# ELECTROMAGNETIC PULSE (EMP): SHOULD THIS BE A PROBLEM OF NATIONAL CONCERN TO PRIVATE ENTERPRISE, BUSINESSES SMALL AND LARGE, AS WELL AS GOVERNMENT?

## FIELD HEARING

BEFORE THE

SUBCOMMITTEE ON
GOVERNMENT PROGRAMS AND OVERSIGHT

OF THE

COMMITTEE ON SMALL BUSINESS
HOUSE OF REPRESENTATIVES

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# ELECTROMAGNETIC PULSE (EMP): SHOULD THIS BE A PROBLEM OF NATIONAL CONCERN TO PRIVATE ENTERPRISE, BUSINESSES SMALL AND LARGE, AS WELL AS GOVERNMENT?

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**TUESDAY, JUNE 1, 1999**

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON GOVERNMENT PROGRAMS AND OVERSIGHT,
COMMITTEE ON SMALL BUSINESS,
*Washington, DC.*

The Subcommittee met, pursuant to notice, at 12:05 p.m., in the Parsons Auditorium, Applied Physics Laboratory, The Johns Hopkins University, 11100 Johns Hopkins Road, Laurel, Maryland, Hon. Roscoe Bartlett, (chairman of the subcommittee) presiding.

Chairman BARTLETT. Let me call our Subcommittee to order.

Good morning. It is a pleasure to welcome you to this hearing of the Subcommittee on Government Programs and Oversight of the House Small Business Committee. I would especially like to thank those of you who have traveled some distance to participate in this hearing.

This hearing is being held because the damage to our economy, businesses large and small—not to mention national security—from electromagnetic pulse (EMP) could dwarf anything associated with the well-known Y2K problem. Yet the EMP threat is virtually ignored by our government and is practically unknown to the general public.

Concerns about the proliferation of nuclear weapons and the possession of such weapons by rogue nations makes a discussion of problems associated with EMP and the magnitude of those problems a most timely topic. However, few congressional hearings have been devoted to this topic, and there is little, if any, public awareness of EMP.

As a matter of fact, I think that, previously, in 1997, we had the first ever full hearing on EMP effects in the R&D Subcommittee of our then National Security Committee. So this will be the second full hearing devoted to the problem of EMP effects.

When I was recently in Vienna, Austria, a member of the Russian Duma, Vladimir Lukin, who was the ambassador to the United States at the end of the Bush administration and the beginning of the Clinton administration—he is now chairman of their Foreign Affairs Committee in the Duma—he was one of three members of the Russian Duma that met with 11 members of the U.S.

Congress in Vienna about five weeks ago, now, to discuss a framework agreement for ending the conflict in Kosovo. He made two comments during those discussions which, I felt, were significant.

One was he said that "You are bombing Yugoslavia and your president says that it is not war. Could we drop an atomic bomb on you and say that it was not war?"

And then, of particular relevance to our hearing today, he said in the hearing, "If we really wanted to hurt you"—and Congressman Curt Weldon, who was leading our delegation, is somewhat fluent in Russian, at least he can understand it, and he knew what Vladimir Lukin was saying before the translation, and he pointed to him and said, "Do you hear what he's saying?"

What Lukin said was, "If we really wanted to hurt you, we would launch an ICBM from the sea with little chance of retaliation"—because, if it comes from the sea, how do you know who did it in today's world?—"and we would detonate the weapon at high altitude, creating an EMP effect which would shut down your country for a month or two," he said.

I am not sure if he appreciates how vulnerable we may be to that type of an EMP lay-down.

Well, I felt that that comment was a significant one, coming from a person of that stature, in particular relevance to our hearing today.

This statement did not surprise me, but, unfortunately, it would come as a surprise to most Americans. I believe it is imperative that our government take steps to defend against EMP. As with Y2K, the public and businesses need to be informed about what steps they could take to prevent or minimize damage from EMP.

It would appear that the number of contracts awarded to small businesses by the federal government for EMP research has diminished significantly in the last five years. Is the federal government placing the correct priority on the problems associated with EMP and with the possibility or probability that they may occur? Is the public being correctly informed by the federal government as to what EMP is, the magnitude of the threat and the problems associated with it?

It is hoped that the testimony today will answer some, if not all, of these questions. Also, it is hoped that the hearing and the permanent record available to the public after the hearing, both in hard copy and in abridged form on the Internet, will provide heightened awareness of what EMP is and the problems it could create.

Again, thank you all for participating in this hearing. And thank you, in the audience, for attending this hearing.

[Mr. Bartlett's statement may be found in the appendix.]

Chairman BARTLETT. Let me welcome our witnesses.

Mr. Ron Wiltsie, Program Manager, Strategic Systems, Applied Physics Laboratory, Johns Hopkins University, thank you, sir.

Dr. Gordon Soper, Group Vice President, Defense Group, Incorporated.

And Dr. Lowell Wood, senior staff member, Lawrence Livermore National Laboratory.

I have the testimony of you three and I have read it, and thank you very much.

And Col. Richard Skinner, Principal Director, C3ISR and Space Systems, Department of Defense.

Thank you all very much for being with us. Let me stipulate that, without objection, your full testimony will be made a part of the public record. If there is additional information you would like to add, we will hold the record open for several days so that you will have an opportunity to do that.

We would encourage you to, perhaps, summarize your written testimony. There will be ample opportunity during the question and answer period which follows to amplify on your testimony.

We will begin with Ron Wiltsie.

**STATEMENT OF RONALD J. WILTSIE, PROGRAM MANAGER, STRATEGIC SYSTEMS, APPLIED PHYSICS LABORATORY, JOHNS HOPKINS UNIVERSITY**

Mr. WILTSIE. Good afternoon, Congressman. Thank you for the opportunity to testify before the Small Business Subcommittee on Government Programs and Oversight.

In this statement, I will consider the phenomenology of electromagnetic pulse, or EMP as it is called, and identify specific EMP-related vulnerabilities of ground system components of the civilian infrastructure.

My full testimony discusses protection against EMP, as well as nuclear threats to space-based elements of the infrastructure. It specifically reviews threat environments and the effects of prompt and delayed radiation exposure on satellite systems. Due to the limitations of time this afternoon, I will not address those aspects in these remarks.

This view graph shows the basic phenomenology of an EMP event. The detonation of a nuclear weapon produces high-energy gamma radiation that travels radially away from the burst center.

When the detonation occurs at high altitudes, greater than 40 kilometers, the gamma rays directed toward the earth encounter the atmosphere, where they interact with air molecules to produce positive ions and recoil electrons, called Compton electrons after the man who discovered the effect.

The gamma radiation interacting with the air molecules produces charge separation as the Compton recoil electrons are ejected and leave behind the more positive ions.

The earth's magnetic field interaction with the Compton recoil electrons causes charge acceleration, which further radiates an electromagnetic field.

EMP is produced by these charge separation and charge acceleration phenomena, which occur in the atmosphere in a layer about 20 kilometers thick and about 30 kilometers above the earth's surface.

The area of the earth's surface directly illuminated by EMP is determined entirely by the height of the burst. All points on the earth's surface within the horizon, as seen from the burst point, will experience EMP effects, as depicted in this view graph.

Note that a burst on the order of 500 kilometers can cover the entire continental United States. The amplitude, duration, and polarization of the wave depend on the location of the burst, the type of weapon, the yield, and the relative position of the observer.

The electric field resulting from a high-altitude nuclear detonation can be on the order of 50 kilovolts per meter with a rise time on the order of ten nanoseconds and a decay time to half-maximum of 200 nanoseconds.

A localized lightning strike, by comparison, 10 meters away, has a higher peak amplitude, but it occurs later than the EMP, and, therefore, protection may be available.

It is important to point out that the peak amplitude, signal rise rate, and duration are not uniform over the illuminated area. The largest peak intensities of the EMP signal occur in that region of the illuminated area where the line of sight to the burst is perpendicular to the earth's magnetic field.

At the edge of the illuminated area, farthest toward the horizon as seen from the burst, the peak field intensity will be lower and the EMP fields will be somewhat longer-lasting than in the areas where the peak intensities are largest, but even there, the levels can be very significant.

The EMP threat is unique in two respects. First, its peak field amplitude and rise rate are high. These features of EMP will induce potentially damaging voltages and currents in unprotected electronic circuits and components.

Second, the area covered by an EMP signal can be immense. As a consequence, large portions of extended power and communications networks, for example, can be simultaneously put at risk. Such far-reaching effects are peculiar to EMP. Neither natural phenomena nor any other nuclear weapon effects are so widespread.

In summary, we have found that the phenomena are very real and well understood by the nuclear weapons effects community. Our strategic systems and our command and control and communications infrastructure have been designed and built to survive and operate effectively in such an environment. However, there would likely be pronounced effects on the civilian infrastructure from such a pulse.

The magnitude and extent of these effects is difficult even to estimate, and, therefore, it is probably not feasible to completely protect the entire infrastructure from the effects of such a pulse.

This concludes my statement. I hope that I have been able to give you an idea of the phenomenology associated with EMP. I sincerely thank you for the opportunity to address the Committee.

[Mr. Wiltsie's statement may be found in the appendix.]

Chairman BARTLETT. Thank you very much.

Dr. Soper.

**STATEMENT OF MR. GORDON K. SOPER, GROUP VICE PRESIDENT, DEFENSE GROUP, INC.**

Dr. SOPER. Thank you. Good afternoon, Mr. Chairman, ladies and gentlemen. I am Gordon Soper. I am the Group Vice President of a small research company called Defense Group, Inc.

I certainly appreciate the opportunity to speak today, first, as a representative of small business and as a recent graduate of 34 years of federal service with the Department of Defense.

As you noted, our formal written testimony has been inserted in the record. I will confine my brief oral remarks to a summarization of that and, obviously, be prepared to respond to your questions.

You mentioned, Mr. Chairman, that almost two years ago, the Chairman of the President's Commission on what was called the Critical Infrastructure Protection Program testified before the R&D Subcommittee of the, then, House National Security Committee, and I quote, "the threat of a major debilitating EMP attack generated by a nuclear weapon is remote at this time."

In the same testimony, the Chairman said, and I quote again, "Such an event is so unlikely and difficult to achieve that I do not believe it warrants serious consideration at this time."

I believe we are here this afternoon to keep the debate on this important issue open, and I thank you for that opportunity.

Granted, an EMP attack is not very likely and it is most certainly difficult to achieve. But the major potential consequences for our national infrastructure call for a more considered response.

I do not believe that EMP is being considered in the ongoing infrastructure protection program. And, except for hearings such as this, the government is devoting relatively little attention to this problem, in my judgment.

I know, as you do, that there are many tough choices facing our country today. We are at war. There are many and important demands on our taxpayers' dollars. In the face of these demands, is it prudent to spend some, if any, of these precious resources on a threat that, to many people, seems far too remote?

I personally believe, however remote, that an EMP attack would result in unacceptable disruption and damage to our commercial electronic infrastructure. We thus are faced with an obvious dilemma. It is without question that "unprotected" electronic systems must be considered at risk when exposed to the environments and effects of nuclear weapon detonations. Unfortunately, the level of risk and the consequences of continental-wide exposure of our electronic infrastructure are simply not calculable to any degree of certainty.

Arguments have been put forth that our electronics infrastructure is of itself so complex, so vast, and so redundant that we can be confident that not all systems will fail simultaneously when exposed to a nuclear explosion environment, particularly a high-altitude nuclear detonation.

It is fair, on the other hand, to assume that upset and damage will occur, but it is impossible on this scale to predict precisely how extensive the damage will be or to predict confidently beforehand whether the system will operate adequately after being exposed to this threat.

Perhaps as a starting point at trying to quantify a "protection" plan for a typical commercial electronics infrastructure, government and industry, working as partners, could begin with a three-point approach.

First, we must focus on protecting those elements that we cannot afford to lose. Next, we should develop a procedure for restarting those systems after distributed, wide-area system failures. Finally, we must be prepared to accept a certain degree of risk for those elements that we simply cannot afford to adequately protect. But we must know which is which.

I have worked on this problem my entire professional career. As my colleague Ron Wiltsie has said, EMP is real. EMP will be generated if nuclear weapons go off. EMP energy, with certainty, will be transmitted into our microelectronics-based society. There truly could be a serious, and, in my opinion, perhaps unacceptable, impact on our civilian infrastructure.

I believe that this matter deserves greater attention than it is being given today. We, as a nation, need a balanced, a rational, and a careful review of this issue to better understand the potential effects on our increasingly sophisticated and, perhaps, increasingly fragile electronics and the aggregate effects on the fast-growing, interconnected, and interrelated networks of systems that make up our civilian and military infrastructure.

One final word or caution, if I may. Look at us. We are getting old. Well, let me speak for myself, at least. The intellectual foundation that underpins this esoteric science is atrophying. I do not see it being replaced. This is not a growth industry for businesses, large or small.

We need your support, Mr. Chairman. You and your colleagues must help to ensure stable budgets for the limited research that is being sponsored by organizations such as the Defense Threat Reduction Agency and the work that is being done at our national laboratories. Without this support, small businesses like mine, like DGI, will not be able to hire and to train the young scientists that will carry on this effort. The threat is not going to go away.

Thank you for the opportunity to be here today. I enjoyed talking to you.

[Dr. Soper's statement may be found in the appendix.]

Chairman BARTLETT. Thank you very much for your testimony.

Tom Clancy may not know all of you, and if he knew all of you, he may not have introduced me to Dr. Lowell Wood the way he did, because he indicated to me that Dr. Wood was the smartest man hired by the U.S. Government, so I was anxious to meet Dr. Wood, and I will say that, after meeting him, I am not sure that I would argue with Tom Clancy. So, I am really pleased to have Dr. Lowell Wood here today.

Dr. Wood.

## STATEMENT OF MR. LOWELL WOOD, SENIOR STAFF MEMBER, LAWRENCE LIVERMORE NATIONAL LABORATORY

Dr. WOOD. Thank you very much, Mr. Chairman. Both you and our mutual friend, Tom Clancy, are much too kind.

Electromagnetic pulses, EMP, generated by high-altitude nuclear explosions have riveted the attention of the military nuclear technical community for three-and-a-half decades, since the first comparatively modest one very unexpectedly and abruptly turned off the lights over a few million square miles of the mid-Pacific.

This EMP also shut down radio stations and street lighting systems, turned off cars, burned out telephone systems, and wreaked other mischief throughout the Hawaiian Islands, nearly 1000 miles distant from ground zero.

The potential for even a single high-altitude explosion of a more deliberate nature to impose continental-scale devastation of much of the equipment of modern civilization and of modern warfare soon became clear. EMP became a technological substrate of the black humor of the times: suppose they gave a war and nobody came?

It was EMP-imposed wreckage, at least as much as that due to blast, fire, and fallout, which sobered detailed studies of the post-nuclear attack recovery process during the 1970s, when essentially nothing electrical or electronic could be relied upon to work, even in rural areas far from nuclear blasts.

It was surprisingly difficult to bootstrap national recovery and post-attack America, in these studies, remains stuck in the very early 20th century until electrical equipment and electronic components began to trickle in to a Jeffersonian America from abroad.

For obvious reasons, the entire topic of EMP was highly classified in those times and congressional oversight was generally circumspect and conducted in closed session. Indeed, this is the first oversight hearing of which I am aware which has taken place outside the rather cloistered confines of the Armed Services Committees and only the second open one held by any committee.

And I congratulate you, Mr. Chairman, for the extraordinary vision and dedication to bedrock, albeit less fashionable aspects of the nation's security and well being, which are evidenced by today's hearing.

The third decade following the high-altitude tests of the early sixties saw the expenditure of roughly five billion present-day dollars by the Defense Special Weapons Agency, now part of the Defense Threat Reduction Agency, and its predecessors, the Defense Atomic Support Agency and the Defense Nuclear Agency, to develop a detailed, working-level understanding of EMP and related nuclear effects phenomena and the consequences for both our own and our adversaries' military hardware systems.

Substantially larger sums were expended by other components of the DOD in order to express this understanding as force and being, primarily to defend especially vital military equipment against EMP's destructive effects.

Regrettably, these defensive efforts directed towards strategic military capabilities were not perfectly fruitful. To be sure, there were some outstanding success stories. However, a number of important military systems were quite incompletely defended and some were defended only on paper.

Even more regrettable was the fact that much military hardware and systems, especially those not considered vital to the conduct of strategic war, were not hardened against the EMP very much at all.

As a result, at the present time, our national profile of vulnerability to EMP attack is highly uneven, with large parts of our military machine and virtually all of the equipment undergirding modern American civilization being EMP-vulnerable.

Through the end of the cold war, our national posture, though unfortunate, arguably could be tolerated. Only one nation, the Soviet Union, could mount EMP attacks on the U.S. and likely only as the first major punch of a fight to the death conducted with EMP-hardened means.

Indicated responses to any EMP attack then were clear. To be sure, the maximum Soviet capability to impose such attacks still exists today, as you noted, in your opening statement, Mr. Chairman, in the strategic forces of the Russian federation.

And I unhesitatingly predict that it will continue to exist for many decades to come. Russian rulers, even the Russian version of liberal democratic leaders, if we ever see such, will not readily forsake such a whip hand over the entire planet.

Today, we watch the ongoing diffusion by purchase and perhaps by illicit routes, at least as much as by indigenous development, of nuclear weapons technologies throughout the third world. At the same time, we are compelled to acknowledge the unique opportunities for defeating both advanced U.S. forces abroad and the American nation itself, which are offered to our adversaries by EMP-centered attacks.

