important milestone in reaching out to the nearly 36,000 local governments across our nation. It comes at a time when EMP is a distant concept competing with a dozen or so critical issue facing local government leaders at any given time.

It is my sincere hope that through this study and through documented case studies at the local level we can not only raise the visibility and importance in understanding the issues involved with EMP – but offer cost-effective and practical solutions to what some regard as the “unthinkable”.

Knowing the world is becoming more increasingly dangerous coupled with the fact our society is ever more dependent on electrical circuitry we can not ignore this key area of national security which in this case begins at the local level.

Dr. Alan R. Shark
Executive Director
Public Technology Institute
Washington, DC

www.pti.org

FOREWORD

Congratulations to the Sage Policy Group of Baltimore and Instant Access Networks (IAN) for this excellent study of the potential economic impact of an electromagnetic pulse (EMP) attack on the Baltimore-Washington-Richmond area. Congratulations also to IAN and Frostburg State University (FSU) for its pilot project on protecting critical infrastructures from the catastrophic consequences of an EMP attack, such as those described here. This study and the work at Frostburg State University is research that should be emulated nation-wide by the private sector and universities in order to find cost-effective strategies for protecting the U.S. economy from the potential for devastating destruction by an EMP attack. The U.S. Congress' blue ribbon **Commission to Assess the Threat to the United States from EMP Attack**, which I established in 2001, recommends exactly this kind of initiative by the private sector to help the U.S. government protect our economy and society from EMP.

Unfortunately, the public and all too many policymakers still do not understand that rogue states and terrorists are obsessed with obtaining nuclear weapons and EMP capability. They are well aware that if they can credibly threaten or actually execute an EMP attack against the United States that they could destroy the critical infrastructures—electrical power, telecommunications, transportation, food and water—that sustain our civilization. As the EMP Commission warned in their report to Congress: "The high-altitude nuclear weapon-generated electromagnetic pulse (EMP) is one of a small number of threats that has the potential to hold our society seriously at risk and might result in the defeat of our military forces….the degradation of infrastructure could have irreversible effects on the country's ability to support its population."

The EMP Commission found that terrorists could perform an EMP attack. A sophisticated intercontinental ballistic missile is not required to make an EMP attack. The EMP Commission found that a short- or medium-range missile, like a Scud or Iran's Shahab-3, launched off a freighter, could make an EMP attack on the United States. Iran has practiced such a launch-mode, firing a Scud missile off a vessel in the Caspian Sea.

A high-yield nuclear weapon is not necessary to perform an EMP attack that would destroy U.S. critical infrastructures. One of the EMP Commission's key findings reported to the U.S. Congress is that: "Certain types of relatively low-yield nuclear weapons can be employed to generate potentially catastrophic EMP effects over wide geographic areas, and designs for variants of such weapons may have been illicitly trafficked for a quarter-century."

Fortunately, the EMP Commission report is ultimately a "good news" story. The Commission proposed a plan to protect the United States from EMP, and provide for a rapid recovery, that could be implemented at modest cost, compared to the magnitude of the threat. The EMP Commission continues its efforts to educate policymakers and the public on the EMP threat and is continuing to develop strategies to protect the United States. The Sage-IAN study and pilot project at Frostburg State University are hopeful signs that the efforts of the EMP Commission, so vital to our national security, are bearing fruit.

Roscoe G. Bartlett (R-6-MD)
Member of U.S. Congress
Senior Member, House Armed Services Committee

Introduction to EMP

Why We Commissioned this Report
Charles L. Manto, CEO, Instant Access Networks, LLC

The goal of this study is to help the American public learn what America's current and potential adversaries already know -- one of the least expensive ways to cause the most amount of damage to America's infrastructure and economy is the use of electromagnetic pulse (EMP). But, this is not just an American problem. All other societies depending on technology-based infrastructure such as those in Europe and Asia are just as vulnerable or more so.

While affirming the validity of the EMP Commission's dire warnings, this study also produced some very good news. Businesses and local governments can substantially reduce the threat by protecting approximately ten percent of their most mission critical infrastructure and facilities. The benefits would be far greater than a corresponding ten percent reductions in losses. **The three city metro area between Richmond, VA, Washington, DC and Baltimore, MD could save $25B to $185B in losses if they were to take these steps to protect their most critical communications and power infrastructure. The East Coast as a whole would save ten times as much.** These are conservative numbers since this does not include the savings that come from maintaining situational awareness and minimizing secondary problems. This type of protection would provide another benefit since the same protection that would protect against intentional electromagnetic interference (EMI) would also protect against natural EMI such as an extreme solar storm. For all these reasons, the section on the "critical ten percent" might be the most helpful part of the study as businesses and local governments responsible for mission critical facilities work through their options for business continuity as outlined in the business continuity fire code, the NFPA 1600.

Hopefully, this study will put a financial face to the problem and suggest quick steps that can be taken to mitigate it. In addition to this study, we are doing what we can to organize companies to provide mass-produced solutions that can be quickly deployed to solve this problem and look forward to working with any company or local government agency concerned about this problem. (See the next steps section at the end of this introduction.)

Origins and Motivation for Study:

My recent interest in electromagnetic pulse (EMP) effects began with investigatory work I led establishing broadband strategies for rural Maryland counties. In coming up with financially sustainable, robust and redundant networks that would meet the vigorous needs of leading mission critical facilities that might make rural areas attractive, I tried to discover any remaining reasons why these rural areas would not be compelling locations for business continuity centers. After extensive searching, there was a particularly troubling one. This is the spill-over effect that a high-altitude electromagnetic pulse would have on rural areas hundreds of miles away from intended urban targets.

So, I began by reading the report of the US Congressional EMP Commission that confirmed my concerns. As circumstance would have it, the Commission was founded by Congressman Roscoe Bartlett who represents rural Western Maryland. I was familiar with similar issues of electromagnetic interference and "Tempest" from electronics and computer-mass storage since the 1980's, but, this report motivated deeper research.