You have heard about the revolution in military affairs and the promise which it extends for far greater effectiveness of a post-revolutionary American military. You have likely heard far less about the classic Achilles heel which EMP poses to any information-intensive military force completely dependent for its electronic data flows on EMP-fragile integrated circuits.

There arises the regrettably real prospect that EMP weaponry, assuredly if nuclear and, perhaps, even if non-nuclear, could abruptly transform a future Desert Storm-type operation from another historic victory to a memorable American defeat.

Such EMP weaponry could also be deployed with only slightly more advanced means from space to rip up the electrical and electronic infrastructure of the American homeland. Thus, the de facto national policy of nakedness to all of our potentially EMP-armed enemies takes on ever more the character of national scale masochism. It is perverse and irrational and is assuredly not necessary or foreordained.

Relative to the two years since any committee of the House last held a hearing on this subject, it is useful to ask what has changed and what has not.

The natural laws governing EMP have not changed, nor has the EMP-oriented Russian strategic nuclear war machine. American preparedness against EMP has not improved. Rather, the operation of Moore's Law continues to endow our national infrastructure with ever higher performance and thus more innately fragile electronics.

Notably, third world nuclear weaponry capabilities and long-range rocketry both continue to advance rapidly. Specifically North Korea, a nation which has elected to lose perhaps as much as a tenth of its population to starvation over the past few years and which is still formally at war with the United Nations and with the United States, nonetheless has been allowed to gain nuclear weapons capabilities and is, even now, on the threshold of intercontinental ballistic missile ownership.

I am sure that if my colleague, Robert Walpole, could be with us today, he would emphasize those points, as he has in recent briefings, both public and private.

In short, our previously low to mediocre national position vis-a-vis EMP attacks has deteriorated remarkably over the past two years, and it is not exaggerating to forecast major peril. It is therefore heartening to see the Congress remain apprised of the EMP threat, for too much of the executive branch has seemingly resigned itself or, worse by far, is actively diluting itself, as my colleague, Dr. Soper, just quoted regarding the nature and severity of EMP.

The executive branch is currently struggling to prepare in a timely manner to cope with the so-called Y2K problem. You should be devoting far more concern to the issue of EMP effects on the nation's infrastructure, for the former, Y2K problem, now is a matter of possible inconvenience, here and there, for a duration of a few days, while the latter, the EMP threat, is truly a life-and-death issue for the nation.

In my prepared statement, I offer a sketch of a plan for a congressional initiative to harden the civilian aspects of the national infrastructure. I believe that such a plan could be implemented quickly and with modest cost and could confer major benefits to the nation's security against this most asymmetrical and unconventional of foreign threats on a few-year time scale.

This plan leverages the substantial and praiseworthy progress being made by the services in quickly and inexpensively hardening COTS, commercial off-the-shelf, hardware of many types for tactical use in EMP-shadowed circumstances.

Such progress may be made with very modest means indeed. Indeed, means such as these, the sort of means that you can pick up at the neighborhood corner electronics shop, what has kind of replaced the dime store in modern America.

I look forward to responding to any questions or comments which you and your colleagues might have regarding this plan.

For the sake of America's future in a nuclear, multi-polar world, one in which diffusion of nuclear weaponry and the means of delivering it at high altitude presently take place more rapidly than at any other time in history, I appeal most earnestly to you and your colleagues to remain seized of this vital issue, for it is one of the few which in and of itself carries the potential of military victory or defeat, perhaps even of national well being with the devastation of American civilization.

Thank you, Mr. Chairman. I will be grateful if my prepared statement can be included in the hearing record as you indicated.

[Dr. Wood's statement may be found in the appendix.]

Chairman BARTLETT. Thank you. Thank you very much.

Col. Skinner.

**STATEMENT OF COL. RICHARD W. SKINNER, PRINCIPAL DIRECTOR, COMMAND, CONTROL, COMMUNICATIONS, INTELLIGENCE, SURVEILLANCE, RECONNAISSANCE AND SPACE, OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE**

Col. SKINNER. Thank you, Mr. Chairman. I am Rick Skinner. I currently serve as the Principal Director, Command, Control, Communications, Intelligence, Surveillance, Reconnaissance and Space Systems in the Office of the Secretary of Defense.

And thank you for the opportunity to address the community on an issue that is of some importance to the Department of Defense, that is, electromagnetic pulse and, similarly, radio frequency weapons. I have submitted a statement for the record, but I would like to summarize a few key points for the Committee.

We know the detonation of a nuclear weapon above the earth's atmosphere will produce electromagnetic pulse that can, under certain circumstances, damage electronic equipment. If the equipment was built and maintained to EMP-hardened specification, the energy will be safely dissipated.

But, in the case of commercial equipment, we do not know what margins or tolerances have been built into this equipment, so it is difficult to predict the extent to which temporary or permanent disruption to the equipment's normal operation will be experienced. When we put this equipment into a complex network, it is difficult to predict how the network will respond to an EMP event.

While EMP is a threat, it is not considered a highly probable threat in today's world. The President's Commission on Critical Infrastructure Protection, led by retired General Tom Marsh, recently assessed threats and vulnerabilities to the national interest and the national infrastructure.

The commission's review included telecommunications, electrical power grids, oil and gas systems, banking and financial systems, emergency services and the continuity of government.

The commission reported that an EMP event would potentially devastate portions of the national infrastructure. At the same time, the commission found EMP is one of the least likely threats. The commission also considered radio frequency weapons. The commission concluded that our adversaries could find easier ways to do more damage than by either use of EMP or RF weapons and that, because of this, the potential for such an event was unlikely.

While an unlikely threat, EMP and RF weapons would have serious impact in military command and control systems, so we have programmed a study and developed responses to this threat. We spend approximately $25 million a year on these activities.

We have a defense technology objective, that is, a science and technology priority, for balanced electromagnetic hardening technology. The goal of this effort is to develop and demonstrate innovative and affordable methods for integrated hardening of systems and testing of military applications against high-power microwave and high-altitude electromagnetic pulse effects.

Some of the efforts underway within this technology objective are the development of a personal computer-based EMP environment and coupling software model, a generic, simple-to-install hardware kit for hardening commercial off-the-shelf computers, and a radio frequency attack detector we call a witness chip. There are other activities within this technology objective, but I thought these three may be of most interest to you.

Based on DOD-sponsored research and other studies from the government and private sector, we have found several things you may find useful. In general, consumer electronics may be upset, but often are not permanently damaged by low to moderate levels of EMP. There are more detailed summaries of our findings in this area in my statement for the record.

Number two, the move from copper communications cable to fiber optics will create a more resilient infrastructure. Fiber optics do not act as an antenna to collect electromagnetic energy and therefore reduce EMP vulnerabilities.

Three, the widespread use of automated systems and factories and medical systems has resulted in the design and manufacture of commercial equipment which is highly immune to noisy electrical environments which are similar to EMP. These design concepts are being employed in other consumer electronics as well. In fact, as Lowell showed, you can go to Radio Shack and find a RF surge protector which, in many ways, represents some of the techniques we would use to protect a system against EMP.

Number four, and most important, perhaps, is that the life cycle maintenance of EMP protection must be addressed if EMP is a concern. This means that modifications, inspections, repair actions, and operations must take into account the EMP integrity of the equipment. This additional operations and maintenance burden must be addressed whenever a decision is made to protect against EMP vulnerabilities.

You may also be interested in another effort which is now just getting underway because it is a small business innovative research activity which the U.S. army is soliciting contracts for. The effort has the title Mitigation of Magnetohydrodynamic Electromagnetic Pulse Effects on Long Lines for Missile Defense Systems and Infrastructure Protection.

The objective of the program is to identify, develop, and demonstrate low-cost techniques to protect military and critical infrastructure systems with long power and communications lines from the effects of EMP.

We would hope that the results of this and similar efforts will assist in our understanding of how best to address the potential EMP threat to our military capability and our national infrastructure.

In summary, we know that while an unlikely event EMP could inflict damage to the national infrastructure. We have taken measures to ensure the critical military command and control structures the nation depends on to respond to such an event are resilient to these threats.

There is concern that a combination of the commercial power grid, telecommunications networks in the private sector, and computing systems remains vulnerable to widespread outages and upsets due to EMP.

Detailed analysis of critical civilian systems would be useful to better understand the magnitude of the problem. We look to the government's critical infrastructure protection program to address these concerns.

Mr. Chairman, on behalf of the Office of the Secretary of Defense, I appreciate the opportunity to present these comments on EMP-related programs and look forward to your questions.

[Col. Skinner's statement may be found in the appendix.]

Chairman BARTLETT. Thank you very much.

What I would like to do first is to get on the record the recent references to EMP and such public things as what "Nuclear Train," I think, was a recent two-part series on television——

Dr. SOPER. "Atomic Train," I think.

Chairman BARTLETT. What was it?

Dr. SOPER. "Atomic Train."

Chairman BARTLETT. "Atomic Train?" "Atomic Train."

How many such references to EMP can the members of the panel remember so that we can get it on the record?

What I want to do is to substantiate that we are not giving away national secrets in talking about EMP, that it is out there in the public.

What other references can you remember? One of you had a list of these in your testimony, I remember.

Dr. SOPER. I referred to at least three. I think the first one, I remember, was a made-for-T.V. movie called "The Day After." The reference to EMP in the "Atomic Train," and a reference in a James Bond Movie, "Golden Eye," and at least one other, "Pandora's Box," I think. And there have been a number of articles in Popular Mechanics-like publications that talk about EMP.

I have written a few articles for publications like Defense Electronics in an effort to, at least, demystify EMP and make the public aware of this relatively esoteric subject.

But, at any rate, attempts have been made at bringing this issue to the public. There are no formal programs that are sponsored by the government. FEMA, the Federal Emergency Management Agency, for example, might be one that you would expect. I just do not know. But those few that I have mentioned are the ones that I remember where EMP was mentioned.

And as I think I said in my written testimony, and my colleague Dr. Wood would appreciate this, some severe liberties were taken with the physics and the description of EMP in some of these movies and publications. So one needs to be careful. While they may be describing EMP, the underlying physics would perhaps not pass a graduate exam at the University of Tennessee, my alma mater.

Chairman BARTLETT. Dr. Wood?

Dr. WOOD. Mr. Chairman, I also was concerned that, since this was an open hearing, that matters be traceable to public documents of the government, and the one that I would particularly commend to the Committee's attention is a book, actually a series, that were sponsored for many years by the old United States Atomic Energy Commission, edited by Samuel Glastone and Philip Dolan, entitled "The Effects of Nuclear Weapons."

This is a volume of most of a thousand pages which discusses nuclear weaponry effects from the standpoint, if you will, of a military officer or a senior policy-oriented civilian to tell them, basically, how nuclear weapons perform and what their effects in the environment are.

There is a quite extensive discussion of EMP there, including some of its quantitative features, and so it is certainly feasible to speak in public rather extensively and in fair detail of what the effects of EMP are.

The matters which the government still considers classified are the details in respect to how nuclear weaponry, particularly specially designed nuclear weaponry, might produce particularly large bursts of EMP or bursts of EMP that have very unusual characteristics that could defeat defensive means. Those are the things, and the only things, which are still withheld in any public debate.

Chairman BARTLETT. Recently in the news was an indication that among those things which the Chinese have been able to secure from our national labs was the design of an EMP-enhanced weapon. That is correct? Are any of you familiar with that?

Dr. WOOD. I am not able to speak to that, Mr. Chairman. I am sorry.

Chairman BARTLETT. Okay. This was in the public press that this was one of the several things that they, presumably, had been able to get from our national laboratories.

Two other public references——

Dr. WOOD. I will be happy to speak to you about that privately.

Chairman BARTLETT. Yes. All I am referencing is what was in the public press, that that was one of the things which they were able to get from our national laboratories.

I first contacted Tom Clancy because in one of his books, he had an EMP scenario, and when I first began an exploration of this, I knew Tom Clancy did good research, and so that is how I got introduced to Dr. Wood, when I called Tom. He suggested he knew little more than was in his book but that I could learn a great deal more from Dr. Wood.

A number of years ago, there was a series on television called "Amerika," spelled with a K. You may remember this series. It was a made-for-television series. It was several episodes, several different evenings were spent with the whole scenario. And some bombs were dropped on Central America and one of the things that happened was that cars quit running, obvious reference to EMP effect. So you can also find it there.

I just wanted to, at the beginning, indicate that this was in the public knowledge if one chose to look. Although most people are not aware of it, it is there, it is out there. We are not talking about something that the world does not know.

Mr. Wiltsie, I wonder if you could show for us again your EMP ground coverage slide. Could you do that? Would that be feasible to show that?

Mr. WILTSIE. Can I have the third slide, please?

Chairman BARTLETT. This is the one. The Rumsfeld Report indicated that they had determined that third world countries were now taking everyday surface ships and modifying them so that you could put missile launchers, like a Scud launcher, on one of those ships. As I understand it, the common Scud gets an apogee of about 180 miles, is that correct?

Dr. WOOD. The extended range Scuds at maximum range, sir, the ones that we saw in Desert Storm, got to about 150 kilometers. The M–9s that the Chinese have been selling into the third world will, indeed, get to above 200 kilometers altitude when you are firing at maximum range. So, yes, 150 to 250 kilometers are the peak altitudes.

Chairman BARTLETT. Which of those circles there would indicate the range for the coverage for a Scud?

Mr. WILTSIE. The tan circle is the height of burst of about 100 kilometers, Congressman, and so it is somewhere between the inside of this and about the middle of it, so you get some significant coverage over the continental United States with that type of weapon.

Chairman BARTLETT. But launched from the sea, it could not get that far inland? How far inland could it get, at apogee?

Mr. WILTSIE. Well, it depends on the launch platform and how close you bring it to the continental United States and what the capability of the launch system is that you have on board that merchant ship.

I would point out that, early in the U.S. ballistic missile program, the sea-launched ballistic missiles, we fired some from merchant-type ships for test purposes prior to going to sea.

Dr. WOOD. Basically, Mr. Chairman, if you move that surface zero from where it is over Kansas or Nebraska, you move that back to Washington D.C., it would be feasible for a ship on the high seas launching a Desert Storm-type Iraqi Scud to put that surface zero anywhere in the Virginia-West Virginia area, as I said, firing outside American territorial waters.

Chairman BARTLETT. So if the center of that circle is now the West Virginia area, it would cover most of the eastern United States.

Mr. WILTSIE. Yes.

Chairman BARTLETT. Perhaps excluding south Florida and Maine?

Dr. WOOD. Well, we used to refer in cold war days to a blue-preferred red attack, Mr. Chairman, and that is the West-Coasters preferred anti-American attack. You drop it on the East Coast.

Chairman BARTLETT. The point that I am trying to make here is that the capability exists for a third world power with a commercial ship modified to put a launcher on it, Scud launchers, essentially every third world nation has a Scud launcher, and if they do not have an atomic weapon, they perhaps can get one from a Russian who has not been paid for the past six months. They are becoming more widely available. Several countries have them now.

The point I was trying to get was that this is not a potential for 20 years from now. It is a potential for here and now, is it not?

Dr. WOOD. The Rumsfeld Commission last summer, Mr. Chairman, specifically raised that possibility. Since that time, you have been able to read in the newspapers, that the Iranians are testing just such a missile in the Caspian Sea, that is to say a sea-launched Scud-type missile.

We are also aware of the fact, sir, that last summer, the Iranians tested the Shahap III missile, which had a range of 800 kilometers, which is greater than that of the Iraqi missiles in Desert Storm.

So there is a specific example of a nation which the current administration repeatedly has cited as a leading state supporter of international terrorism which the administration does not credit with currently owning nuclear weapons, but does own nuclear-capable missiles which have a range greater than the Iraqis demonstrated in Desert Storm and which missile classes are being tested in barge launches in the Caspian Sea, and it is very difficult to believe that they intend to deploy those missiles in the Caspian Sea.

Chairman BARTLETT. Thank you.

Mr. Wiltsie, if you were to hypothesize a launch from the sea—and, by the way, Vladimir Lukin indicated that there would be little risk of retaliation if the launch occurred from the sea simply because you would not know which of the dozen countries capable of the launch had actually done it, so who are you going to incinerate if there is a launch from the sea—but if you are going to hypothesize——

Dr. WOOD. That is a classic example, Mr. Chairman.

Chairman BARTLETT. Yes, sir.

Dr. WOOD. Chairman Lukin, of course, as you indicated in your statement, has a very extended background with respect to Soviet, and now Russian, national security matters. And that is a prospect which was very extensively considered in times past.

It is difficult to take his statements as anything other than coming from a very knowledgeable expert on the other side.

Chairman BARTLETT. Thank you. Yes, he was the ambassador, as I mentioned, at the end of the Bush administration, the beginning of this administration. He is now chairman of foreign affairs.

Dr. WOOD. He is generally considered to be one of the most capable Soviet ambassadors in recent decades.

Chairman BARTLETT. Thank you.

Dr. WOOD. If I might mention one other item referring to the Duma debate. In the Duma debate a few years ago, I believe less than three years ago, with respect to whether the Russian federations should ratify the comprehensive test ban treaty, one of the statements which was offered, first to Mr. Lukin's defense committee of the Duma, and then in open debate in the Duma, from the Russian defense minister was a statement that the comprehensive test ban should not be ratified by the Russian confederation because it would cut off the vital phases of development of enhanced EMP weaponry by the Russian federation, and this was cited by the Russian defense minister as, from his standpoint, one of the primary reasons why the CTBT should not be ratified by Russia.

Chairman BARTLETT. Thank you.