EMP Assumptions:

In short, I tried to review as many IEEE publications and Internet articles I could find. I also interviewed as many technical experts who have worked on EMP related programs from the 1960's to the current day in order to get a consensus of what various technical experts in nuclear effects and electrical engineering thought about the issue.

From the chart of assumptions in Exhibit 2, you will see a wide range of opinions that various experts will assert would be the result of EMP events of various sizes divided into low, medium and high impact scenarios. Because of the complexity of the types of EMP events and the complexity of the ways EMP impacts a given item or environment, this appeared to be a practical way to bound the problem. What is the magnitude or extent of an EMP event? As you will see, it is "larger than a breadbox and smaller than a freight train" and all bad.

All of this information can be found in "open" or non-classified sources. You will also see that various foreign military and terrorist organizations have published their own capabilities and plans to use EMP against the US and other targets dependent on technical infrastructure vulnerable to EMP. All you have to do is your own web-based research and meet EMP experts who will, almost always, fall into the range of assumptions listed in that chart.

Preparing for the worst case while avoiding extremes

By studying a regional EMP event, we can focus on what would be a simpler attack that many more organizations could afford to do without any state sponsorship. Since many more could afford this type of an EMP assault, it represents the more likely scenarios. Within this range of regional EMP scenarios, the most likely scenarios may well be in the mid-range of impact or half-way to the low impact range. In the Richmond to Baltimore region, the impact to financial output ranges from $34B to $770B. Being conservative, I would normally think of the most likely range being somewhere between $100 and $300B. Extrapolating to the East Coast area as a whole would mean a ten times larger loss of one to three trillion dollars.

However, those with mission critical facilities, and those who are responsible for all-hazards planning must also consider the worst case scenario and have a plan to deal with it even if the worst case is not the most likely. For that reason, we have outlined the entire range of scenarios.

Those who have to consider worst case scenarios should also work through the implications of more serious scenarios this study did not address, namely continental-wide EMP scenarios. For example, in a continental-wide EMP event, all areas of the country will be similarly impacted and unable to provide as much assistance to neighboring regions. A continental scenario could also suggest dire consequences including the inability of the country to feed much of its population. Again, I mention this so that readers can see the many steps we have taken to avoid painting an extreme picture while acknowledging more severe worst case scenarios that should not be ignored.

Economic Model

We commissioned the Sage Policy Group to model the financial impact of EMP on a regional economy using the IMPLAN model. Detailed information about the model is included in the report, but, in brief, it is the same model economists use to help local and state government officials understand the direct and indirect benefits and costs associated with the location of a new corporate facility in a given area. This study looks at economic output and does not attempt to estimate the costs associated with infrastructure damage, replacement costs, or secondary effects due to the loss of infrastructure (such as the cost due to the inability of a community to put out fires). For this and many other reasons, the financial impacts reported here are conservative and do not reflect the full financial impact of EMP.

What Next:

There are a group of mission critical facility designers and managers in public safety and the private sector who are participating in the first of a series of pilot projects to discover relatively inexpensive ways to protect their mission critical facilities. The first portion of the pilot is to examine customer requirements for mass-produced EMP protected rooms. The second will be to examine requirements for mass-produced EMP protected micro-grids maximizing the use of renewable energy sources. Participants in the pilots include universities, local governments and companies listed on the project website, www.safe9-1-1.com. This project is funded in part by the Maryland Technology Development Fund (TEDCO), sponsored by Frostburg State University of the University of Maryland System, and facilitated by Public Technology Institute. If your organization wishes to join the pilot, you are welcome to contact us at rfrazier@stop-EMP.com or rmosley@pti.org.

For more information contact Robin Frazier, VP of Inter-governmental Affairs as Instant Access Networks, LLC, at rfrazier@stop-EMP.com, or Ronda Mosley of PTI at rmosley@pti.org.

If you are interested in supporting a follow-on study to estimate the costs associated with repair and secondary effects of an EMP event, feel free to contact any of the above or staff at Sage Policy Group.

Most of the government sponsored research in EMP effects were done prior to the 1990's when the Cold War ended. Much of the critical infrastructure that was not controlled by computers or sensitive devices built from integrated circuits back in the mid 1980s now is computer controlled and likely to be more sensitive to EMP. Hopefully, the work of the US EMP Commission and sporadic work of studies that continue to be published through IEEE will encourage further discovery and mitigation of the vulnerabilities of components and systems of critical infrastructure and facilities.

Initial Economic Assessment of Electromagnetic Pulse (EMP) Impact upon the Baltimore-Washington-Richmond Region

Synopsis

This impact assessment concludes that an electromagnetic pulse (EMP) attack affecting the Baltimore-Washington-Richmond region would result in economic output loss potentially exceeding $770 billion, or 7 percent of the nation's annual gross domestic product. Even under the most favorable assumptions, including both shielding and unshielding critical infrastructure, an EMP might still result in damage that would require one month of recovery and economic loss of $9 billion and $34 billion respectively.

Introduction

This paper examines the economic consequences of an EMP (electromagnetic pulse) on the economy of a metropolitan region stretching from Baltimore, Maryland to Richmond, Virginia. The Baltimore-Washington-Richmond area likely comprises only one-tenth of the economic loss that would occur to the region impacted by a regional EMP event given the likely breadth of impact. This case study is intended to be illustrative of the economic damage that EMP could inflict and presents a range of low, medium and high estimates all within bounds accepted by a broad range of EMP experts. However, this study is preliminary and seeks to raise as many questions as it seeks to answer. This study does not assess the cost to replace damaged infrastructure directly or indirectly impacted from EMP.

The study does focus upon the economic effects of EMP experienced by a region impacted by a high-altitude EMP pulse generated by a nuclear device detonated between 30-80 miles above ground impacting an area at least 500 miles in radius. This type of detonation produces rapid pulses (within nano-seconds) that elude the protection offered by normal surge protectors or lightening arrestors. A larger nuclear device detonated at 300-400 miles above ground would impact the entire continent and may also produce a substantial slower pulse (known as E-3) that can cause additional damage. In these instances of high-altitude EMP, no one would feel the heat or blast but merely experience the effects of the disruption or damage to the electronic and power infrastructure. Other intentional electromagnetic interference such as EMP can be produced from a number of sources that range from EMP generators used at close range or EMP explosives that would cover a neighborhood.

Various government reports, such as the one by the US Congressional EMP Commission and the Congressional Research Service, have confirmed the growing likelihood of EMP events of various kinds. These reports and related Congressional testimony support the contention that relatively available and inexpensive SCUD type missiles are capable of carrying the required payload that could be launched from a small ship 200 or more miles off the East Coast of the United States and detonated between thirty and eighty miles high. Any EMP-inflicted damage delivered from this altitude would extend out hundreds of miles beyond the region considered in this study, significantly complicating the recovery process and the restoration of economic activity while producing economic consequences roughly ten times greater than those impacting the Baltimore-Washington-Richmond region.

Nature of Regional Effects

There are many factors that would influence the impact of an EMP. Altitude would directly and geometrically affect the area illuminated or covered by emitted energy. As is true with sunlight at the equator vis-à-vis sunlight at the earth's poles, the area directly below the EMP would receive more intense energy than areas at the perimeter. However, an EMP pulse creates charge at the end of a line of sight that remains consequential. Objects can also be deliberately or inadvertently shielded from the EMP.

At the extreme, the type of EMP considered here delivers a burst of energy to any metallic surface within a direct line of EMP origin, particularly those exceeding one meter in length. These metal objects act like antennae and conduct a surge of energy along their span. The types of objects that act like antennae in these situations include electrical power and telephone lines, pipelines, airplanes, cars, and trucks. Because EMP bursts are typically associated with high altitudes, they are also likely to affect satellites within a direct line of EMP origin.

The damage that can be inflicted by an EMP on such objects may vary for a number of reasons, depending on how the objects accepts or 'couples' the energy, how large the item is, how delicate it is and what secondary effects may be produced within the system once it is disrupted or damaged. For example, SCADA (system control and data acquisition) devices that are connected to larger power systems can be disrupted or damaged causing management and safety measures to be defeated. This can result in larger system failures and damage. The range of effects is outlined in Exhibit 2. In general, the surge of electrical power through a circuit as a result of an EMP could disrupt or damage most electronic devices, especially those with modern low-voltage integrated circuits.

These include not only the obvious—computers and telephones—but also the electronic devices that are embedded in virtually every aspect of a productive economy. These include electronic components in automobiles, the communications and control equipment embedded in electrical power transmission systems, communications systems themselves, pipelines that deliver fuel, and electronic components integrated into ATMs. Heating and air conditioning systems, elevators, and lighting systems that enable us to work in large buildings are typically dependent on electronic controls that would be disrupted or damaged by EMP, compromising use of such buildings until those systems are restored. As mentioned, the first of several pulses acting within nanoseconds is faster than surge protectors and lightening arrestors are able to act.

Equipment connected to conductive wires such as power or phone lines (even water lines) are especially vulnerable since the long lines effectively serve as huge receiving antennae. For that reason, EMP can also disrupt or even damage basic electrical distribution equipment. Long electrical transmission lines are highly susceptible to attracting and conveying the electrical energy released by EMP. Not only are longer lines more likely to receive the EMP, the energy collected can increase along the length of the lines (according to some estimates to as much as 3,000,000 volts). Consequently, EMP is likely to cause short circuits and damage major components of the electrical power transmission and distribution system.

Because the economy is so interconnected and so dependent on electricity to power that interconnectedness, very little of the electrical, communications, or electronic infrastructure would escape unaffected. Smaller devices, unplugged from the grid, have a higher likelihood of being unaffected. However, only equipment that is shielded from both radiated and conducted pulses that meet military specifications such as the series 188-125 could be counted upon to survive without disruption or damage. Civilian critical infrastructure is largely unprotected at this time.

In sum, a high-altitude nuclear weapon carried by a SCUD type missile and detonated only 30-80 miles in height can produce an electromagnetic pulse (EMP) that would directly impact a region of 500-800 miles in radius disrupting and meaningfully damaging the electrical power generation, transmission and distribution system with the simultaneous destruction of much of the communications and electronic equipment and infrastructure that drives the economy. In other words, EMP attacks the very interconnectedness that supports and enables the economy to function at a level consistent with our current quality of life.

An EMP from a larger weapon detonated 300 miles above the central United States would impact the entire continental US and much of Canada and Mexico producing the same effect as flipping an enormous switch and simply shutting down all the economy for an extended period of time. An event impacting a single region would still make it possible for recovery support to be provided by the rest of the nation, thereby reducing the time it would take to recover.

The Baltimore-Washington-Richmond Regional Economy

The economy of the Baltimore-Washington-Richmond region is large and complex. It constitutes approximately 4 percent of the nation's output and is characterized by a substantial presence of information technology/security, biotechnology/medical research, finance and insurance, government/government contracting, health care and professional/business services.

Exhibit 1 summarizes the annual value of this economy and the contributions made by major economic sectors. In 2005, as a share of the regional economy, government constituted the largest sector—almost 20 percent of total regional product. Real estate and professional and technical services, each, contributed 12 percent or more to the regional economy.

Exhibit 1: Gross domestic product for Baltimore-Washington-Richmond region, 2005

Economic sector	Value of regional GDP (millions)	Share of regional GDP	Share of US GDP	Regional share relative to US share
Total	525,905	100.0%	4.2%	N.A.
Agriculture, forestry, fishing, and hunting	1,672	0.3%	1.4%	22.6%
Mining	1,501	0.3%	0.7%	40.6%
Utilities	10,195	1.9%	4.3%	45.4%
Construction	25,090	4.8%	4.2%	112.9%
Durable goods manufacturing	15,377	2.9%	1.8%	165.1%
Non-durable goods manufacturing	17,621	3.4%	2.8%	119.4%
Wholesale trade	21,688	4.1%	3.0%	139.4%
Retail trade	28,984	5.5%	3.5%	157.6%
Transportation and warehousing	10,556	2.0%	2.9%	68.9%
Information	26,940	5.1%	4.7%	110.0%
Finance and insurance	35,176	6.7%	3.5%	192.3%
Real estate, rental, and leasing	69,255	13.2%	4.4%	297.2%
Professional and technical services	64,383	12.2%	7.5%	164.0%
Management of companies	6,851	1.3%	3.0%	43.9%
Administrative and waste services	14,665	2.8%	3.9%	71.4%
Educational services	6,322	1.2%	5.6%	21.5%
Health care and social assistance	31,771	6.0%	3.7%	164.4%
Arts, entertainment, and recreation	3,335	0.6%	2.8%	22.4%
Accommodation and food services	13,938	2.7%	4.1%	64.3%
Other services	16,459	3.1%	5.6%	56.0%
Government	103,044	19.6%	7.0%	280.4%