I would like to return for just a moment to the coverage slide and ask Mr. Wiltsie——

Mr. WILTSIE. Can we dim the lights again, please?

Chairman BARTLETT. If we were to hypothesize four launches, northeast, southeast, northwest, and southwest, with a Scud, which is now available to a lot of different powers, would that blanket all of the United States? It would appear to me that it would, with considerable overlap.

Mr. WILTSIE. There is a good possibility that it could. You would have to be careful where you placed your launch platforms.

You would have to, perhaps, get a launch platform into the Gulf of Mexico area and up off the northwest coast of the United States, but I think if you are using merchant ships with Scud-like missiles, yes, you can largely cover the continental United States with four simultaneous launches and you will probably have some increased effect in some areas by the multiple nature of the launches. More than one launch causes you more severe problems.

Chairman BARTLETT. Dr. Soper, what sort of intensity of laydown would you expect from that kind of a scenario?

Dr. SOPER. If I remember correctly, some work was done by the Defense Nuclear Agency, now part of the Defense Threat Reduction Agency, that posed the question of how many high-altitude detonations would it take to essentially blanket the United States with EMP in the tens of kilovolts per meter range?

And I know the answer to that, and the reason I am not stating it is because I do not remember whether it is classified or not and I will be glad to address that with you off line.

Chairman BARTLETT. I have seen, Dr. Wood, public statements to the effect that a single large—that is a megaton or more—weapon detonated at 300 miles high over Nebraska would produce at the margins of our country 10 to 20 kilovolts. Is that not correct?

Dr. WOOD. It is certainly the case, sir, that megaton-class weaponry is capable of doing that. However, it should be realized that it is also possible to do that with specially designed weapons whose yield would be much, much, much less than a megaton.

Chairman BARTLETT. It might be worth noting that the weapons that the Chinese have on 18 of their Long March missiles which, presumably, are capable of reaching our country, are 4.4 megatons, correct?

Dr. WOOD. That is the approximate yield which is publicly attributed to them, sir, but the point is that the EMP yield of a nuclear weapon is not at all well correlated necessarily with its explosive yield. You can get much larger yields with a specially designed 10 kiloton device, you can get much larger electromagnetic pulses with a specially designed kiloton device than you can with a crudely designed 10 megaton device. The EMP output of a device, its EMP consequences, are very poorly related to its total explosive yield.

Chairman BARTLETT. But for the record, is it not true that EMP is an unavoidable consequence of every nuclear explosion?

Dr. WOOD. Indeed.

Chairman BARTLETT. So whether you are aiming for it or not, you get an EMP——

Dr. WOOD. Oh yes. You kind of get the base output, no matter what you do. If you wish to maximize the EMP consequences of a nuclear explosion, you can make those consequences be very, very severe or quite modest yield. But, in general, for a given class of device, as you increase the yield, the EMP consequences of it will increase, but the point that I am trying to make is that if you hop from class to class of nuclear weaponry, you can find classes in which the EMP yield can be very, very large, even though the explosive yield is very modest indeed.

Dr. SOPER. One aspect that we should remember is, for the most part, we are focusing on what is generally called high-altitude EMP. The unique aspect of a high altitude nuclear detonation is that it can be "see" horizon-to-horizon and places at risk, simultaneously, many electronic systems.

Bursts on or near the ground produce localized, but very intense, electromagnetic environments as well that can couple into electrical conductors, antennas and the like. It does not have the great expanse, of course, that a high-altitude nuclear detonation does.

Dr. WOOD. That is a very good point of Dr. Soper's. My remarks with respect to different classes of nuclear explosives and their EMP consequences were concerned with high-altitude bursts that have very large area coverage.

Mr. WILTSIE. I would point out, Mr. Congressman, that DTRA, in their old days, it was DNA and so forth, did some calculations that gave you 20 kilovolts per meter for a burst at about 300 kilometers over the large area of the United States and the only thing

I am not sure of is what the yield was that they used on that weapon. Those calculations have been done.

Chairman BARTLETT. What kind of damage would you expect from 10 to 20 thousand volts, that is 10 to 20 kilovolts? What would you expect in microelectronic equipment?

Dr. WOOD. I know of no microelectronic equipment, per se, that could stand anything like that type of electric field. As I commented in my opening statement and also in my prepared statement, modern microelectronics are becoming ever more fragile with the passage of time, as far as their intrinsic hardness is concerned, because the elementary devices, the individual transistors, become ever smaller and, thus, it takes a smaller and smaller amount of EMP-imposed power to destroy those devices.

Now, it is indeed the case that, because of the very high frequency and that ever higher frequency at which such devices operate these days, that it has become highly desirable to wrap them in metallic wrappers, if you will, to keep one device from generating electromagnetic interference which would impair the proper operation of the neighboring device.

The Federal Communications Commission, for instance, requires certain types of decoupling and of wrappers, conductive wrappers, for such equipment. And so you have two countervailing effects: the devices themselves, modern integrated circuits, are ever more fragile, but, because of their high frequency of operation, they are wrapped in things which make them ever more robust.

And so the product of a very large number and a very small number is what gives you the net EMP hardness for a system. That number, frankly, can wander all over the map. Some systems can be amazingly tough, even though they are composed of exceedingly fragile components inside them. Some systems which, on the other hand, are not extremely well decoupled from the environment may be very fragile, indeed, even though they have rather old components that are intrinsically fairly robust.

So you really have to test individual pieces of equipment and you have to test systems and, very, very crucially, Mr. Chairman, you have to test them in realistic circumstances. Some of the testing I have seen done is kind of comically bad in that they will take a piece of computer gear and they will take all the cables off of it and they will set it in the test environment and they will not plug it in to a power line and they will test it and then say, "My goodness, look how robust it is."

But if you bothered to plug in an a modem or you bothered to plug in a power line or, particularly, if you bothered to turn the power on so that the computer was running at the time, you would discover a very, very different EMP vulnerability and it would be a much more severe vulnerability.

So it is important to look at systems and it is important to look at them in realistic operating conditions, not contrived testing conditions. And some of the contrived ones are remarkably misleading. But in realistic testing conditions, you have to look at them and the good news is it is pretty easy to do that.

Chairman BARTLETT. Dr. Soper.

Dr. SOPER. I think Dr. Wood hit on a very important comment that I would like to amplify a little bit. Namely, it is engineeringly simple to design an EMP-protected enclosure. Volumes the size of this room are not difficult to protect and at a not-exorbitant cost. But the one thing that Dr. Wood pointed out, and I think needs mentioning, is that we must have the ability to test the improvements that we have made, in order to demonstrate that the protection that you have provided do, indeed, provide that protection.

When we were doing underground nuclear testing—at least the Department of Defense nuclear testing on effects—not one time did we put a system underground that we had tested before or had designed as well as we could, that we did not find a problem. Not one single time.

And analysis allows you to learn more and more about what you know about and absolutely nothing about what you do not know about. It is the unknown unknowns that, quite often, create the large problem.

And as I scan the audience, I see a few people here, today, that helped in the very basic EMP protection designs that, if used and if tested—and there are ways to test those designs so I do not mean to imply that EMP needs to be tested in an underground environment—that if it is realistically tested, you can, with some degree of certainty, know that the equipment inside will survive.

It is obviously unrealistic to test at one time an entire continent-wide electronics-based infrastructure. You could do it with a high-altitude nuclear test, but I suspect that that is environmentally not wise.

Dr. WOOD. You will get to do the environmental impacts statement on that.

Dr. SOPER. So I think what Dr. Wood is pointing out is that there are ways to approach the problem with EMP and there are ways to protect against it, realistically and cost-effectively and with some surety, but it needs to be done carefully and it, in general, is cheaper if you do it at the very beginning than if you do it later in its life cycle when you decide, “Oh, there is a problem here and I need to go back and protect.”

Dr. WOOD. As a specific example, Mr. Chairman, the type of EMP robustness that is associated with power line surges is feasible to gain for the cost of two or three dollars worth of parts. Literally, you can protect a computer system—a personal computer system, for instance, may cost two or three thousand dollars—for a tenth of a percent if you design it in from the beginning. The total cost might be has high as 1 percent.

This is discovered not only by people who are working commercially but even those folks in the armed forces that trying to take commercial equipment and adapt it for military purposes, hardening against EMP, discovering that very modest changes, things that can be done quickly and easily even after the equipment is manufactured and is sold to the DOD, discovering that costs of the order of 1 percent, 2 percent, 3 percent, are not at all atypical as far as gaining the EMP hardening is concerned.

It is the doing of it and the testing and the certification of it which is the really important thing. Dr. Soper made a very crucial point and that is when military systems over the last few decades were hauled into specially engineered environments so they could be realistically tested for EMP, in spite of intensive endeavor beforehand to make sure that those systems would be robust, they never passed. They always failed.

They had to be fixed and sometimes fixed again and sometimes even fixed a third time before they would pass that type of rigorous full-op system scale examination, you know, with Mother Nature conducting the exam and DNA coming in afterwards and issuing the score sheet.

So it is important to not only view as modern technology—and some of these components here did not exist 20 years, these very high-tech lightning arresters, these little green objects—it is important to exercise prudence by designing them and putting them into your equipment, but it is also crucial to test to make sure that you did the right things and that you did the right things right as you have done it.

Small errors in attempting to secure EMP hardness can have ruinously large consequences. Good intentions do not quite do the job with respect to EMP robustness.

Chairman BARTLETT. I would like to spend just a moment on looking at this hardening.

It is my understanding that the rise time of an EMP pulse is measured in nanoseconds, which is very, very much faster than lightning, for instance, that usual lightening arrestor probably won't work, the surge protectors for lightning will not work as a surge protector for EMP. That is correct?

Dr. WOOD. The fast component of EMP is, indeed, just as you have described it. It rises much, much faster, many orders of magnitude faster, than does the electric field associated with a standard lightning bolt. Yes, sir.

And so standard lightning protective means have little, if any, efficacy as far as EMP defenses are concerned. They are just too slow and, indeed, in many of our military systems that are designed to exploit EMP effects, a lot of attention is given to making the rise time be exceedingly brief because you can step around many types of EMP defenses by having as high a frequency a pulse, as fast a rise time as you possibly can generate.

Chairman BARTLETT. But are there surge protectors that will respond quickly enough to protect from EMP?

Dr. WOOD. Very definitely.

Dr. SOPER. Yes.

Chairman BARTLETT. But they are generally not used, is what you are saying?

Dr. WOOD. They were very difficult to lay hands on a quarter century ago. They were expensive, they were finicky, they were not terribly robust, and so forth.

General advance of the technological base and, specifically, requirements for protecting very delicate electronic equipment have made those components available, not only readily available these days, but exceedingly cheaply available.

As I said, components such as these, very fast surge clippers, you simply could not buy a quarter century ago, almost for love nor money, DOD could buy them, but that was about all. Nowadays, everybody walks down and buys them for a buck nineteen at retail in single quantities. And they are remarkably effective as far as clipping the pulses associated with EMP on power and signal lines both.

Chairman BARTLETT. One of the reasons that we are paying little attention to this as a nation is that, in the view of many people, the probability is very low and, therefore, it is not worth the effort.

I remember that Tom Marsh, in our hearing just less than two years ago now indicated that—and he was chair of the Presidential Commission on Critical Infrastructure—he indicated that they had looked at EMP but decided it was not a high probability and, therefore, they did not look at it any further.

I suggested at that hearing that, if he had not done so already, that I was sure when he went home that evening, he was going to cancel the fire insurance on his home because it was not much probability that his home was going to burn and therefore why would he commit these resources to buy an insurance policy on the home?

I want to come back to the coverage and the Scud launchers and so forth, because I have the feeling that if we had an enemy that had only four nuclear weapons, that he could probably do us greater harm by exploding them at altitude than he could by dropping them on any four places in the country. Would that not be correct?

Dr. WOOD. Of course. That is self-evident.

Chairman BARTLETT. Now, if that is self-evident and since more and more of our potential enemies are——

Dr. WOOD. You do not have to take my word for it. You could ask Mr. Lukin, Chairman Lukin.

Chairman BARTLETT. Yes, I am sure he understands that. But if more and more of our enemies——

Dr. WOOD. Everybody understands that who has looked seriously at the matter, and those that dismiss it and say that it is a negligible threat and so forth are simply whistling past the graveyard, Mr. Chairman.

Chairman BARTLETT. My concern is that this is not a really unlikely occurrence. If we have enemies that are bent on doing us harm, all of them now have Scud launchers. Several of them have nuclear weapons. Those who do not have them will be able to acquire them within the foreseeable future. And if, in fact, we are as vulnerable as many people think we are to an EMP lay-down, why would that not be the attack of choice? This is, I would think, the ultimate, asymmetric terrorist weapon, is it not?

Dr. WOOD. There are, as I said—you know, from the cold war days—the blue preferred red attacks and an EMP attack is the blue unpreferred red attack. It is the thing which the defender least wants to face and so the defender is very strongly inclined to say let us just pretend it will never happen.

The fact of the matter is that in every war game, every strategic war game that I ever either was present at or read about, the Soviet attack on the United States always commenced with an EMP lay-down. It did not do it because it was traditional. It did it because it was so insanely effective.

You know, what do you do with your first few bombs at the very beginning of a major attack? You do the EMP lay-down—frankly, you use them in any way that most strongly damages your opponent, the guy that you are attacking. And the way that they always went was EMP lay-down. They did not use them to attack SAC headquarters in Omaha. They certainly did not waste them on Washington, DC. They always went for the EMP lay-down, and it was because it was a much more effective way to expend the first half-dozen or dozen major explosions than any other way there was. And that persists to the present time.

The laws of nature have not changed. The United States vulnerability to EMP has not changed. Nothing has changed. But this is such an unpreferred red attack—and I am speaking of generic red, here, against generic blue—it is so strongly unpreferred that the way that is becoming fashionable to cope with it simply to deny it, to say, "Surely this cannot be. Mommy, make this not to happen."

Chairman BARTLETT. Let us go back in history to our first high-altitude burst where we learned about EMP. One of them was at the Johnston Island, the Starfish, was it, in 1962?

Dr. SOPER. Yes.

Chairman BARTLETT. Was there one at Kwajalein Atoll, too?

Dr. SOPER. I do not think so.

Chairman BARTLETT. How many of these high-altitude bursts have we real experience with?

Dr. SOPER. We had four in 1962 and two in 1958. Teak and Orange in 1958 and four in 1962, Starfish being the highest, and it was a 1.4 megaton burst at 400 kilometers. Checkmate, Kingfish—and what was the other one—Checkmate, Kingfish, Starfish and—at any rate, there were four at different altitudes.

Chairman BARTLETT. And it was roughly 800 to 1000 miles from Hawaii?

Dr. SOPER. Eight hundred.

Chairman BARTLETT. Eight hundred miles from Hawaii?

Dr. SOPER. Starfish was off Johnston Atoll. Yes.

Chairman BARTLETT. And what were the effects on Hawaii of that burst?

Dr. WOOD. As I said in my opening statement, sir, they shut down radio stations, street lighting systems, they stopped cars, burned out telephone systems. Those are the effects which are documented in public and referred to in "The Effects of Nuclear Weapons" by Glastone.

Chairman BARTLETT. We did not have very much in microelectronics, then, and I know of no computers in cars. Were that to be repeated today, what would the effects be?

Dr. WOOD. It clearly would be much more severe, because the electronics that would be subjected to that electromagnetic pulse are much more vulnerable to them.

Dr. SOPER. And I am not sure this is useful, but remember, the same nuclear detonation at high altitude that creates EMP on the ground also affects satellites within line of sight of the burst as well as—we know from those high altitude tests—disrupts the communication channels that link the ground station to the satellite.

So one should not limit your consideration—if you are going to do a balanced study of this—from EMP as the only damaging effect from high-altitude nuclear detonations, but rather recognize that other bad things happen as well, if that gives you any comfort.

Chairman BARTLETT. Let us turn for a moment to the satellite picture. How much more intense is the radiation, the effects from this high-altitude nuclear explosion, than the worst solar storms that we see that disrupt our communications?

Dr. WOOD. On the ground or in space, sir?

Chairman BARTLETT. In space.

Dr. WOOD. In space, the flavor of damage that comes at you that is like EMP is really of a rather different sort. There is no atmosphere to generate the electromagnetic pulse, but there is the spacecraft itself, and what you will realize there is called system-generated EMP. It is the consequence of having matter around in the immediate vicinity of the electronics that you are concerned about and the effect, as I said, is different in kind as well as different in magnitude.

It generally imposes a much more severe threat, as far as electronic survival is concerned, at a reference distance from a reference explosion, because, as I said, you are kind of in the radiating region itself. The spacecraft is intercepting the radiation from the device, it is converting it into radio frequency and microwave frequency electrical energy within the spacecraft and, unless you are extremely careful, major chunks of your electronic plant tend to die on the spot, die instantly.

Chairman BARTLETT. These, as I understand, are called prompt effects?

Dr. WOOD. These are the prompt effects, sir. There are also the delayed effects associated with the radioactive debris from the nuclear device remaining in the magnetosphere of the earth, and that radioactive debris "pumps up," is the popular term, and it is a fairly accurate description—it greatly augments the flux particles in the Van Allen belts of the earth, and these enhanced populations of high-energy particles tend to destroy spacecraft on a continuing basis.

Anything from minutes to weeks of damage are done before the electronics will actually fail. Instead of failing on time scales of 10 or 20 years, they fail on time scales of tens of minutes to, typically, a few tens of days.

Dr. SOPER. I call your attention to an article in "Defense Electronics". It is not all that old. It was written in 1995. "Satellite Survivability in Space: Don't Count on It." It is, I think, one of the early attempts at describing the phenomena that Dr. Wood just mentioned; not only are there prompt effects but delayed effects, as the satellites continually pass through these pumped up Van Allen belts, and lists in here the degradation of many of the well-known satellites. It, perhaps, is an interesting article to read and it is scientifically correct.

Chairman BARTLETT. Without objection, we will include that as a part of this record, because I think that it is relative to what we are talking about.

[The information may be found in the appendix.]

Dr. WOOD. It is relevant, sir, both with respect to civilian and military satellites, and, of course, there is a wealth of both of those. The very large majority of satellites in earth orbit that are functioning these days are civilian, and they carry everything from your TV programs to a good chunk of the traffic on the Internet. They provide environmental monitoring and, of course, there are the scientific research satellites.

All of these are potentially vulnerable to both the prompt and the delayed effects of nuclear explosions at high altitude and, as Dr. Soper has pointed out, the links on the ground, the so-called ground stations with which one gives commands to satellites, sends data up to satellites, and receives data from satellites—those ground stations are exceedingly sensitive, necessarily, because the satellites do not have the ability to transmit or receive power readily because of the small antennas they must necessarily deploy.

Ground stations are exceedingly sensitive and they are among the ones which can be expected to die most readily from the effects of electromagnetic pulse on the ground.

And so when we speak of civilian infrastructure, we should be reminded that key portions of civilian infrastructure exist in space these days, and those portions, both because of their fragile ground links and because the satellites themselves are fragile, can be expected to be highly vulnerable to even a single high-altitude nuclear explosion.

Chairman BARTLETT. How many satellites do we have that are hardened to EMP?

Dr. WOOD. We have the military satellites, sir.

Chairman BARTLETT. How many of those are there? Two? Is that correct? The two MILSTAR satellites?

Col. SKINNER. Certainly, the two MILSTAR satellites have been hardened specifically against this kind of threat, but that is not to say that the other defense satellites are not hardened as well. For example, our early warning satellite systems must be hardened against the eventuality that an adversary would try to preempt our ability to detect their attack on the United States.

So every satellite system has its own set of requirements that respond to the perceived threat against that kind of system, but I certainly do agree with the rest of the witnesses on this panel that some commercial systems have completely ignored the potential threat.

I will say that the most systems operating geosynchronous are because of the long lives expected of satellites operating at that location do take the long duration dose quite well and are built to quite high standard, but the promptness, which Dr. Wood has explained, will take out satellites, and particularly those operating in the new emerging low earth orbiting communications satellites unless they are hardened against that threat will succumb to radiation very, very quickly and shorten their lives very substantially.

Dr. WOOD. On the time scale of most of two decades ago, Mr. Chairman, satellites whose survivability in wartime was considered crucial were actually taken and tested by the Defense Nuclear Agency against nuclear EMP, and these tests were formidable. They were remarkable, as far as their engineering features were concerned.

They were also remarkably expensive, and yet the tests were done because it was considered important in the 1960s and 1970s and in the early 1980s to understand and to have, at a certifiable level, confidence that some subset of satellites would actually survive.

Regrettably enough, that practice has ceased in recent times and, now, with all respect to not only the colonel but the department which he represents, the Department of Defense simply is not in a position to certify objectively that any of its satellites are EMP robust. They simply cannot do that anymore.

Chairman BARTLETT. Including the two MILSTAR?

Dr. WOOD. Yes, sir. Including the two MILSTAR. They simply can not certify that they are robust, objectively. The can tell you they believe they are. They can submit stacks of documents with people's signatures on them as high as the sky saying that all these people think they are, but they can no longer tell you that they are known to be robust.

Chairman BARTLETT. It is my understanding that some 85 to 90 percent of all military communications traffic now moves over commercial sources. Is that correct?

Col. SKINNER. That is the kind of number that we see on a day-to-day basis. Yes, sir.

Chairman BARTLETT. Which means that after a high-altitude burst, within a relatively short period of time, the military would be denied 85 to 90 percent of its present communication capability?

Col. SKINNER. Well, keeping in mind, now, that the high-altitude bursts that we are talking about are in the 300 kilometer range and our geosynchronous satellites are 40,000 kilometers above the earth, we have some advantage in a reduction of field strength at that longer distance from the burst. But certainly we do not expect our survivable communications command and control system to be supported on commercial satellites except via good luck, and because of that our essential emergency communications network is based on EMP-protected communication systems.

Dr. WOOD. And MEECN, by and large, does not count on satellites surviving. The Minimum Essential Emergency Communications Network has features which do not involve satellites extensively for just the reasons that you have been exploring, Mr. Chairman. It is not just civilian satellites, but a number of military satellites whose survivability in an EMP-intensive environment could be considered to be very much in doubt.

Chairman BARTLETT. If we were to presume an EMP lay-down producing 10 to 20 kilovolts, how much of our national infrastructure would be disrupted and how much of it would be damaged by that kind of voltage?

Dr. WOOD. It has never been tested, sir, and so, objectively, no man can say. Estimates can be made, the basis, for instance, of what happens to long-distance electrical transmissions systems and long-distance telephone systems during severe solar storms, which generate very low frequency, low amplitude electromagnetic pulse light phenomena.

In other words, of the three basic flavors of nuclear electromagnetic pulse, there is a very low frequency, low amplitude portion of it that is mimicked by severe solar storms and when we look at the consequences for telephony and power systems of those storms and we look and see what the pulses are that are measured and calculated to be generated by nuclear explosions, we say, "Hmm. Those systems are not going to survive the low frequency portions of nuclear EMP, now are they?"

Chairman BARTLETT. Is it conceivable that our power grid and our communications network would be shut down by such an EMP attack?

Dr. WOOD. Ten to 20 kilovolts, in my considered not completely ignorant professional opinion, would shut down the power grid in this country if it saw a 10 to 20 kilovolt nuclear EMP and the low frequency correlates of that. Yes, sir.

Chairman BARTLETT. Yes, sir?

Dr. SOPER. I tend to be on Lowell's side on this, but you should understand there is a ongoing, and I would use the word "raging" debate over just that issue. I think EPRI—and I am not sure I remember what that acronym stands for——

Dr. WOOD. The Electrical Power Research Institute.

Dr. SOPER. The Electrical Power Research Institute. And some of their people looked into this issue, as did the Department of Energy, and I do not have at my fingertips the results of that. But there are well-meaning people who have looked at this in some scientific detail that suggest that there would not be a catastrophic shutdown of the power grid. So there is a debate on that issue as well as the telecommunications infrastructure.

Dr. WOOD. I appreciate Dr. Soper's comment on that, because it needs to be clear that this is a matter of opinion. I gave you only my personal opinion. Other professional opinions may differ. The fact of the matter is that the tests have not been done.

Dr. SOPER. That is correct.

Dr. WOOD. It is certainly feasible to do the tests and those who say that it is feasible to do the test, very simply, fall short of a nuclear explosion. You inject current and voltage into power systems and see how they perform. The very fact that these tests have never been done, I suggest, says that the optimists know what the answer will be, and it will not support their position. If they are so confident that there will be no consequences, I challenge them to do the tests.

Chairman BARTLETT. And the test is doable?

Dr. WOOD. Oh, yes.

Dr. SOPER. Oh, yes.

Dr. WOOD. Very simply, in a straightforward manner, with entirely non-nuclear means. You just take high-power pulse generating equipment and inject pulses into electric power systems and say, "Now, how do they perform?"

And having looked in some detail over the past 35 years with respect to how civilian power systems do perform and why they undergo large-scale outages, I can assure you they do not degrade gracefully.

They degrade anti-gracefully, if you will, Mr. Chairman, something like a high-tech house of cards. You pull out a key card and the whole structure crumbles on a time scale of tens of seconds to a few minutes. They are not built to be stressed. They are built to stand up to lightning stroke in worst case, an isolated lightning stroke. If you put down lightning strokes all over the system, they fail, and they fail in a quite readily predictable fashion, and the terrible thing about them, Mr. Chairman, is, once having failed, they do not get back up.

The power system is built to run in stay state. It is not build to come up when it has a great deal of load connected to it and generation arrives in a hit-and-miss sort of fashion. And it is not feasible, as people have discovered—everything from the northeast blackout of 1965 on to the more recent smaller scale spectacular blackouts that have occurred at various places around the country—it is not feasible to put a power system back together automatically.

It is put together by people using telephones and walkie talkies and so forth, and they basically paste the system back together on a time scale of tens of minutes to many hours.

And if those systems, if the telephone systems and the walkie talkies and so on, do not work as well, and there are not neighboring power systems that are intact that can provide generation, that can serve as power sinks as necessary and so forth, the system just simply does not come back up. And it is not a matter of, "Well, is it going to take a day or is it going to take a week?" or whatever the answer is. It just does not come back up ever.

Chairman BARTLETT. But can we not go to the warehouse and get the spare parts that were zapped and put them back in?

Dr. WOOD. If your test equipment happens to be working, then you will slowly be able to repair the systems that burned out, but, of course, the test equipment died too.

When a large power system's transformer gives out, when the insulation fails internal to a transformer on a large power system, what you do is you ship in a new transformer, typically on a time scale of three to twelve months and you ship it in by barge and huge trucks and so forth and you install it in place. It is a major operation. It is massive surgery at that particular switching station or main interconnection substation.

When big power system components fail, they have failed permanently and you repair them on time scales, literally, sir, of months. That is to have a single component fail.

When you have a hundred components failed all over an interconnection—it has never happened before and nobody has any idea how long it would take to rebuild it, but I confidently predict it would take well in excess of a year and that is if all the rest of the national technical infrastructure, economic infrastructure, and so forth were working.

Chairman BARTLETT. Will it be working?

Dr. WOOD. Of course not. It will all have failed. That is the nature of a large-scale EMP attack. Everything fails. Not every single component everywhere fails, but the pattern is that of a shotgun blast. You may get hit here, you may get there, or whatever, but most all of it will have got hit somewhere with at least one pellet and that is the same sense in which EMP failure will occur.

Some things—by happenstance, by good luck, by robust construction, by being in a sheltered environment, in a tin warehouse or something like that—some components will survive. Most will fail.

And because they fail at random points, they will be, first of all, difficult to determine that they truly have failed, and, secondly, there will not be nearly enough spare parts to replace them, even if all the power equipment and the derricks and the cranes and the barges and the trains and so forth—even if those were all working, which, of course, they will not be.

Chairman BARTLETT. The picture you are painting is a pretty grim one. If it took a year to get our power grid back operational, what happens in the meantime?

Dr. WOOD. My loose, informal characterization of it sir, is it is a continental-scale time machine. We essentially pick up the continent and move it back in time by about one century and you live like our grandfather and great-grandfathers and so on did in the 1890s until you rebuild. You do without telephones. You do without television, and you do without electric power, mostly, except in a few fortunate locations.

You just live, as I said, in a Jeffersonian America, a pastoral America. And if it happens that there is not enough fuel to heat with in the winter time and there is not enough food to go around because agriculture has become so inefficient and so on, the population simply shrinks to meet the carrying capacity of the system.

Chairman BARTLETT. But, demographically, we are very different than our Jeffersonian beginnings, are we not?

Dr. WOOD. Within a factor of ten. There would be tens of millions of Americans left.

Chairman BARTLETT. I appreciate this characterization because what we want to accomplish by this hearing is two things, one to indicate that small business needs to be better utilized. There is lots of capability in small business to address this problem. It is not being addressed. And the other intent of our hearing is to raise the public consciousness.

This is an eventuality which we cannot risk, in my view, which is why I have fire insurance on my home because, were that to burn, that would be a catastrophic event for me, so I insulate myself against that by buying an insurance policy.

Dr. WOOD. And yet, Mr. Chairman, the likelihood that your home will burn in any given year is, perhaps, one chance in 300 to one chance in 500. That is why your fire insurance has the magnitude—your premium, the annual premium, has the magnitude that it does. Several centuries will go by, on the average, before your home will burn.

And what you have to ask the people who come before this Committee and before the armed services committees, before the intelligence committees, and so forth, is, “Can you give me a certification of likelihood of an EMP attack of one part in 300 per year? Otherwise, where is the national fire insurance?”

Chairman BARTLETT. Which is a very good way of characterizing it.

Dr. Soper, you had a comment?

Dr. SOPER. If I may, Mr. Chairman, might I ask you a question? Is that all right?

Chairman BARTLETT. Yes, sir.

Dr. SOPER. We have all stated our appreciation that you are holding this hearing and are willing to ask the kinds of questions that you are.

Are you the single voice in Congress thinking and asking questions about this? I know that I have spoken before to Congressman Weldon and others, but it seems to me that, before this issue gets fully debated and all sides are heard and the issues are clearly defined and programs for small business, and large as well, put into place to help answer those questions, you have to get more of your fellow Congresspersons involved and energized and perhaps more hearings in different committees need to be held.

It is a difficult problem, as Dr. Wood has pointed out. It is a potentially devastating problem, as all of us, I think, would agree, and it is more than, I think, one person in Congress, perhaps, can take on by him or herself.

So my suggestion, or my request, would be to encourage your fellow Congressmen and Congresswomen to pick up the mantle and ask these same questions or work on this problem.

Chairman BARTLETT. Thank you. We are in a lot better shape than when we started. When we started, two-thirds of the members of our National Security Committee, now the Armed Forces Committee, did not even know what EMP was. Now, I think, they all know what it is. We certainly have the attention of Curt Weldon and his Subcommittee on R&D.

They held the first ever full hearing. This is the second in the life of the Congress. The third will be held this summer and it will be focused almost exclusively on the effects of EMP on the national infrastructure, because we are very concerned that we need a study, that we need a concerted effort to look at what those effects would be and what we can now do to ameliorate those effects and what we can do after the event to recover from it. I think we need to look at it in both of those veins.

So it is getting more attention in the Congress and each of us in the Congress tends to focus on issues where we think we can make a difference. This is one of the areas that has kind of been ceded to me.

I have the recognition now of a number of the members of our National Security, our Armed Forces committee, and we are focusing on this and hoping to raise the public consciousness so that something will happen.

After all, it will not happen until the public consciousness is raised. We have a representative government and the people we represent need to demand that their government focus on issues of importance to them and I think this is one of those.

Dr. SOPER. This is true, that chemical and biological agents and their weaponry is also part of weapons of mass destruction portfolio and chemical and biological issues did not receive that much attention until, I am told—I do not know this for sure, I am told that President Clinton read Mr. Preston's Book "The Cobra Event" or "The Cobra Affair" where this was discussed and literally within a few days, briefings were put together by the Department of Defense and briefed into the Oval Office.

I am not suggesting that you go bang on his door to talk about the EMP issue, but it goes without question that that high-level attention, in general, begets high-level attention. I am not sure how useful that comment was, but——

Chairman BARTLETT. I appreciate that. Thank you very much.

Dr. Wood, you had a comment?

Dr. WOOD. I would suggest, in the context of the general matter of informing the Congress and the public and the hearings that have been held and that you contemplate holding that you have already made a remarkable degree of progress, Mr. Chairman. That is, there does not seem to be very much debate with respect to not only what EMP is—I mean, that, after all, is a technical matter—but what its consequences would be.

There just does not seem to be a lot of argument about that, at least that I have heard. The argument is simply over how likely is it. And I would suggest that you and your like-minded colleagues are well over halfway to the finish line because you have got the technical basis, the factual basis, fairly well nailed down and stipulated to.

You know, at the present time, everybody says, "Yes, if it happened, it could be remarkably severe. The consequences could be grave, that we might be knocked out as a modern nation."

You know, this, I think, is a remarkable amount of progress, considering that the matter really has not been publicly debated for more than two or three years.

The people—and I would suggest that the issue before the Congress at the present time is a very clear cut one relative to other issues of comparable gravity and complexity—namely, you simply have to ask the folks who say it can happen for the bases of their belief. Where are the analyses?

Gen. Marsh, for instance, where are the analyses that support your belief that this, in spite of its devastating potential, that it is so unlikely that nothing need be done?

I recall to you the, perhaps applicable, perhaps not applicable, circumstances around the *Challenger* disaster 13 years ago that, when the Rogers Commission commenced inquiring of NASA as to why they had done the things that they had done and not done other things and so forth, they said that the shuttle had one chance in 100,000 of crashing and losing the shuttle and the crew on any given mission. One chance in 100,000, so they never worried about it.

Now, the fact of the matter is they had one chance in 24, which is quite a bit different than a chance in 100,000. At least that was the objective record.

And so when the Rogers Commission went back and said, "Well, where did that one chance in a hundred thousand per flight come from?" They discovered it was represented many places in the record, but they could find no analysis whatsoever that supported the number. None.

It was literally a free-floating established article of faith in the NASA church that it was a chance in 100,000, but no basis for it whatsoever. Not one guy had ever sat down and written a three-page or a ten-page or a thirty-page analysis saying that we have only ten parts per million of likelihood of failure per mission. There is nothing there.

Nowadays, the established likelihood, the documented likelihood and so forth, is one launch in 40 will crash. And that is what happens when not only NASA but their independent contractors and so forth went back and did the study of the same system that was believed to have a chance in 100,000. It now has lots and lots of analysis. Instead, it is one chance in 40. And that difference of a factor of 2500 is remarkably large.

And so I say to the folks that are on the record as saying, "Ignore this. It can not possibly happen. It would be terrible if it did, but it will not happen," is where is your analyses? Where are the numbers that say what the likelihood is of the U.S. getting hit with an EMP lay-down, not just from Mr. Lukin and his friends in the former Soviet Union, but from the North Koreans, the Iraqis, the Iranians, the South Asians, the whatever? Where is the analysis that says that?