Sources: US Bureau of Economic Analysis, US Census Bureau

One way to characterize the region's economy is to assess the contributions of the various sectors relative to national norms. The rightmost column, "Regional share relative to US share," compares the contribution of each economic sector in the regional economy to the contribution that sector makes the national economy. For example, only 0.3 percent of the Baltimore-Washington-Richmond regional economy is attributable to agriculture, forestry, fishing, and hunting activities, whereas that sector contributes 1.4 percent of the gross domestic product for the nation. At the other extreme, real estate, rental, and leasing activities account for over 13 percent of the Baltimore-Washington-Richmond regional economy, but just over 4 percent of the national economy. Thus, agriculture, forestry, fishing, and hunting are much less important to the regional economy than to the nation as a whole. Real estate on the other hand is three times as important to the Baltimore-Washington-Richmond regional economy as it is to the national economy. The prominence of government to this regional economy is also underscored by the fact that government's contribution to the regional economy is almost three times government's contribution to the national economy.

Reviewing the prominent sectors in this regional economy also demonstrates the region's vulnerability to economic damage from an EMP. While electricity, communications, and electronics are vital to every aspect of the American economy, it is particularly easy to see the effects of disruptions to this infrastructure on government, professional and technical services, and real estate. These sectors are highly reliant on computers and telecommunications on a continual basis. Alternatively, relatively little economic activity may be available after an EMP. Aside from a few subsistence farmers, some fishing and hunting activities, the economic impacts of disruption to the electrical power system and the electrical and electronic infrastructure could be pervasive and potentially profound.

Methodology

In an attempt to quantify those economic impacts on the Baltimore-Washington-Richmond regional economy, a series of assumptions has been made. One set of assumptions applies to disruption and damage to the electrical power system, communications systems, and other critical infrastructure that might occur as a result of an EMP. A second set of assumptions applies to the time required to repair that damage and fully restore economic activity. In combination, these assumptions can be used to estimate the ultimate effects of an EMP on the region's economic capacity.

Exhibit 2 summarizes these assumptions, which cover four types of infrastructure—the electrical grid that distributes electricity, communications systems, system control and data acquisition elements (SCADA), and various types of electronic equipment. While SCADA devices themselves may be smaller and less likely to experience disruption or damage by themselves, they are often connected to systems that have connections to larger systems and wiring that increases their vulnerability. Lack of these controls can lead to serious damage to power systems that rely on these controls for system management and safety. These types of infrastructure include both physical equipment and software that are vulnerable to damage from EMPs and that are critical to the basic functioning of the economy.

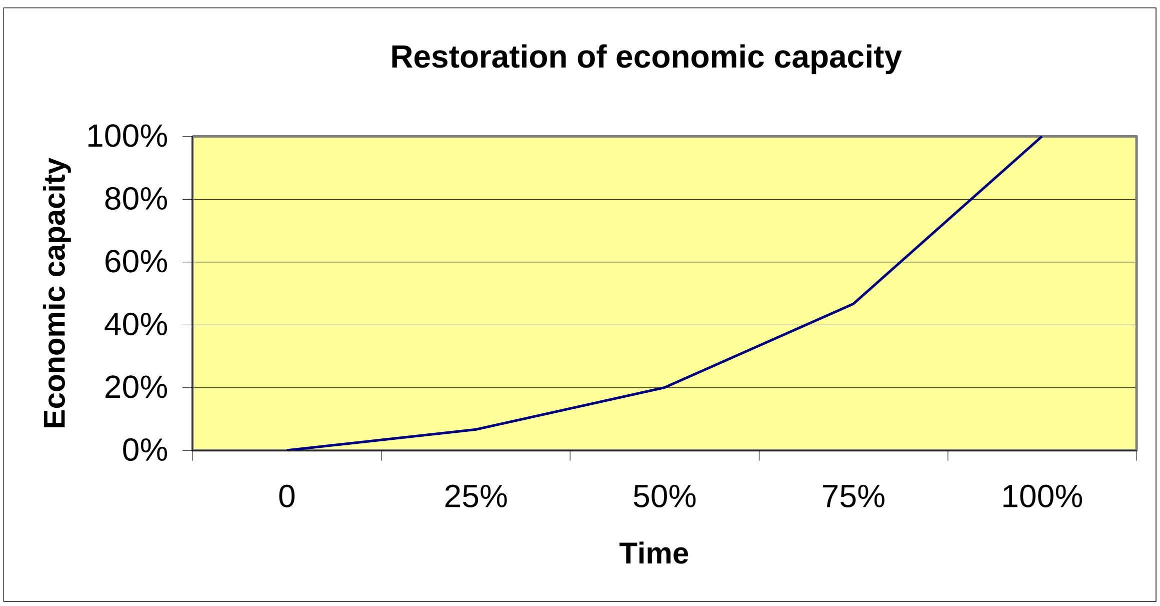
Exhibit 2: Assumptions on likely impacts of EMP

Infrastructure	*Percent of capacity damaged*			*Midpoint of replacement times (months)*		
	Low case	Mid case	High case	Low case	Mid case	High case
Electric grid						
Transformers	10%	40%	70%	2.5	13.5	33.0
Other	30%	40%	50%	1.5	5.0	10.0
Communications systems						
Large	10%	20%	50%	4.0	18.0	27.0
Small	5%	20%	50%	2.0	12.0	17.0
SCADA						
All types	5%	20%	50%	1.5	5.0	10.0
Electronics						
Large	20%	45%	70%	4.0	12.0	17.0
Small	1%	2%	3%	1.5	5.0	10.0
Source: Charles Manto, Instant Access Networks						

The assumptions are grouped into three scenarios or cases that cover a broad range of damage and damage duration. In the worst case, not only is the damage widespread, but the duration of disrepair lasts for years. In such cases, there are numerous complicating factors that slow the recovery process. The quantity of replacement equipment needed to restore the economy may quickly exhaust readily available supplies and in extreme cases existing manufacturing capacity. In such cases, the availability of skilled labor to replace and restore key infrastructure elements may also be in extraordinarily short supply. More extensive damage is also likely to be associated with high-altitude EMP that would affect areas much larger than the Baltimore-Washington-Richmond region, further complicating recovery efforts. Alternatively, in the best case, utility companies may have relatively quick access to replacement equipment and businesses may be able to order new electronic devices relatively easily.

Once damage is done restoration efforts begin. It is unlikely that restoration occurs in an orderly, linear fashion. More likely, restoration efforts will start slowly and gather speed as basic infrastructure is brought on line. This analysis assumes that restoration will occur in a geometric progression.[1] This analysis assumes that during each subsequent quarter, twice the capacity will be restored vis-à-vis the preceding quarter. Under this assumption, if the restoration of full economic capacity took four months, 7 percent of capacity would be restored after the first month. After the second month, 20 percent of capacity would be restored; after the third month, 47 percent of capacity would be restored and so on. Full capacity would be restored at the end of four months. Exhibit 3 presents a graph of this trend line of restoration.

Exhibit 3: Estimated trend in restoration of economic capacity



This analysis of EMP economic impacts also makes assumptions about the interrelationships between types of affected infrastructure. For example, damage to

[1] Admittedly, a simplifying and optimistic assumption. More likely, restoration will take place in fits and starts, with plateaus followed by relatively rapid bursts in activity as electrical and communications infrastructure comes back on line in lumpy fashion.

SCADA equipment is assumed to be highly correlated with damage to either the electrical grid or communications systems. Damage to electronic equipment is assumed to be highly correlated with damage to the electrical grid.

Similarly, damage to large and small elements of the electrical grid or communications systems is also assumed to be highly correlated. Damage to control items within a major power network may result in damage of its own. As a result, damage to the electrical grid or to communications systems is assumed to subsume damage to SCADA equipment and to electronic equipment.

On the other hand, damage to the electrical grid and to communications systems is assumed to be both independent and interdependent. Both systems will suffer direct EMP damage that is not necessarily a function of the damage rendered upon the other. However, damage to the electrical grid will degrade the ability of communications networks to function while damage to communications systems will degrade the ability of electric utilities to restore their systems.

As a result of these assumptions, the cumulative effect of an EMP on critical infrastructure is assumed to be largely determined by impacts on the electrical grid and communications systems. Cumulative damage is then determined by multiplying the remaining capacity of the electrical grid by the remaining capacity of communication systems under three scenarios. For example, under the high case, an EMP damages 50 percent of the capacity of the electric grid and 50 percent of the capacity of communication systems. The analysis assumes that the economy is then able to operate at only 25 percent of capacity (i.e., 50% multiplied by 50%).

The restoration of economic activity, once damage is inflicted, occurs over the periods of time shown in Exhibit 2 and follows the trend line shown in Exhibit 3. Under these assumptions, basic problems in restoring economic productivity include repair to the electrical power system and replacement of capital equipment critical to the communications systems infrastructure.

Economic output losses are calculated utilizing IMPLAN, an input-output econometric model that includes locally specific multipliers. Additional detail regarding IMPLAN is presented as an appendix.

Analytical Findings

The economic losses associated with this damage to economic activity are estimated on the basis of the annual value of economic activity shown in Exhibit 1. The annual value of that economic activity for the region is $526 billion, or almost $44 billion a month. For example, if half the economic capacity is unavailable for a month, the economic loss is estimated at roughly $22 billion. The analysis also assumes that in the absence of an EMP the regional economy would grow at just over one-quarter of 1 percent per month, the recent national average for economic growth (approximately 3 percent/annum).

Therefore, total regional economic activity in month 1 of the analysis is estimated at $44 billion, but by month 33 predicted monthly economic activity has grown to $48 billion.

Exhibit 4 presents a quantitative estimate of the damage to the region's economy under the three scenarios. Available economic capacity at month 0 is an estimate of the damage to the regional economy's operations immediately after an EMP. The exhibit then presents the increased economic capacity by month as full capacity is restored. For each month and each scenario, Exhibit 4 presents the accompanying estimated economic loss.

The least economic activity is lost under the low impact case. Immediately after an EMP, it is estimated that 63 percent of economic capacity would be available. One month later, available economic capacity is almost 69 percent and the economic loss in that month is estimated at just over $16 billion. After two months 97 percent of economic capacity is available, but the monthly loss is still high at almost $14 billion, while the cumulative loss reaches $30 billion. By the end of the third month, over 97 percent of economic capacity is available, the monthly economic loss has been trimmed to $3 billion and the cumulative loss has reached $33 billion. At the end of the fourth month, full economic capacity has been restored; but another billion dollars in economic losses have been suffered.

The cumulative loss has reached $34 billion. As shown in the exhibit below, the middle case and high case require much lengthier recovery periods from much greater damage, resulting in vastly greater economic losses.