And, by the way, we sure hope that there will not be a Rumsfeld Commission that comes along six weeks after the CIA, the Director of Central Intelligence last May testified that there was 10 to 15 years of margin before the North Koreans would have an ICBM; six weeks later comes the Rumsfeld Commission that says, "It might happen in a matter of five years or less," and six weeks after that, sir, they did it. They launched a prototype ICBM. You know, three months after the DCI said, "Do not worry, you got 10 to 15 years."

And so you ask, "Well, where was the analysis that supported that 10 to 15 year estimate?" and, by and large, it did not exist.

So there is a lot of free-floating, very widely subscribed to, highly established superstition, sir, with respect to national security issues, and it does not much matter whether it is North Korean ICBMs or EMP or biological warfare attacks coming out of the Middle East. These are free-floating, sir. They have no basis in analysis, let alone a basis in fact.

Chairman BARTLETT. I do not know how one arrives at the probability, but I would just like to, for a moment, reiterate some of the things that we have gone over in our question-and-answer period here.

The first is that a number of nations now have the capability, with modifying commercial ships and a Scud launcher, to place a missile over our continent.

Secondly, you would not know——

Dr. WOOD. If I might interject, sir?

Chairman BARTLETT. Sir?

Dr. WOOD. To do so in a fashion that might be exceedingly difficult to trace or to attribute. That is to say, it is a Lukin-type attack, if I can adapt your quotation. It not only happens, but it happens in a fashion and in a manner that is basically impossible to respond to. There is no basis for retaliation because the United States government could not establish, to American standards of proof, as to where the attack came from.

Chairman BARTLETT. Now, would that not immeasurably increase the probability that it would occur? If they had the capability, if the effect on us would be devastating and if we did not even know who did it so that we would not know to whom to respond, would not that increase the probability that it might happen.

Dr. WOOD. When I was a kid growing up, this was called "leaning with your glass chin." You know, you provide an exceedingly attractive opportunity for your opponent and then you do nothing to defend against it.

Yes, sir. That is seemingly exactly what it is, and I think the reason that I would disagree so strongly with Gen. Marsh's testimony of July of 1997 is simply that, in a world in which people did not respond to incentives, his assessment might have considerable validity. But when you have people that dislike the United States and dislike everything that it does and stands for and this, that, or whatever, dislike it rather intensely, they have the method, motive and opportunity to do something about that dislike because we have left ourselves wide open to EMP attack and they have the potential of attacking without it being known as to where the attack came from, you have created an enormous incentive. You know, in terms of human motivation and human behavior, you have created an enormous incentive for just that type of attack.

Chairman BARTLETT. Talking about people disliking us, a recent member of the Duma came to our country the week before last and he said that our president had been able to accomplish in 45 days, at that time, what the Soviet Communists had failed to accomplish in 70 years; that was to get the Russian people to hate Americans.

For the first time since the cold war began, Russians were in the streets demonstrating against America. The Soviet Communists had failed to do that in 70 years. He said our president accomplished that in 45 days of bombing of Kosovo.

Dr. WOOD. Not to worry, Mr. Chairman. You know, do not get too excited. It is still six months before Duma elections and it is a full year until they select another president. Not to worry too much.

Chairman BARTLETT. I want to ask members of the panel if they have any observations they have not had an opportunity to make before we adjourn our meeting.

Dr. SOPER. The only comment that I would like to make is that I am disappointed that one chair is empty, because I think one of the important—albeit difficult to discuss in open session—important issue is, at least as a government impression of the threat, of the probabilities that Dr. Wood is talking about, it would have been nice to at least have had that on the record to understand.

Chairman BARTLETT. From classified and non-classified discussions with Bob Walpole, I can tell you that his position—I believe the position of the CIA is very much closer to the position of Dr. Soper and Dr. Wood than it is to the position of DOD.

Is that a fair assessment, Dr. Wood?

Dr. WOOD. That is my impression from a number of classified discussions and briefings that I have done in the company of Mr. Walpole.

I, of course, do not want to put words in his mouth, and I would like to clarify, Mr. Chairman, in this context that I summarized the statements of DCI 13 months ago on the subject of the North Korean and Iranian missile threats as saying that the analysis turned out to be remarkably thin and thoroughly mistaken.

I would like to clarify that as saying that I think that Mr. Walpole and his colleagues supported the DCI within the parameters that they were given to work within. It is just that they never thought, and Mr. Walpole has said this publicly, that the North Koreans would jump so rapidly to a three-stage rocket.

You know, three stages is kind of the number that you need if you are a fledgling, missile only power if you want ICBM capability, and it was believed that that would be a long time coming. Well, it turned out to be an incredibly short time coming.

So within the parameters that they worked and the way that the job that they were given to do, they, I think, performed credibly. The problem was simply that they were wrong by 10 to 15 years. I know that Mr. Walpole has clarified very substantially subsequently, the parameters within which they worked and, as I said, I think they did a very professional job within those parameters, but the institutional parameters were simply wildly wrong.

Chairman BARTLETT. The religious world is very familiar with the miracle of conversion. The CIA has recently had that experience relative to these kinds of threats, I think.

Mr. Wiltsie, the Applied Physics Laboratory has been for our military an honest broker for a number of years now. There are obviously different opinions relative to the probability of an EMP lay-down, different opinions relative to the effect of an EMP lay-down, different opinions relative to what we ought to be doing in anticipation of that kind of an eventuality.

Is this the kind of thing that the Applied Physics Laboratory could be an honest broker for or would there be others who would be more appropriately fitted for this role?

Mr. WILTSIE. Well, I think the Applied Physics Laboratory certainly could be an honest broker for this. I mean, I am not qualified to say if there are others that are more qualified than APL to do such a task, but we have looked at it at your behest since early 1997 and I think we have a feeling for the technology involved and probably could serve a useful purpose in that role.

Chairman BARTLETT. I thank you very much. We certainly need someone to look at the national picture, not the military, the civilian part of it. What would be the likely consequences, immediate consequences? What would be the long-term consequences? What could we do to ameliorate those effects and what would we do after the event occurred?

And I do not think that either of these have been given very much attention and I think that, considering the devastating effects that this might very well have on our country, that this would be a very inviting opportunity for enemies, and I think that it is somewhat irresponsible of us not to be looking at what we could do to ameliorate the effects and what we might do after the event occurred.

And the analogy of the insurance policy—that is all that I would ask, is that a prudent nation should invest in an adequate insurance premium the way you do for your home and the liability on your automobile and that sort of thing. We have not done that, I think, in any way relative to this. It has been ignored.

Perhaps it is too hard, Dr. Wood, and if it is too hard to deal with, you just ignore it. Do you think that has been something of a factor in our response?

Dr. WOOD. Yes. That and the intellectual tenor of the times is in the direction of kind of a comprehensive denuclearization of American military thought and, thus, of the civilian consequences of it.

I would just invite your consideration, Mr. Chairman, and that of your colleagues in Congress, to the qualitative difference between the situation that obtained after a rather junior—I think he was a deputy foreign minister or assistant foreign minister of

China made the remark a few years ago that we would not interfere with the Chinese dealing with the Taiwan issue because we cared more about Los Angeles than we cared about Taipei. Well, that caused the Washington establishment, at least from my perspective, to run off screaming into the night.

You come back with a statement that you and a number of your colleagues, including Mr. Weldon, heard from the chairman of the defense committee of the state Duma of Russia and a gentleman who is very highly placed in the Russian national security establishment, by saying, "If we really wanted to hurt you, here is what we would do," and describe a very credible threat and you can hear a pin drop in response.

There is not only nobody running off screaming in the night, they are not even murmuring in the daytime about it. You know, it is a remarkable difference.

You know, the Chinese can barely extend a credible threat. They could blow up a dozen and a half American cities and that is the end of it. The Russians can incinerate the North American continent, and yet they say, "You know, if we really wanted to hurt you, this is what we would do."

I am very struck by the difference in reaction to it.

Chairman BARTLETT. And he said that without fear of reprisal.

Dr. WOOD. Sure.

Chairman BARTLETT. Because it would be done from the sea and because we would not know who did it.

Dr. WOOD. The Russians and, very frankly, most everybody else, but the Russians in their sleep know how to attack from the sea so that we would never see the attack coming. Never ever. Very reliably. Certifiably, if you will, how to attack so that it was unattributable.

Chairman BARTLETT. Well, I want to thank all of you very much for coming. You have helped immeasurably in our goal of raising the public consciousness of this.

We will hold the record open for questions from our colleagues, if they wish to ask them, and we will hold the record open for additional inputs that all of you would like to make.

I want to thank the Applied Physics Laboratory for hosting us and I want to really thank all of you for coming and testifying today.

Our hearing will be in adjournment.

[Whereupon, at 2:05 p.m., the Subcommittee was adjourned.]

*APPENDIX*

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ROSCOE BARTLETT, MARYLAND
CHAIRMAN

DANNY K. DAVIS, ILLINOIS
RANKING MINORITY MEMBER

Congress of the United States
House of Representatives
106th Congress
Committee on Small Business
Subcommittee on Government Programs and Oversight
B-363 Rayburn House Office Building
Washington, DC 20515-0516

## OPENING STATEMENT

### CHAIRMAN ROSCOE G. BARTLETT
### SUBCOMMITTEE ON GOVERNMENT PROGRAMS AND OVERSIGHT
### HOUSE COMMITTEE ON SMALL BUSINESS

**Good morning. Let me call the Subcommittee to order. It is a pleasure to welcome you to this hearing of the Subcommittee on Government Programs and Oversight of the House Small Business Committee. I would especially like to thank those of you that have traveled some distance to participate in this hearing.**

**This hearing is being held because the damage to our economy - businesses large and small - not to mention national security from Electro-Magnetic pulse (EMP) could dwarf anything associated with the well known Y2K problem. Yet, the EMP threat is virtually ignored by our government and is practically unknown to the public.**

**Concerns about the proliferation of nuclear weapons and the possession of such weapons by rogue nations, make the discussion of problems associated with EMP and the magnitude of those problems a most timely topic. However, few Congressional hearings have been devoted to this topic, and there is little, if any, public awareness of EMP.**

**When I was recently in Vienna, Austria, a member of the Russian Duma candidly told me, "you know if we really wanted to hurt you, we would set off an atomic weapon at high altitude above your country and produce an EMP that would destroy your entire electrical power grid, computer, and telecommunications infrastructure."**

**This statement did not surprise me, but unfortunately it would come as a surprise to most Americans. I believe it is imperative that our government take steps to defend against EMP. As with Y2K, the public and businesses need to be informed about what steps they could take to prevent or minimize damage from EMP.**

**It would appear that the number of contracts awarded to small businesses by the federal government for EMP research has diminished in the last five years. Is the federal government placing the correct priority on the problems associated with EMP and with the possibility or probability that they may occur? Is the public being correctly informed by the federal government as to what EMP is, the magnitude of the threat and the problems associated with it?**

**It is hoped that the testimony today will answer some, if not all of these questions. Also, it is hoped that the hearing and the permanent record available to the public after the hearing, both in hard copy and in an abridged form on the internet, will provide heightened awareness of what EMP is and the problems it could create**

**Again thank you all for participating in this hearing. And thank you in the audience for attending this hearing.**

**STATEMENT**

**MR. RONALD J. WILTSIE**
**PROGRAM MANAGER**
**STRATEGIC SYSTEMS**

**THE JOHNS HOPKINS UNIVERSITY**
**APPLIED PHYSICS LABORATORY**

**SUBCOMMITTEE ON GOVERNMENT PROGRAMS AND OVERSIGHT**
**HEARING ON ELECTROMAGNETIC PULSE**

**HOUSE SMALL BUSINESS COMMITTEE**

**June 1, 1999**

**OUTLINE**

- **•OVERVIEW OF HIGH ALTITUDE NUCLEAR EFFECTS**
- **•ELECTRONICS AND SYSTEM SUSCEPTIBILITY**
  - **•GROUND SYSTEMS**
  - **•SPACE SYSTEMS**
- **•HARDENING CONSIDERATIONS**
- **•SUMMARY**

Good Afternoon. Thank you for the opportunity to testify before the Small Business Subcommittee on Government Programs and Oversight. I am Ron Wiltsie, The Program Manager for Strategic Systems at the Johns Hopkins University Applied Physics Laboratory, located in Howard County, Maryland.

In July 1997 Congressman Bartlett asked the Applied Physics Laboratory to advise him on the subject of this hearing, the Electromagnetic Pulse (EMP) produced by a high altitude, nuclear explosion and the implications for defense systems and capabilities, and civilian infrastructure. On July 16, 1997 the former Director of the Laboratory, Dr. Gary Smith, testified before the House National Security Subcommittee on Military Research and Development.

My testimony today will cover the following topics: an overview of the nuclear effects caused by a high altitude burst including the basic physics of EMP generation; the susceptibility of ground and space systems to EMP attack with emphasis on the vulnerability of the installed electronics; and the protection or hardening of potentially vulnerable system elements from the effects of EMP.

**NUCLEAR EFFECTS**

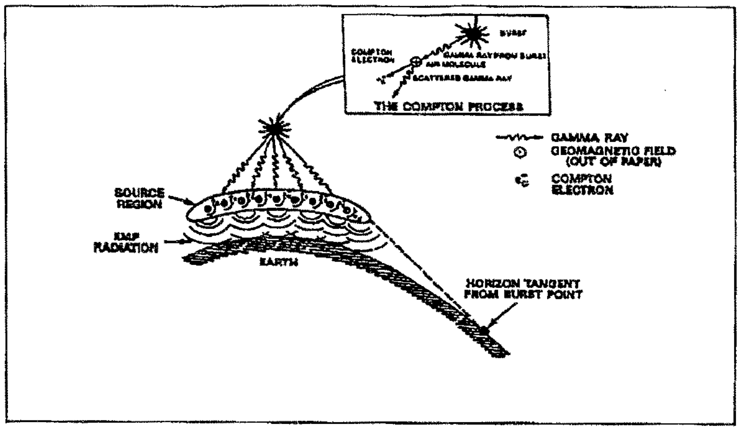
**OVERVIEW**

Discussion of the effects of a nuclear attack on the United States has, for the most part, focused on the effects such attacks would have on our defense capabilities, on our ability to function militarily in such a situation and to prevail on favorable terms. Mutual understanding by the United States and its adversaries of the widespread and cataclysmic damage that hundreds of megatons of nuclear explosions would cause to our society and its infrastructure, and the corresponding damage a like response would cause an adversary, was the centerpiece of the philosophy that underlay the Cold War: Mutual Assured Destruction. The Cold War is over, but the threat from nuclear explosions remains. These could result from a coordinated attack using substantial numbers of modern weapons or an attack of at most a few crude weapons in the hands of terrorists or rogue nations. The latter scenario is of particular concern in the post-Cold War era.

**BURST ALTITUDE EFFECT**

- **SURFACE, NEAR SURFACE BURST BLAST, SHOCK, THERMAL, LOCALIZED EMP**
- **MEDIUM ALTITUDE/ATMOSPHERIC BLACKOUT, EMP LIMITED AREA**
- **HIGH ALTITUDE BURST (100's OF KMs) EMP WIDE AREA, X RAYS, GAMMAS NEUTRONS, (SPACE SYSTEMS THREAT)**

The immense amount of energy liberated by a nuclear explosion, principally in the form of X-rays, gamma rays and high-energy neutrons, can produce a wide range of effects. The well-known effects of a near-surface or ground burst, which including blast, ground shock and thermal radiation, are actually indirect: they result from conversion of the bomb's energy into thermal and kinetic forms. Effects of a nuclear detonation at high altitude on satellites and missiles in flight, on the other hand, are direct: the energy from the detonation interacts in its original form with the target system to induce malfunction or damage. A nuclear detonation also changes the surrounding environment, causing radio and optical propagation disturbances which adversely affect communications over an extremely wide range of frequencies. An additional, and very important, effect of a high-altitude detonation, particularly for airborne and ground systems, is the electromagnetic pulse (EMP) that results from the conversion in the Earth's ionosphere of weapon gamma-ray energy to radio-frequency energy which propagates toward the Earth's surface.




The detonation of a nuclear weapon produces high-energy gamma radiation that travels radially away from the burst center. When the detonation occurs at high altitudes where the mean free path of the gamma photons is very long, these photons travel long distances before they interact with other particles. Gamma rays directed toward the earth encounter the atmosphere where they interact with air molecules to produce positive ions and recoil electrons which are called Compton electrons after the man who discovered the effect. The Compton recoil electrons also travel away from the detonation point but are deflected by the earth's magnetic field. The figure above depicts this situation.

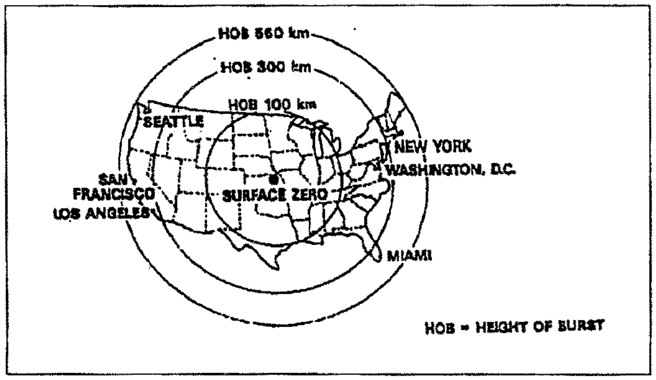
The gamma radiation interacting with the air molecules produces charge separation as the Compton recoil electrons are ejected and leave behind the more massive, positive ions. The earth's magnetic field interaction with the Compton recoil electrons causes charge acceleration, which further radiates an electromagnetic field. High Altitude EMP (HEMP) is produced by these charge separation and charge acceleration phenomena, which occur in the atmosphere in a layer about 20 kilometers (km) thick and 30 km above the earth's surface. The effective source region covers the earth within the solid angle subtended by rays from the detonation point that are tangent to the atmosphere.