Exhibit 4: Restoration of economic capacity and measures of economic loss

Month	Available economic capacity			Economic loss (billions)					
				Low case		Middle case		High case	
	Low case	Middle case	High case	Monthly	Cumu-lative	Monthly	Cumu-lative	Monthly	Cumu-lative
0	63.0%	48.0%	25.0%	N.A.	0.0	N.A.	0.0	N.A.	0.0
1	68.9%	50.0%	25.4%	$16.2	$16.2	$22.8	$22.8	$32.9	$32.9
2	92.7%	53.7%	25.9%	$13.7	$29.9	$22.0	$44.8	$32.8	$65.6
3	97.4%	58.4%	26.4%	$3.2	$33.1	$20.4	$65.2	$32.7	$98.3
4	100.0%	66.5%	26.8%	$1.1	**$34.2**	$18.4	$83.6	$32.5	$130.8
5		67.2%	27.3%			$14.9	$98.4	$32.4	$163.2
6		68.3%	27.8%			$14.6	$113.0	$32.3	$195.5
7		69.4%	28.2%			$14.1	$127.1	$32.2	$227.7
8		71.5%	29.0%			$13.6	$140.7	$32.1	$259.8
9		73.5%	29.9%			$12.8	$153.5	$31.8	$291.6
10		76.0%	30.9%			$11.9	$165.4	$31.5	$323.1
11		79.2%	31.9%			$10.8	$176.2	$31.1	$354.2
12		82.5%	32.9%			$9.4	$185.6	$30.7	$384.9
13		85.9%	34.0%			$7.9	$193.5	$30.4	$415.3
14		89.3%	35.0%			$6.4	$199.9	$30.0	$445.3
15		92.0%	36.6%			$4.9	$204.7	$29.6	$474.9
16		94.7%	38.3%			$3.7	$208.4	$28.9	$503.8
17		97.3%	40.5%			$2.4	$210.8	$28.2	$532.0
18		100.0%	42.8%			$1.2	**$212.0**	$27.3	$559.3
19			45.2%					$26.3	$585.6
20			47.6%					$25.3	$610.9
21			50.1%					$24.2	$635.1
22			54.4%					$23.1	$658.3
23			58.9%					$21.2	$679.5
24			63.6%					$19.2	$698.6
25			69.5%					$17.0	$715.7
26			75.7%					$14.3	$730.0
27			82.2%					$11.4	$741.4
28			85.2%					$8.4	$749.7
29			88.1%					$7.0	$756.7
30			91.1%					$5.6	$762.4
31			94.1%					$4.2	$766.6
32			97.0%					$2.8	$769.4
33			100.0%					$1.4	**$770.8**

Source: Sage

To gain some perspective on the value of these economic losses, the cumulative losses under the three cases can be compared to the annual regional gross domestic product and the annual national gross domestic product. As noted earlier, in 2005, the estimated regional gross domestic product for the Baltimore-Washington Richmond region was $526 billion. In that same year, the US gross domestic product was just over $11 trillion.

Exhibit 5 summarizes the time required for full recovery of economic capacity and the cumulative value of lost economic activity during the recovery period for each of the three scenarios. That cumulative value is also presented as a share of the regional and national gross domestic product for 2005. For the low case, the cumulative economic loss of $34 billion represents 6.5 percent of the annual regional gross domestic product and 0.3 percent of the national gross domestic product. At the other extreme, the high case loss of $771 billion is almost one and one-half times the annual regional gross domestic product and is equal to 7.0 percent of the annual national gross domestic product.

Exhibit 5: Economic loss relative to regional and U.S. gross domestic product, 2005

	Low case	*Middle case*	*High case*
Months for full recovery	4	18	33
Total lost value of economic activity (billions)	$34	$212	$771
Total lost value as share of annual regional gross domestic product	6.5%	40%	147%
Total lost value as share of annual national gross domestic product	0.3%	1.9%	7.0%

Other Considerations

The discussion above assumes a fairly orderly effort to restore economic capacity. It is certainly possible that chaos would complicate the restoration process, at least during early stages. Disaster response is highly dependent on communications and coordination, but EMP would likely destroy the telecommunications system or at least render it unreliable. Unlike hurricanes and other natural disasters, there is no reason to believe that EMP could be anticipated. Thus, opportunities to pre-position materials and supplies may not exist for EMP. There is also at least some historic precedence for civil disorder when electric power systems fail. A lightning strike on July 13, 1977, led to a blackout in New York City and citywide looting and disorder, including arson.

The economic impact estimates above are based on the primary impacts of EMP on the electrical system and electrical and electronic infrastructure. No consideration is given to secondary or tertiary impacts. For example, overloaded electrical circuits can give rise to fires. Under any circumstance, firefighting after EMP could be difficult as the lack of power to maintain water pressure could severely limit firefighting efforts.

Disabled telecommunications systems would cripple the ability of police or other emergency personnel to respond. Widespread damage to computer and electronic equipment would presumably result in the loss of substantial quantities of electronically stored data. At a minimum, these lost data would be a temporary inconvenience, but could also be a significant source of long-term economic loss.

One of the consequences of Hurricane Katrina was the dispersal of population and economic activity away from the impact area. As noted earlier, high-altitude EMP at a 30-80 mile altitude would result in a regional impact, but one around 300 miles above ground would impact the entire continental US and most of the industrial sections of Canada and Mexico. In the event of a continental-wide EMP, escaping the economic damage of the Baltimore-Washington-Richmond region by moving to Philadelphia, Atlanta, or Chicago simply may not be possible. In that event, there could be an entire collapse of the economy as we know it for a period of years.

There are likely to be many constraints on the ability of the region's economy to restore itself. For example, between 1,100 and 1,200 medium to large power transformers are sold in the United States each year. The largest transformers in the region take one to two years to build and additional time for deployment. The best financed utilities strive to keep as many as 10 percent of their transformers in stock since their schedules assume as long as five years to put one into use. If an EMP resulted in an instantaneous demand for 10-70 percent of replaced medium to large power transformers, it would require using all of the spares (assuming the spares were not damaged) at a minimum and 600 percent more in the worst case. It is unclear how quickly replacement transformers could be delivered to the region. Once what little stock available is used, customers would have to wait in line for their turn to receive their orders. Additional build-out of factory facilities would likely need to be made to fulfill large back logs of orders. At that point, we would hope that in the scenario presenting the least damage, there would not be a second EMP hit six months later when no spares are left.

Skilled labor would also be an essential part of a restoration effort. The mobilization of utility workers in response to natural disasters is a familiar story. An EMP, however, would likely require similar mobilizations of skilled personnel to restore the electrical and electronic infrastructure. It is unclear whether the industries and businesses required for infrastructure restoration have the organizational experience or capacity to quickly mobilize in response to an EMP disaster or to sustain the effort needed for recovery.

The financial investment necessary to restore economic capacity on a regional basis is substantial. Presumably the insurance industry would be a critical player in amassing the capital necessary for this investment. The experience of Hurricane Katrina, however, suggests that the insurance industry may at times be a barrier to recovery. Were an EMP considered an act of war, insurance claims might be legitimately rejected. For a variety of reasons, the lack of capital could substantially delay the restoration of economic capacity and increase the economic costs associated with an EMP.

The inevitable reinvestment necessary for economic recovery would itself generate economic activity. These billions of dollars would create new jobs, income, and economic output (although to a large extent outside of the United States since much of this infrastructure is manufactured elsewhere). The experience of Hurricane Katrina, however, suggests that this new and atypical economic activity would be a mere fraction of the economic activity lost as a result of EMP. As of mid-2006, the Bush Administration had sought roughly $10.5 billion for Katrina rebuilding efforts. Estimates of damage from Katrina range from $150 billion to $300 billion.[2]

A number of commentators have asserted that the long-term effect of Hurricane Katrina on the country as a whole may be insignificant. The relocation of economic activities

[2] Burton, Mark L.; Hicks, Michael J. "Hurricane Katrina: Preliminary Estimates of Commercial and Public Sector Damages." *Marshall University: Center for Business and Economic Research.* September, 2005.

outside of the area affected by the hurricane and the overall resilience of the American economy may result in little long-term economic impact. Conceivably, some might argue that the long-term impact from EMP on the Baltimore-Washington Richmond region might be similarly minimal. Indeed, EMP could have the effect of accelerating investment in capital equipment, and therefore upgrading the region's infrastructure and economic vitality. But given the central importance of the greater Washington area to the functioning of the world's monetary system, its role in providing leadership, particularly at times of war, and its outsized importance as a center of innovation, an EMP attack on this region could take decades from which to fully recover, and were the damage to impact a broader area, much longer than that.

Protecting the Critical 10 Percent

This study also assumes that any community that can protect roughly ten percent of its critical infrastructure such as energy and communications requirements will gain much more than a ten percent reduction of loss. Despite the general loss of economic output, protecting that critical ten percent of infrastructure will make it possible to maintain water distribution for drinking and fire protection and the general though minimal communications necessary to protect life and property.

To see the potential advantages of shielding, the analysis looked at the option of protecting 10 percent of the strategic components of the communications systems and creating EMP protected micro-grids that would provide communities with 10 percent of its most critical power needs. The local nature of micro-grids also makes it inherently easier to protect from EMP.

The economic impacts associated with this alternative are based on the following assumption: by shielding equipment, 10 percentage points of damage are assumed to be eliminated from the effects of an EMP (e.g., if 30% of equipment is damaged when no equipment is shielded, then 20 percent of equipment is damaged if strategic components are shielded). Because partial shielding will reduce damage to critical infrastructure, it will tend to reduce the time required to recover full economic vitality, though initial recovery would be significantly enhanced or ensured. For example, if the Baltimore/Annapolis area had protected roughly ten percent of its strategic infrastructure, such as power through the use of EMP protected micro-grids and related systems and emergency communications through the use of shielded systems and related SCADA devices, it could ensure its water supply, the functioning of its emergency communication centers and hospitals. If those essential services were not available and local government had no situational awareness or ability to respond to fires and other emergencies, then the situation would get worse instead of better and far less immediate help could be brought to bear.

The number of confounding factors influencing total recovery time is substantial. While it is assumed that shielding might have substantial near-term beneficial effect, the uncertainties of this effect for the long-term (e.g., if EMP damage were extensive) are substantial. For example, if a large number of electric transformers and much of the telecommunications system are damaged (except for EMP immune elements), maintaining situational awareness may well facilitate the initial deployment of the available transformers in the most strategic locations. However, the backlog back at the factory producing transformers might not be meaningfully improved if that backlog takes years to fulfill. Additional factory capacity would similarly take time to become available. Accordingly, the estimate long-term recovery time is left largely unchanged. Because of this approach, and the fact that secondary and tertiary effects are not considered along with damage estimates, these ranges of economic effects due to EMP should all be considered low or conservative estimates of actual damage.

Exhibit 6 summarizes the changes in the percentage of economic capacity damaged with and without shielding. The latter case is the same as shown in Exhibit 2. Only changes to the electrical grid and communications systems are shown because only these infrastructure elements are used to calculate total EMP damages. Also, note that economic capacity damage is not the same as infrastructure damage. Even if 10% infrastructure is protected in the low EMP impact scenario, equipment will be damaged and the economic impact will be less.

Exhibit 6: Assumptions on damage if some strategic equipment is shielded

Infrastructure	*Percent of economic capacity damaged with shielding*			*Percent of economic capacity damaged without shielding*		
	Low case	Mid case	High case	Low case	Mid case	High case
Electric grid						
Transformers	0%	10%	40%	10%	20%	50%
Other	20%	30%	40%	30%	40%	50%
Communications systems						
Large	0%	10%	40%	10%	20%	50%
Small	0%	10%	40%	10%	20%	50%

Exhibit 7 presents assumptions regarding recovery times with and without shielding. In general the reduction in recovery times is similar to the reduced damage, that is, proportionately; recovery times are reduced more in the least destructive scenario and less in the most destructive scenario. In the low case, recovery time is reduced close to zero for key elements because most of the potentially damaged key infrastructure is assumed to be shielded and thus to escape damage. In the high case, while the reduction in recovery time is substantial, it is still assumed that key aspects of the electric grid and communications systems will not fully recover for 2 years or longer.