**EMP**

- **LARGE AREA COVERED (1000's OF KMs)**
  - **INSTANTANEOUS**
  - **SIMULTANEOUS**
- **EXTREMELY HIGH ELECTRIC FIELDS (1000's KV/M)**
- **BROADBAND SPECTRUM COVERAGE**

The EMP threat is unique in two respects. First, its peak field amplitude and rise rate are high. These features of EMP will induce potentially damaging voltages and currents in unprotected electronic circuits and components. Second, the area covered by an EMP signal can be immense. As a consequence, large portions of extended power and communications networks, for example, can be simultaneously put at risk. Such far-reaching effects are peculiar to EMP. Neither natural phenomena nor any other nuclear weapon effects are so widespread.

The electromagnetic pulse produced by a nuclear detonation at high altitude (i.e., between roughly 40 and 100 kilometers) has been the subject of a great deal of theoretical and experimental research for nearly 40 years. The theory is now well understood and sophisticated computer programs that model the physical processes involved in EMP generation are now routinely used to predict EMP environments. The peak fields of this broad-band electromagnetic signal can reach many tens of kilovolts per meter with frequencies ranging from near DC to several hundred MHz. The high-frequency, high-amplitude portion of the EMP can couple well into antennas and other structures whose frequency responses lie in this region. The lower amplitude, lower frequency portion of the EMP signal couples well to structures whose characteristic dimensions are tens of kilometers such as telephone or power lines, on which the EMP can generate currents of several kiloamperes. Finally, a very low amplitude field lasting for hundreds of seconds is generated by magnetohydrodynamic phenomena associated with the dynamics of the explosion's fireball. Its amplitude is only a few tens of volts per kilometer, but because of its low frequency content, this component of the EMP can penetrate the Earth or sea water to great depths and can couple efficiently to very long, deeply buried cables such as large power grids on land.




The area of the Earth's surface directly illuminated by EMP is determined entirely by the height of the burst: all points on the Earth's surface within the horizon as seen from the burst point will experience EMP effects. It is important to point out, however, that the peak amplitude, signal rise rate and duration are not uniform over the illuminated area. The largest peak intensities of the EMP signal occur in that region of the illuminated area where the line of sight to the burst is perpendicular to the Earth's magnetic field. At the edge of the illuminated area (farthest toward the horizon as seen from the burst), the peak field intensity will be lower and the EMP fields will be somewhat longer-lasting than in the areas where the peak intensities are largest.

## SYSTEM SUSCEPTIBILITY

An electromagnetic field interacts with metallic conductors by inducing currents to flow through them. A television antenna, for example, is a collection of metal conductors arranged to facilitate the induced current flow in the frequency range allocated for television broadcasting and to transfer the signal to the receiver. Other conducting structures such as aircraft, ships, automobiles, railroad tracks, power lines, and communication lines connected to ground facilities also effectively serve as antennas for EMP coupling. If the resulting induced currents and voltages--which can be large--are allowed to interact with sensitive electronic circuits and components, they can induce upset in digital logic circuits or cause damage to the components themselves.

Ground facilities, for example those housing the large computers central to the functioning of our financial system, are typically nodes in a larger network and are connected to overhead or buried cables for power and communication. They are also connected to buried pipes for water supply and waste disposal, and are typically equipped with communication antennas of various types. All of these features can direct EMP energy into the facility. Analyses and simulated EMP testing have shown that currents carried to a facility by long overhead or buried conductors can reach thousands of amperes. Shorter penetrating conductors can carry hundreds of amperes into a facility. Direct EMP penetration through the walls and windows of an unshielded building can induce currents of tens of amperes on illuminated interior conductors.

| |
|---|
| **SYSTEM SUSCEPTIBILITY** |
| • **GREATLY INCREASES PROBABILITY OF UPSET/BURNOUT IN ELECTRICAL/ELECTRONIC CIRCUITS** |
| • **NOTHING LIKE EMP OCCURS IN A NON-NUCLEAR ENVIRONMENT** |
| • **ELECTRONIC SYSTEMS ARE MORE VULNERABLE TODAY** |
|     • **SOLID STATE DEVICES** |
|     • **DIGITAL VICE ANALOG CIRCUITS** |
|     • **DESIGN EMPHASIS ON PERFORMANCE/$COST, NOT ROBUSTNESS** |
| • **SPECIFIC SYSTEM SURVIVABILITY NOT CLEAR** |

When EMP energy enters the interior of a potentially vulnerable system, it can cause a variety of adverse effects. These effects include transient, resettable, or permanent upset of digital logic circuits, and performance degradation or burnout of electronic components. The collected EMP energy itself can cause malfunction or device failure directly or it can trigger the system's internal power sources in unintended ways, causing damage to be done by the power sources within the system itself.

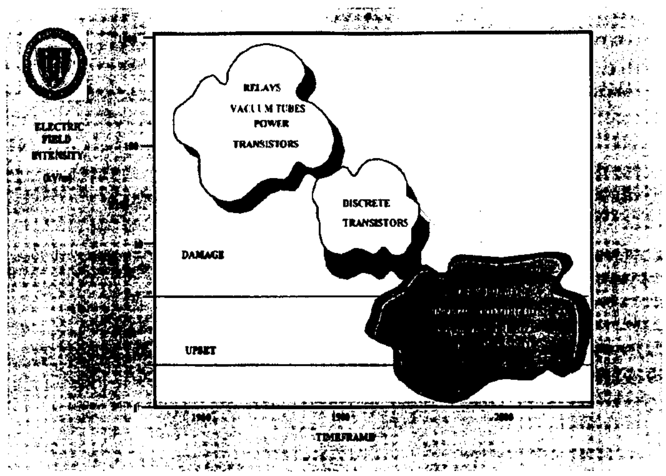
EMP introduces two collectively unique features to the overall picture of system susceptibility to nuclear effects. These features, taken together, distinguish EMP from all other forms, both natural and manmade, of electrical stress and response.

1. Stresses induced by EMP can significantly exceed those ordinarily encountered in system circuits and components and can thereby increase the probability of upset and burnout occurring in electrical and electronic systems.

2. EMP can cause this increase to occur nearly simultaneously over a large area: about one million square kilometers for a high altitude burst.

EMP simulation testing has shown that unprotected systems frequently experience both permanent damage and transient upset when subjected to EMP-like stresses. Temporary system outages, circuit upsets and permanent failures of semiconductor devices have all been observed. In view of our inability to predict the occurrence of damage or upset in systems which were not specifically designed to be "hard" to EMP, reliable conclusions concerning the EMP survivability of a specific system cannot be drawn in the absence of a detailed test and evaluation of that system. The general pattern, however, is clear. Protection from EMP effects is necessary for critical systems, and high confidence in system hardness can be gained only through testing under conditions that closely approximate the threat.

**General Sensitivity of Unhardened Electronics to HEMP***




Electronic systems have tended to become more susceptible to EMP over the years, largely as a result of the advances in electronics technology made since the development of the transistor. The current and voltage levels associated with the normal operation of electronic devices, and the power or energy levels at which failure can occur, have all fallen steadily as solid-state and integrated-circuit technologies have placed ever-increasing numbers of devices and circuits on semiconductor chips. In addition, the increasing use of digital circuitry to perform ever more complex functions has added to the risk and the seriousness of the consequences of digital logic upset. As anyone who has experienced a momentary power fluctuation while using a personal computer will attest, such upsets can readily occur with unpredictable, and usually unfortunate, results.

*ASSUMES 100 ns PULSE, 1A AVERAGE COUPLED AT 25 kV/m; 100 ohm IMPEDANCE

**SPACE-BASED ELEMENTS**

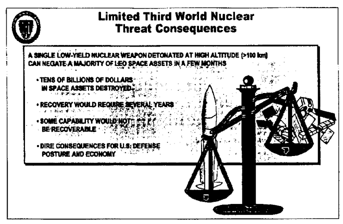
- KEY ELEMENT IN COMMERCIAL TELECOMMUNICATIONS
- GEOSYNCHRONOUS SLOTS AT A PREIMUM
- THREATS
  - •BURST AT GREATER THAN 40 KM
  - •PROMPT RADIATION
    - •X-RAY INDUCED SHOCK WAVES-SHORT RANGE
    - •PROTECTION ADDS 3% TO 5% OF PRODUCTION COST
  - •DELAYED RADIATION
    - •DOMINANT EFFECT FOR COLLATERAL DAMAGE WITH MULTIPLE BURSTS
    - •SINGLE BURST - SEVERAL MEGA RADS IN A FEW DAYS

Satellites play an essential role in U.S. military strategic and tactical communications by enabling critical command, control, detection, early warning and precise timing functions. Satellites have also become a key element in our civil telecommunications industry. Space has become crowded, and slots for geosynchronous satellites are at a premium. Interconnected low-orbit systems made up of multiple satellite nodes will soon give the user the capability to instantaneously connect to other users worldwide. Parts of this space-based civilian infrastructure could be put at significant risk in the event of one or more nuclear detonations in space.

Satellites can only be affected by detonations at high altitudes. For low-altitude bursts, the atmosphere itself greatly shields the satellite from the nuclear radiation. In general, the detonation altitudes at which satellites can be affected are not well defined because they depend on the attenuation of the atmosphere, the range of possible weapon yields, geometrical factors, and satellite sensitivities. A reasonable rule of thumb, however, is that for nuclear detonations below about 40 kilometers, satellites, particularly communications satellites, will not be affected by the direct radiation. The high-altitude regime of interest therefore excludes ground and air bursts. Included in this altitude regime are the increasingly possible high- altitude detonations which could occur as a result of a determined terrorist or rogue-state attack.

The prompt radiation effects occur immediately, result in either upset or permanent damage of electronics, and are caused by direct neutron, X-ray and gamma-ray interactions with the satellite. X-ray induced shock damage to certain microcircuits, as well as gamma-ray induced ionization upset or burnout, occurs at relatively short ranges. System-generated electromagnetic pulse (SGEMP) refers to the electromagnetic fields generated by the motion of electrons scattered out of (satellite) material by ionizing radiation (primarily X-rays). Threshold levels for SGEMP-induced upset and damage are very difficult to predict. However, of the most important implications for unhardened satellites is that potentially damaging effects can occur even at radiation levels associated with extremely large burst-to-satellite separations.

Perhaps a more threatening challenge to our commercial satellite constellations is that from enhanced trapped radiation that results from delayed nuclear effects. These enhanced effects depend on a number of factors: the yield and number of bursts and, to a certain extent, the details of the bomb design; the latitude (and to a lesser extent the longitude); and height of the burst(s) and, of course, the "kind" of orbit the satellite is in-low earth orbit (Landsat, Teledesic, and Iridium, for example), medium earth orbit (Global Positioning Satellite (GPS) and Odyssey, for example) or geosynchronous earth orbit (Anik, Galaxy, and GOES, for example). 11




Because time on orbit is a major cost discriminator in satellite design, most U.S. commercial satellites are designed and built with "hardening" to the natural environment as a requirement. Even so, there are examples of satellite failures due to severe magnetic storms. In addition, during the 1962 high-altitude nuclear testing series, a number of low earth orbit satellites failed as a result of the total dose effects resulting from the enhanced trapped radiation. It is not at all obvious that protection to the natural environment will adequately protect commercial satellites from enhanced effects from one or a few high-altitude bursts. The worst scenarios involve high-altitude, low-latitude (~20°) bursts, even at relatively low (~50 kiloton [kT]) yields. Here, low earth orbit satellites (at altitudes less than about 1000 km)-which, in the natural environment, see the lowest natural threat and therefore receive the least hardening-can be subjected to high levels of total dose radiation that can last for months and even years and affect the satellites' useful lifetimes. In the case of high-latitude detonations (>45°), the enhanced radiation is short-lived--perhaps a few days or weeks--and is more or less independent on the height of burst. Although the lifetimes of commercial satellites are highly scenario-dependent, burst(s) at lower latitudes tend to enhance the lower regions of the Van Allen belts and pose a threat mainly to satellites in low earth orbit.

# HARDENING

Protection or hardening of potentially vulnerable system elements from the effects of EMP requires that these elements be shielded from the EMP field and from potentially dangerous EMP-induced currents and voltages. To put the problem in perspective, consider that the high-altitude EMP can induce open-circuit voltages of the order of megavolts or short-circuit currents of the order of ten kiloamperes on overhead conductors such as power lines. Small-signal electronic circuits typically operate at levels of a few volts or a few tens of milliamperes. To prevent EMP-induced transients on power lines from producing upset in these circuits, sufficient protection must be provided to reduce by at least seven orders of magnitude the transient peaks induced on the power lines to levels which can be tolerated by the small-signal circuits operated from these lines. Certain sensitive circuits such as magnetic disk read-head amplifiers, require even more isolation.

All approaches to the protection problem are based on the idea that a barrier must be erected between the stresses induced by the EMP and the system elements that these stresses can adversely affect. The various approaches differ principally in the choice of barrier location.

**EMP PROTECTION**

- **INTEGRAL SHIELDING**
  - **COMPLETELY CLOSED**
  - **PERFECTLY CONDUCTING**
  - **MODIFIED FOR SYSTEM FUNCTIONALITY**
  - **VALIDATION AND MAINTENANCE EASY**
  - **COSTLY FOR MOST APPLICATIONS**
- **ELEMENT SHIELDING**
  - **INDIVIDUALLY HARDENED PIECE PARTS**
  - **NUMBER OF ELEMENTS CAN BE LARGE**
  - **VALIDATION AND MAINTENANCE MORE DIFFICULT**
  - **RISK OF INCOMPLETE PROTECTION**
  - **OFTEN MOST EXPEDITIOUS**
  - **LESS COSTLY**
- **REDUNDANCY HELPS**
- **MINIMUM ESSENTIAL SYSTEM PROTECTION**

A completely closed (integral) and perfectly conducting shell around a space totally excludes externally generated electromagnetic fields from the enclosed region. This is the basis for the integral-shielding approach to EMP protection: One effectively wraps the system to be protected in a metallic shield without apertures or other penetrations (a "Faraday cage") and thereby isolates it from the hostile electromagnetic environment. For any system to be useful, however, it must interact with the world outside. A pilot must be able to see through cockpit windows, communications must be maintained, manned ground facilities must be supplied with air and water, and often with externally generated power. For these reasons the integral shielding approach to EMP protection is modified to permit those penetrations that are necessary to the system's function, while closing all unnecessary penetrations. The means employed for effective penetration protection include filters and surge arrestors for line penetrations such as those associated with antenna and power connections; wire-mesh or transparent conductive-film coatings for windows where visibility must be preserved; metal honeycomb for ventilation ports; and conducting gaskets for doors and hatches.

At the other end of the spectrum of EMP protection lies hardening at the individual-element level. In this approach, the barriers between the EMP stresses and the potentially vulnerable elements are chosen close to the elements themselves. Local rather than global shielding is used, and individually hardened piece parts (diodes, transistors, and integrated circuits), hardened circuit and fault-tolerant logic design, and terminal protection devices (filters and limiters) are employed to protect the system elements. The number of such elements, however, can be extremely large, and the number of protection measures that must be applied to the system will be correspondingly large. As a consequence, hardness validation and maintenance can be difficult when individual-element hardening is used. Furthermore, the risk of incomplete system protection can be substantial. Even given these shortcomings, individual-element hardening is often the most expeditious approach for adding EMP protection to an existing facility or complex. The risk of incompleteness of the protection will be higher than for an integral shield with protected penetrations and the increase in system hardness may not be quantifiable, but the cost will be relatively low.

**SUMMARY**

- EMP EFFECTS
  - INSTANTANEOUS
  - SIMULTANEOUS OVER A WIDE REGION
  - HIGH ELECTRIC FIELDS
  - POTENTIAL TO SEVERELY AFFECT GROUND SYSTEMS AND SATELLITES
  - COVERAGE AND LEVELS WELL UNDERSTOOD
- INCREASED INFRASTRUCTURE SUSCEPTIBILITY TO EMP
  - SOLID STATE SYSTEM PROLIFERATION
  - MORE SENSITIVE COMPONENTS
  - EFFECTS ON TERRESTRIAL SYSTEMS NOT WELL UNDERSTOOD
  - LIMITED TESTING (1980s)
- HARDENING
  - INTEGRAL SHIELDING
  - ELEMENT SHIELDING

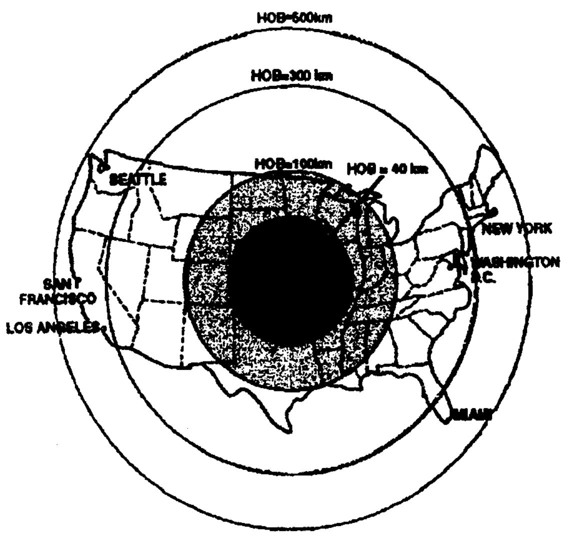
For a high altitude nuclear burst, the EMP effects can be tremendous and far reaching. The EMP from a single hydrogen bomb exploded 300 kilometers over the heart of the United States could set up strong electrical fields over nearly all of North America. Since EMP is electromagnetic radiation traveling at the speed of light, all of the area would be affected instantaneously and simultaneously. HEMP can induce large voltages and currents in power lines, communication cables, radio towers, and other long conductors serving a facility. Other notable collectors of EMP include railroad tracks, large antennas, pipes, cables, wires in buildings, and metal fencing. Although materials underground are partially shielded by the ground, they are still collectors, and these collectors deliver the EMP energy to some larger facility. This produces surges that can destroy the connected device, such as, power generators or long distance telephone systems. An EMP burst could destroy many services needed to sustain the civilian infrastructure.

Society has entered the information age and is more dependent on electronic systems that work with components that are very susceptible to excessive electric currents and voltages. Many needed systems are controlled by semiconductors in some way. Failure of semi-conductive chips could destroy industrial processes, transportation networks, power and phone systems, financial systems, and access to water supplies.

The "integral shielding with penetration control" approach to system protection has proven most attractive for hardening many classes of military systems and C3 facilities. A new strategic missile system, for example, is an ideal candidate for this form of EMP protection because it is new, high value, and requires a low-risk, high-confidence hardening approach. Finally, the fact that the system is relatively compact and enclosed means that it possesses few necessary penetrations that will require protection. Because the number of necessary protection measures is small, system hardness will be relatively easy to validate and maintain over its life cycle. This is definitely not the case, however, for a system of continental size such as a commercial banking network, a transportation communications system or an interconnected telephone network.

Only if the most important penetrations and the most critical electronics boxes can be identified and protected--and engineering judgement and experience will be crucial in making the necessary identifications--one can reasonably expect to achieve a significant reduction in the vulnerability of the system using element shielding. As the system becomes more complex, however, the confidence in this approach degrades rapidly.

# EMP Ground Coverages for High Altitude Bursts

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# A PROFILE OF APL

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY

# WHAT IS THE APPLIED PHYSICS LABORATORY?

- A research and development organization dedicated to solving problems of national security and global interest
- A leader in technology application and innovative system development in partnership with Government and industry
  - Provides objective technical leadership for multiorganizational programs
  - Avoids competition with industry in core work areas
  - Transfers mature systems or prototypes to industry for production
- A not-for-profit division of The Johns Hopkins University (JHU), founded in 1942

# APL FACTS

- Conducts more than 200 separate programs for the Navy, Army, Air Force, NASA, BMDO, DARPA, the Departments of Transportation and Treasury, and others

- Maintains 90 specialized research and test facilities
- Operates with average annual commitment level of $420M
- Subcontracts approximately 40% of funding, mainly to industrial organizations
- Operates the primary site of the JHU Whiting School of Engineering, one of the largest part-time graduate engineering programs in the United States
  - The APL Education Center offers eight master's degree programs serving students from APL and the community
  - Majority of instructors are APL employees

# Areas of Expertise

APL's wide breadth of systems and technical diversity, combined with unparalleled depth based on 50 years of experience, resident professionals, and core capabilities. APL provides an unbiased, expert source of innovation in solving problems in the origination, development, test, and production of complex systems.

### Systems

Missile, combat, spacecraft, communications, surveillance, radar, command and control, information display, and transportation.

### Technologies

Electronics, information processing, navigation, guidance, propulsion, aerodynamics, oceanography, space physics, sonar, software development, signal processing, materials, and biomedicine.

### Joint Service Mission Support

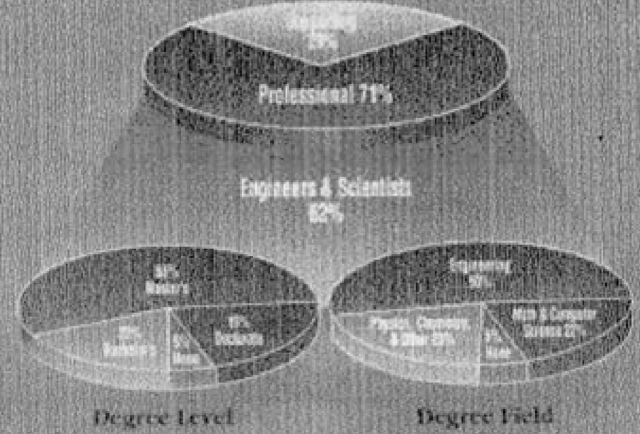
Strike, ship defense, strategic deterrence, tactical and ballistic missile defense, space and electronic warfare, littoral warfare, surveillance, and antisubmarine warfare.

### Significant Capabilities

- Strategic systems test and evaluation
- Submarine security and survivability
- Space science and engineering
- Combat and guided missile R&D
- Theater air defense
- Information warfare technology (C4I, ISR, IW)
- Simulation, modeling, and operations analysis
- Mission-related R&D

## Staff Summary

**Full-Time Staff: 2,750 Subcontractors: 600**



# SELECTED PROGRAMS

**Midcourse Space Experiment (MSX):** Multiuse, remote sensing satellite for missile defense and environmental data collection.

**Near Earth Asteroid Rendezvous (NEAR):** APL satellite to orbit an asteroid. First in NASA's Discovery Program of "faster, cheaper, better" space missions.

**Cooperative Engagement Capability (CEC):** An advanced antiair warfare system of shared sensor and weapons data that allows a battle group to enlarge its defensive battle space and increase its effectiveness.

**Theater Air Defense:** Developing the concepts, architectures, and systems to detect, track, and engage ballistic missiles that threaten U.S. Naval forces.

**Aegis Combat System:** Providing advanced display and processing systems for Navy cruisers for continued improvement of APL-developed command, control, radar, and weapons systems.

**Tomahawk:** As the technical direction agent, APL develops, tests and evaluates advanced missile flight and guidance systems.

**Fleet Ballistic Missile Evaluation:** Measuring system performance and assuring accuracy and reliability for the U.S. nuclear deterrence forces.

**SSBN Security Program:** Understanding oceanography, remote sensing, and submarine operations in order to enhance submarine stealth and survivability.

**Hypersonic Technology Program:** Developing and assessing air breathing propulsion systems and advanced aerothermodynamic applications.

**Commercial Vehicle Information Systems and Networks (CVISN):** Information system architect for DOT Intelligent Transportation System to increase the safety and productivity of commercial vehicle operations.

**Advanced Natural Gas Vehicle (ANGV):** Integrating technologies to obtain a natural-gas powered compact vehicle with normal automobile performance and emissions well below future California standards.

**Telemedicine:** Developing low-cost satellite-based communication and information systems to link medical facilities and global naval forces to conduct real-time clinical consultations and remote telesurgery.

**Securities Technology Institute:** Evaluating advanced technologies for use in U.S. currency to reduce counterfeiting.

**Chemical-Biological Counterproliferation:** Sensor systems and methods to provide security and defense for U.S. forces and to counter possible terrorists and foreign agents.

# SIGNIFICANT ATTRIBUTES

### Relationship with the University

- Provides mutual benefits: a world-class university, superior medical institutions, outstanding research and development organization
- Collaborates on research programs with other Hopkins divisions
- APL shares Hopkins' research commitment for public service
- University supports APL's long-term Government relationship

### System-Level Technical Leadership Roles

- Thorough knowledge of operational requirements
- Long-term mutual commitment by APL and sponsors
- Technical leadership throughout system life cycles

### Breadth of Capabilities

- Spans the mission areas and disciplines of the military services
- Wide range of expertise in science and technology
- Complete program responsibility from concept development to implementation, installation, test, and evaluation

### Synergism Among Individual Tasks at APL

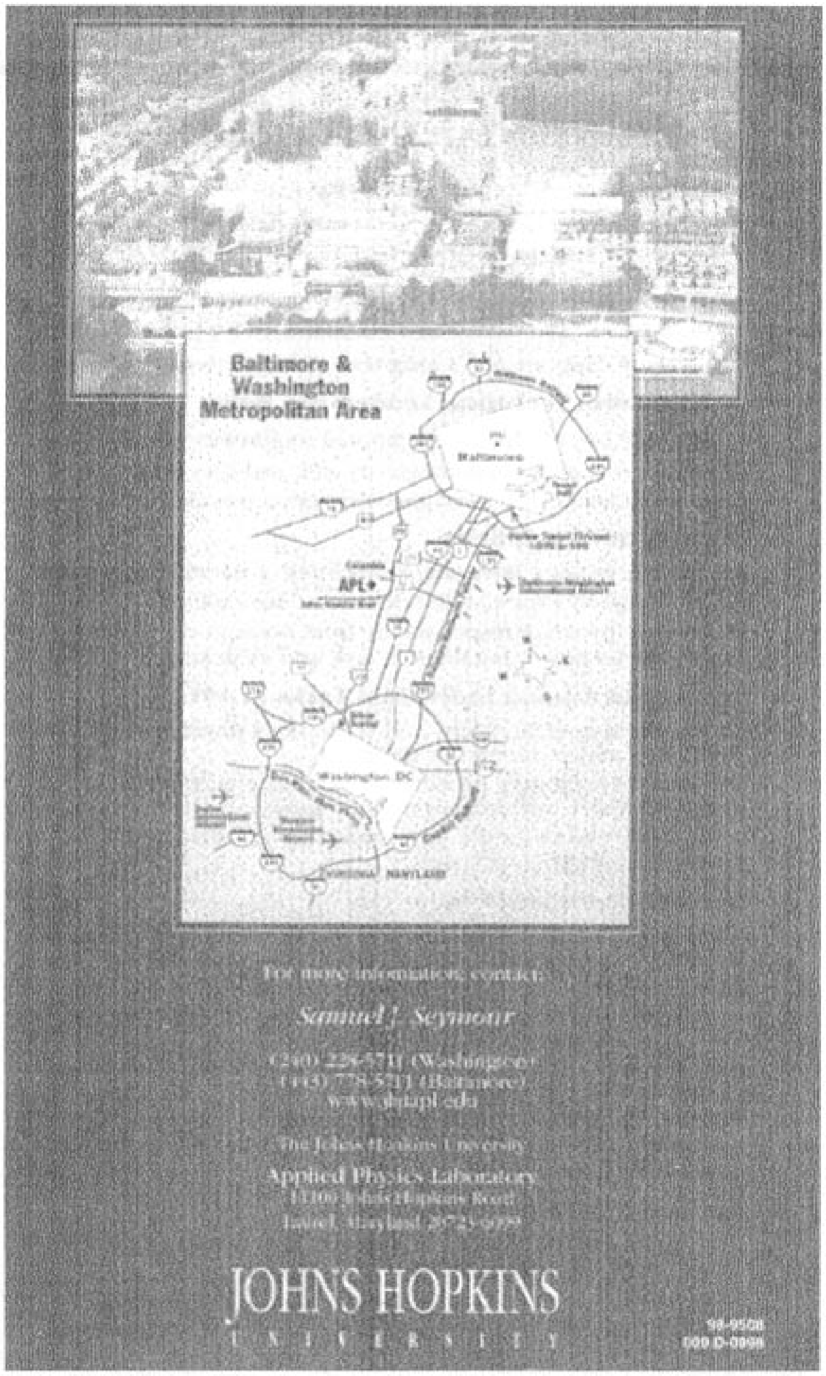
- Interprogram relationships and technology transfer foster creativity and economy for sponsors
- Long-term continuity provides system insight for future developments; anticipates program needs
- Critical resources for the Government maintained across individual program changes

### Independence and Objectivity

- Performs technical assessments through authoritative scientific studies and expert national interdisciplinary teams
- Acts as liaison between Government and industry. As a trusted, impartial, noncompetitive technical agent, APL shares and protects proprietary information.
- Accepts funding principally from the Government, free from profit considerations
- Obtains individual tasks through sponsoring program managers based on expertise and performance. APL has no guaranteed annual funding

### Applied Problem Solving

- Develops innovative solutions to complex problems through knowledge of sponsor needs
- Coordinates large internal and multiorganizational teams
- Develops expert knowledge of systems, systems engineering, and relevant technologies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Applied Physics Laboratory
JOHNS HOPKINS
UNIVERSITY

TESTIMONY

Gordon K. Soper, PhD

Subcommittee on Government Programs and Oversight

Hearing on Electromagnetic Pulse

House Small Business Committee

June 1, 1999

Mr. Chairman, I am Gordon K. Soper, Group Vice President of Defense Group Inc. (DGI). DGI is a high technology services and hardware company providing research, development, analysis, integration management and marketing support to a wide range of government and commercial customers. I appreciate the opportunity to appear before you today in order to help this Committee develop a better understanding of the magnitude of the problems that an electromagnetic pulse--or EMP--generated by the detonation of a nuclear weapon over the US could cause to both the civilian and military infrastructure of our country. In 1997, testimony before the Subcommittee on Research and Development of the House National Security Committee helped to open this important problem to public debate. Using that information as background and building on the complementary testimony of my colleague Mr. Wiltsie of the Applied Physics Laboratory, I will focus my remarks today on those problems that could occur as a result of one or more nuclear detonations at altitudes of 60 kilometers or higher above the earth. Such a detonation is often referred to as a *high-altitude*, or exoatmospheric, nuclear detonation.

Obviously, placing the nuclear weapon at an altitude such that high altitude EMP effects would be significant will require a ballistic missile, thus narrowing the candidate sources for the threat. I will leave to the intelligence community any effort to define who might be able to detonate such a weapon over US territory and the plausible scenarios one should consider.

While you have specifically concentrated your concerns on the effects of the nuclear electromagnetic pulse, I would like to point out that a nuclear detonation above the atmosphere also produces several other effects that would add to possible infrastructure degradation. A brief review of these other effects is in order. You are likely aware that copious amounts of x-rays, gamma rays, neutrons, electrons, and radioactive debris material are released in a nuclear detonation. All of these forms of radiation can impinge on satellites in their orbits within thousands of kilometers of the detonation along a direct line of sight to the burst. Depending on a number of factors, some satellites could receive severe enough radiation exposure to destroy their critical electronics subsystems (if they are not radiation-hardened). In addition, the naturally occurring Van Allen radiation belts that surround the earth would be enhanced by the nuclear detonation, trapping some of the ionizing particles for many months. This would result in satellites accumulating substantially higher levels of radiation than normal as their orbits periodically pass through the enhanced or "pumped-up" radiation belts. The resulting dramatic increase in the total accumulated dosage would significantly reduce the useful lifetime of a number of our satellites. The results of a Defense Nuclear Agency study several years ago showed that "the explosion of a single high-altitude low-yield nuclear weapon could destroy $14 billion worth of low-earth-orbit satellites that would transit through the enhanced radiation belts produced by such a nuclear event." That figure has doubtlessly increased today. Two examples given in the DNA work cite the expected decreased lifetime of Iridium satellites from 72 months to 24 months and of the Globalstar satellite from 90 months to only one month! The Defense Threat Reduction Agency (the successor to the former Defense Special Weapons Agency that, in turn, succeeded the Defense Nuclear Agency) has directed a study by the RAND Corporation to consider the worldwide economic impact of such losses. It is evident that a complete discussion of the effects of high altitude nuclear detonations on the civilian infrastructure would include consideration of the damaging radiation effects on our commercial and military satellites, and the degradation to communication and data links connecting the satellites to the ground networks, as well as the effects of EMP on terrestrial-based systems.

With this as a preamble, let me turn to a brief discussion of the possible consequences of high altitude EMP on the civilian infrastructure.

I said possible consequences because there are a multitude of unknowns and uncertainties surrounding the potential effects. First, let me tell you what we know with some degree of certainty. We know how nuclear weapon detonations generate EMP. We also know how this pulse would electromagnetically couple to antennas and electrical cables and how it would penetrate various electronic systems, down to the individual components. Finally, electrical engineers have learned how to effectively shield equipment and facilities from such a pulse, and they know the proper protective devices to apply to electrical or mechanical penetrations into a facility. Based on experience gained from DoD sponsored research to better understand the cost to radiation-harden strategic systems, we have even gotten a sense of the costs associated with EMP protection. In general, nuclear hardening costs (including electromagnetic hardening) represent a small percentage of total system costs. For example, satellite system hardening costs, driven by strategic X-ray hardening requirements, are on the order of 5% of the total cost, and hardening a satellite to the natural environment typically costs less than about 1% of the total system life cycle cost. Recent studies have also shown the cost for EMP hardening of ground systems to be about 2% or less of a hardened ground-based system's total cost. These minimal cost hardening deltas depend upon defining the threat early in the system design, designing radiation hardness into the system from the beginning and, most importantly, making use of an available domestic radiation-hardening technology infrastructure.

What is less well known is the effect of EMP on modern, unprotected, commercial-off-the-shelf electronic systems and subsystems such as computers on a network. Even modern automobiles, which have an increasing number of operational functions dependent upon microprocessors, could be affected by an EMP signal. Some test data exist to support this. Furthermore, even the word "unprotected" is difficult to define. This is true since electronics with no intentional hardening against EMP still may have some inherent level of protection because the basic design of the equipment often takes into account the existence of electromagnetic interference (EMI), the need for electromagnetic compatibility (EMC), and the possibility of exposure to lightning. It is interesting to note that equipment built to European standards should be harder because of the tougher EMI/EMC specifications that are being applied within the EU. These specifications now include EMP environments as well.