Exhibit 7: Assumptions on recovery times if some strategic equipment is shielded

Infrastructure	*Midpoint of replacement times with shielding (months)*			*Midpoint of replacement times without shielding (months)*		
	Low case	Mid case	High case	Low case	Mid case	High case
Electric grid						
Transformers	0.0	1.5	27.0	1.5	13.5	33.0
Other	1.0	1.5	5.0	1.5	5.0	10.0
Communications systems						
Large	0.0	4.0	24.0	4.0	18.0	27.0
Small	0.0	4.0	15.0	4.0	12.0	17.0

With shielding, more economic capacity would survive an EMP. Exhibit 8 lists the available economic capacity immediately after an EMP with and without shielding strategic elements of the electrical grid and communications systems. The effects are substantial. In the high case, available capacity increases from 25 percent to over 30 percent. In the low case, the increase is estimated to be from 63 percent to 80 percent.

Exhibit 8: Available economic capacity with and without shielding

Post-EMP capacity with shielding			*Post-EMP capacity without shielding*		
Low case	Middle case	High case	Low case	Middle case	High case
80.0%	63.0%	33.0%	63.0%	48.0%	25.0%

With less damage to critical infrastructure and faster recovery times, shielding would also reduce the value of lost economic activity. As shown in Exhibit 9, shielding results in loss mitigation ranging from $25 billion to $185 billion.

Exhibit 9: Total economic loss with and without shielding

	Post-EMP capacity with shielding			*Post-EMP capacity without shielding*		
	Low case	Middle case	High case	Low case	Middle case	High case
Total lost value of economic activity (billions)	$9	$30	$586	$34	$212	$771
Total lost value as share of annual regional gross domestic product	1.7%	5.7%	111.0%	6.5%	40.0%	147.0%
Total lost value as share of annual national gross domestic product	0.1%	0.3%	5.3%	0.3%	1.9%	7.0%

Conclusion

An EMP impacting the Baltimore-Washington-Richmond region could be expected to result in a loss of economic activity between $34 billion and $770 billion. This estimate does not include the replacement cost of damaged infrastructure and equipment or secondary effects due to the loss of infrastructure. Policymakers could proactively limit damage and expedite recovery times through shielding activities that protect key communications and energy-related infrastructures, water supply, and key emergency response functions. This study estimates that savings associated with shielding 10 percent of critical infrastructure could reduce anticipated damage to economic productivity by $25 billion to $185 billion.

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Appendix: IMPLAN Description

IMPLAN is an economic impact assessment software system. The system was originally developed and is now maintained by the Minnesota IMPLAN Group (MIG). It combines a set of extensive databases concerning economic factors, multipliers and demographic statistics with a highly refined and detailed system of modeling software. IMPLAN allows the user to develop local-level input-output models that can estimate the economic impact of new firms moving into an area as well as the impacts of professional sports teams, recreation and tourism, and residential development. The model accomplishes this by identifying direct impacts by sector, then developing a set of indirect and induced impacts by sector through the use of industry-specific multipliers, local purchase coefficients, income-to-output ratios, and other factors and relationships.

There are two major components to IMPLAN: data files and software. An impact analysis using IMPLAN starts by identifying expenditures in terms of the sectoring scheme for the model. Each spending category becomes a "group" of "events" in IMPLAN, where each event specifies the portion of activity allocated to a specific IMPLAN sector. Groups of events can then be used to run impact analysis individually or can be combined into a project consisting of several groups. Once the direct economic impacts have been identified, IMPLAN can calculate the indirect and induced impacts based on a set of multipliers and additional factors.

The hallmark of IMPLAN is the specificity of its economic datasets. The database includes information for five-hundred-and-twenty-eight different industries (generally at the three or four digit Standard Industrial Classification level), and twenty-one different economic variables. Along with these data files, national input-output structural matrices detail the interrelationships between and among these sectors. The database also contains a full schedule of Social Accounting Matrix (SAM) data. All of this data is available at the national, state, and county level.

Another strength of the IMPLAN system is its flexibility. It allows the user to augment any of the data or algorithmic relationships within each model in order to more precisely account for regional relationships. This includes inputting different output-to-income ratios for a given industry, different wage rates, and different multipliers where appropriate. IMPLAN also provides the user with a choice of trade-flow assumptions, including the modification of regional purchase coefficients, which determine the mix of goods and services purchased locally with each dollar in each sector. Moreover, the system also allows the user to create custom impact analyses by entering changes in final demand. This flexibility is a critically important feature in terms of the Sage proposed approach. Sage is uniquely qualified to develop data and factors tailored to this project, and, where appropriate, overwrite the default data contained in the IMPLAN database.

A final advantage of IMPLAN is its credibility and acceptance within the profession. There are over five hundred active users of IMPLAN databases and software within the federal and state governments, universities, and among private sector consultants. The following list provides a sampling of IMPLAN users.

Sample of IMPLAN Users:

Academic Institutions

Alabama A&M University
Albany State University
Auburn University
Cornell University
Duke University
Iowa State University
Michigan Tech University
Ohio State
Penn State University
Portland State University
Purdue University
Stanford University
Texas A&M University
University of California – Berkeley
University of Wisconsin
University of Minnesota
Virginia Tech
West Virginia University
Marshall University/College of Business

Federal Government Agencies

Argonne National Lab
Fed. Emergency Man. Agency (FEMA)
US Dep't of Agriculture, Forest Service
US Dep't of Ag., Econ Research Service
US Dep't of Int., Bureau of Land Mgmt.
US Dep't of Int., Fish and Wildlife Serv.
US Dep't of Int., National Parks Service
US Army Corps of Engineers

State Government Agencies

MD Dep't of Natural Resources
Missouri Department of Economic Development
California Energy Commission
Florida Division of Forestry
Illinois Dep't of Natural Resources
New Mexico Department of Tourism
South Carolina Employment Security
Utah Department of Natural Resources
Wisconsin Department of Transportation

Private Consulting Firms

Coopers & Lybrand
Batelle Pacific NW Laboratories
Boise Cascade Corporation
Charles River Associates
CIC Research
BTG/Delta Research Division
Crestar Bank
Deloitte & Touche
Ernst & Young
Jack Faucett Associates
KPMG Peat Marwick
Price Waterhouse LLP
SMS Research
Economic Research Associates
American Economics Group, Inc.
L.E. Peabody Associates, Inc.
The Kalorama Consulting Group
West Virginia Research League