Even though quantitative data are missing, based on my experience with testing of older electronics, I can suggest some likely results. I will address briefly some of the components of the US infrastructure and then touch upon industry, individuals, and the government. The US infrastructure consists of many components, including the electrical power grid, telecommunications networks, the Internet, transportation, other public utilities (water, sewer, and natural gas systems), and medical and emergency services, all of which today depend on increasingly sophisticated, and perhaps increasingly fragile, electronic systems, subsystems and individual components.

It is difficult to generalize about EMP effects on the civilian infrastructure as a whole. It is perhaps more useful to focus on two of the most critical infrastructure components, the telecommunications network and the commercial power grid, as a way of describing the problems that our country might face as a result of an EMP attack.

Because of its obvious importance, the robustness of the U.S. telecommunications system to an EMP threat has been the object of a great deal of attention. The civil telecommunications networks would be very difficult and expensive to protect with high confidence, because of their great spatial extent and the diversity of their elements. The Department of Defense sponsored several assessments of EMP vulnerability of leased portions of the commercial telecommunications network, beginning in the late 1960s. Even though the Bell Telephone Laboratories developed an excellent understanding of the EMP problem and applied that knowledge to the design and protection of parts of their network that were used by the government for special communications, no conclusive evidence was found that the system would--or would not--fail catastrophically under EMP-induced stress. There is simply no way that such an expansive and diverse system can be realistically tested. This is of course one of the unique aspects of an EMP threat: large portions of extended terrestrial networks can be simultaneously put at risk. Such far-reaching effects are peculiar to EMP. Thus we cannot be confident that the network would function reliably after exposure to one or more high-altitude nuclear bursts. While the conversion to less susceptible optical fibers as a transmission medium continues, a large percentage of our communications is still carried on overhead copper transmission cables to which EMP energy can couple very well. Various protection devices for lightning and other interference mechanisms have been installed, but they were not designed to provide EMP protection per se. Thus, there remains a debate within the technical community on the effectiveness of lightning protection as applied to EMP. Good engineering design and EMP awareness may improve the robustness of parts of the telecommunications network. I would anticipate that the almost ubiquitous cellular technology has vulnerabilities to EMP as well, but I am not aware of any EMP-related electromagnetic testing that may have taken place for this technology.

In general, the same uncertainties pertain to the vulnerability of the electrical power grid, although there are obvious differences. While much of this grid comprises aboveground cables, it is designed to operate at higher currents and voltages than telecommunications equipment, and it is also designed to shift power flow around the grid and thereby isolate problem areas. The need for resilience against lightning strikes again provides the incentive for much of this protection. As with telecommunications, it is the computers and controlling electronics that are potentially vulnerable and whose degradation or failure could disrupt service. This general statement applies to the other components of the infrastructure as well. It is the modern electronics that are crucial to, and at the heart of, most of the infrastructure elements that are potentially vulnerable. For example, water, sewage, and fuel distribution systems include electrical pumps controlled by microprocessors and both pumps and microprocessors have varying susceptibilities to EMP. Emergency fire, police, and medical response teams are all heavily reliant upon potentially vulnerable communications equipment. The medical community is replete with diagnostic and treatment equipment controlled by microelectronics that is sensitive to very small EM fields. Without careful attention, the pervasiveness of electronics that has led us into the Information Age could also become our Achilles' Heel.

Industry, large and small, faces similar vulnerabilities. In addition to infrastructure-related disruptions, their own electrical equipment would be susceptible to likely upset or interference and to possible damage. Of course, the degree of potential damage to various businesses is related to their dependence on vulnerable electronics. Data stored on permanent magnetic storage devices would likely suffer only minor losses; data on dynamic storage in semiconductor memory might not fare as well. Operations that rely upon a steady flow of networked information (much of our blossoming E-commerce, for example) would likely find this capability disrupted for an extended period. Again, there is simply a void in our knowledge as to the expected effects on the multitude of electronics throughout the commercial sector. While not necessarily a national security issue, the same is true on the individual level. Home electronics including garage door openers, VCR's, stereos, television, telephones, computers, and even Sony Play Stations and Nintendo 64's (!) are vulnerable, with varying impacts on our lives.

Experts are often criticized for the uncertainty with which they describe EMP effects on the civilian infrastructure. Unlike many of our military systems on which extensive EMP testing has been accomplished, most components of the most modern commercial equipment simply have not been tested in an EMP-like environment. Even with testing of individual pieces of equipment, the analysis of the aggregate effects on entire interrelated networks of equipment becomes a formidable task. Variables such as the degradation of the induced EMP signal by a varying number of barriers such as building walls and the type of equipment case material, the variation of field levels within a building, the almost infinite assortment of cabling types and pathways connecting equipment, variation in electrical components' susceptibilities to EMP, and even the type of ongoing operation (transferring data internally or to an output device, processing data, in a wait state, etc.) make significant differences in the EMP effects that could occur. Extensive testing which varies these parameters could help to bound the problem, but predicting system-wide effects based on testing of individual pieces of equipment is extremely difficult. Therefore, my answer of necessity lacks detailed quantitative data.

Thankfully, the Cold War is over, and the threat of a massive nuclear exchange is greatly diminished. The end of the Cold War resulted in an appropriate shift of priorities away from nuclear weapons matters, including a decline in support for research on EMP issues and for testing of electronic equipment. This is true, not only for the military, but also especially for the civilian sector. Based on my government experience and my continuing involvement in the field, I agree with your assertion that the number of contracts and their dollar value awarded to small businesses by the federal government for EMP research has diminished in the last five years. I have been unable to track down the exact numbers. Some anecdotal evidence from discussions with industry, however, suggests a decrease in the number of involved companies by one-half or more, and up to a tenfold decrease in funding for EMP-related R&D and testing.

Your analogy with the Y2K problem is an appropriate one, but, as with most analogies, it has its limitations. EMP and Y2K are related in that both are primarily based on the burgeoning presence of electronics in our lives and the commensurate impact that disruption of those electronics could cause. It is also tough to get a balanced view for either case. Y2K and EMP have always included both doubters and doomsday prognosticators. However, we must remember that EMP is both hardware and software oriented; momentary system upset or actual physical damage may occur. The biggest difference between EMP and Y2K is the fact that while January 1, 2000 <u>will</u> arrive with a precise degree of certainty and predictability, an EMP event has a high probability of never occurring. This simple fact leads to part of the difference in our responses to these issues.

The Commission on Infrastructure Protection and Presidential Decision Directives (PDD) 62 and 63 were initiated to address some of the issues related to potential threats from terrorists and hackers working against the US infrastructure. However, the report does not address the possible implications of an electromagnetic pulse event. The reason is summed up in testimony presented by General Robert T. Marsh, U.S. Air Force, Retired, and Chairman, President's Commission On Critical Infrastructure Protection, on the **THREAT POSED BY ELECTROMAGNETIC PULSE (EMP) TO U.S. MILITARY SYSTEMS AND CIVIL INFRASTRUCTURE,** presented to the House of Representatives, Committee on National Security, Military Research and Development Subcommittee, in Washington, DC, on Wednesday, July 16, 1997. In his statement General Marsh testified that:

> The EMP effects of nuclear weapons, as was noted earlier, were thoroughly studied and well understood during the cold war. At great cost, we hardened our strategic nuclear forces and our critical command and control systems against such effects. We built extensive special test facilities and tested these systems to assure their continued operation under attack.
>
> Obviously, the nuclear threat from hostile nations cannot be dismissed today, but we consider it a remote possibility. Likewise, we consider a terrorist acquiring a nuclear weapon and positioning it at the high altitude necessary for the generation of an EMP burst that would debilitate our infrastructures to be a very remote possibility. Consequently, we are not considering any special measures to counter such a threat, though a high-altitude EMP attack could devastate the telecommunications and other critical infrastructures.
>
> The present likelihood of a terrorist obtaining a nuclear weapon is uncertain. But even if it happened, generating the high-altitude explosion required to produce a devastating EMP attack would be extremely challenging. There are many easier, less costly, and more dramatic ways for terrorists to use nuclear weapons than delivery to a high altitude. Such an event is so unlikely and difficult to achieve that I do not believe it warrants serious concern at this time. The administration's policy is to prevent proliferation and unauthorized access.
>
> In conclusion, Mr. Chairman, I believe the threat of a major debilitating EMP attack generated by a nuclear weapon is remote at this time. This is also true of the more localized effects of RF weapons, although this area needs to be kept under surveillance

and may warrant the development of countermeasures in the future.

While I would agree with most of the General's statement, I believe that this unchallenged view in the group's report resulted in little attention being paid to EMP in the ongoing Infrastructure Protection Program. However, I am happy to report that some work is still being directed at this problem. While I do not have many details, there exists a nascent program at the Defense Threat Reduction Agency that is starting to examine the electromagnetic aspects of Infrastructure Protection. (It is interesting to note the changing emphasis on nuclear matters reflected in the evolution of that agency from the Defense Nuclear Agency to the Defense Special Weapons Agency to the current Defense Threat Reduction Agency.)

One of your questions asked, "Is the federal government placing the correct priority on the infrastructure problems associated with EMP and with the possibility or probability that they may occur?" You have probably guessed already that my response to this question is that in my judgment the government is devoting few, if any, resources and relatively little attention to this issue. Granted, an EMP attack is not very likely, but the major potential consequences call for an appropriate response. Perhaps a first step would be the formation of a similar Commission on Infrastructure Protection that would address this specific problem.

Similarly the question was asked, "Is the public being correctly informed by the federal government as to what EMP is, the magnitude of the threat, and the problems associated with it?" I am unaware of any government effort to provide this type of information to the public. Perhaps such a question should be addressed to the Federal Emergency Management Agency. There have been a number of "Popular Mechanics"-like articles that have attempted to demystify the EMP threat and present a pedestrian view of its effects. The public is also being exposed (no pun intended) to EMP from popular novels such as The Day After and movies such as Atomic

Train and Pandora's Box, and the James Bond movie, GoldenEye. While it might make for good box office, these media descriptions often take liberties with the scientific correctness of EMP and its effects. This situation leaves the general public with, at best, a comic book understanding of EMP and, at worst, a dangerous misperception of the threat such an event could have on our society.

I have worked on this problem for my entire professional career. EMP is real. EMP will be generated if nuclear weapons go off. EMP energy, with certainty, would be transmitted into our microelectronics-based society. There truly could be a serious impact on our civilian infrastructure. I believe that this matter deserves greater attention than it is being given today. I am not advocating a crash program, nor do I support large expenditures of our limited resources to address this issue. I also am not a doomsday advocate suggesting that EMP will plunge the world into electronic darkness. However, we as a nation do need a balanced, rational and careful review of this issue to understand better the potential effects on late-1990s vintage electronics and the aggregate effects on the fast-growing, interconnected and interrelated networks of systems that make up our civilian and military infrastructure.

Thank you for the opportunity to be here today to provide my comments on this very important problem. I would be pleased to respond to your questions.

*EMBARGOED UNTIL RELEASED BY THE SUBCOMMITTEE*

# PREPARED STATEMENT

**Supporting Invited Testimony To Be Presented By**

## Dr. Lowell Wood*

**On**

## *Electromagnetic Pulse And The National Infrastructure*

**Before The**

## Subcommittee on Government Programs and Oversight

**Committee on Small Business**

**United States House of Representatives**

**12:00 Noon, 1 June 1999**

**Parsons Auditorium, Johns Hopkins Applied Physics Laboratory, Laurel MD**

*"If you would have peace, prepare for war."*
– Benjamin Franklin

I am grateful for the Committee's kind invitation to offer testimony today on electromagnetic pulse (EMP) and its implications for our Nation's military and civilian infrastructures and, indeed, for the continuation of American civilization.

**BACKGROUND.** I have been an interested observer of both American and foreign capabilities with respect to electromagnetic pulse (EMP) phenomena for three decades, and I have been actively involved with both offensive and defensive aspects of electromagnetic pulse weaponry for the past quarter-century. During the '70s, I served on the Defense Nuclear Agency's Scientific Advisory Group on Effects (SAGE), the DoD's senior technical review group concerned with nuclear electromagnetic pulse, as well as all other military nuclear issues having a technical character. In the late '70s and early '80s, I worked on "Third Generation" nuclear weaponry, a major component of which was nuclear explosive-driven generators of electromagnetic pulses of potentially greatly increased efficiency and military effectiveness; spinoffs involving non-nuclear means of generating potent EMP also engaged my attention. Later in the '80s and early '90s when strategic defense was emphasized, I worked on the development of defensive technologies of very high efficacy against nuclear EMP, with particular reference to military space systems. With the fall of the Soviet Union, my attention in these respects has turned to the implications of EMP in a nuclear-multipolar world, while remaining mindful of the EMP implications of the enduring Russian strategic nuclear force structure.

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I have been privileged to appear on a number of occasions before the Subcommittees of the Armed Services Committee of the House of Representatives during the past quarter-century, testifying on a variety of national security topics; I last testified there on the subject of nuclear EMP in July 1997. I have also served that Committee in a technical advisory capacity, initially under Chairman Les Aspin nearly a decade ago, and more recently under the leadership of Chairmen Floyd Spence and Duncan Hunter. However, this is my first appearance before the Committee on Small Business.

**SOME HISTORICAL PERSPECTIVE.** More than a third-century ago, due both to commentary from our British allies and to some truly striking experimental results, military technologists in the United States became generally aware that *high-altitude* nuclear explosions often generated electromagnetic effects of completely unprecedented magnitudes, physical and temporal scales – and effects on both the physical environment and human handiwork. (It had been appreciated in a rather qualitative manner for some time previously by American workers that electromagnetic phenomena of singularly large magnitudes and quite exotic natures occurred in the immediate vicinity of nuclear fireballs created near the Earth's surface, but these effects were largely ignored against the background of the nuclear explosion-unique blast and heat effects.)

The first American high-altitude nuclear weaponry experiments after the Soviet breaking of the nuclear test moratorium of '58-'61 revealed a wealth of phenomenology of completely unprecedented – and largely completely unanticipated – character. ***Most fortunately, these tests took place over Johnston Island in the mid-Pacific rather than the Nevada Test Site, or "electromagnetic pulse" would still be indelibly imprinted in the minds of the citizenry of the western U.S., as well as in the history books.*** As it was, significant damage was done to both civilian and military electrical systems throughout the Hawaiian Islands, over 800 miles away from ground zero. The origin and nature of this damage was successfully obscured at the time – aided by its mysterious character and the essentially incredible truth.

Intensive effects commenced to understand what had happened – and what might happen in the event of hostilities involving high-altitude nuclear weaponry usage. These efforts were spurred by the knowledge that the Soviets had experimented extensively with high-altitude nuclear weaponry, including some uniquely high-yield explosions, during their '61-'62 test series, and presumably understood the implications of these at least as well as we did. American efforts were complicated by the cessation of high-altitude testing associated with implementation of the Atmospheric Test Ban Treaty in '63, so that access to experimental truth was greatly complicated and, in some crucial respects, entirely precluded.

At this point, the Soviet Union and the United States commenced to engage the nuclear EMP issue somewhat analogously to two men fencing with very sharp blades in utter darkness: both knew that the weaponry which they wielded was extremely potent, but neither knew the other's time-varying posture, let alone the precise location of either vulnerable spots or especially well-armored ones. This deadly duel continued for three decades, through the collapse of the Soviet Union. It continues today. It will continue into the foreseeable future. ***EMP crippling of the American military machine and of the modern American nation remain real prospects.***

**THE NATURE OF EMP.** Electromagnetic pulse is sufficiently alien to ordinary human experience that it seems to many to be either magic or illusion. Such entirely understandable human reactions have not facilitated the development or implementation of apt responses to the profound threats which it poses, either by political or military leaders. Thus, a few operationally-oriented fundamentals may be of use:

***EMP is really severe static electricity, everywhere, all at once.*** Without needing to understand the undeniably esoteric means by which EMP arises in various military circumstances, it suffices to recall that it presents itself as something closely akin to static electricity, extremely intense but exceedingly brief, everywhere within line-of-sight to a high-altitude nuclear explosion, "all at once." (This "static electricity" pulse is carried on radio-frequency electromagnetic waves of uniquely high intensity. The bomb's extraordinarily intense prompt radiations essentially transform the entire atmosphere underneath it into a gigantic radio transmitter-antenna radiating at maximum-possible intensity – for a very brief interval. The bomb's fireball, expanding rapidly in the presence of the Earth's magnetic field, gives rise to a second manifestation of EMP which is of particular significance for long metallic lines, such as electrical and telephone systems.)

Extended metallic structures within line-of-sight of the explosion – telephone and electrical lines, radio and TV antennae, fence wires, etc. – then serve to gather up the broadcast energy of EMP and deliver it into whatever they connect to, often with locally ruinous results which appear retrospectively to be basically similar to those resulting from a lightning-strike. However, since the damage occurs thousands of times more swiftly than does that of a lightning-strike, most types of lightning-protective devices are essentially useless. Since it travels at the speed-of-light, EMP arrives essentially instantaneously, from the general direction of the explosion.

***EMP can blanket an entire U.S.-sized continent from a single source.*** EMP originates primarily in the interaction of gamma-radiation from a nuclear explosion with the Earth's atmosphere at altitudes of a few dozen kilometers and propagates predominantly toward the Earth's surface. (The low-frequency, long-time component of EMP arises from fireball interactions with the Earth's magnetic field, as already noted.) Thus, since you can readily see a bomb explosion a few hundred kilometers above the central U.S. from anywhere in the "lower 48", the EMP arising from that explosion's interactions with the Earth's atmosphere can also "see" you.

To be sure, at greater distances, the intensity of the pulse will be smaller, but usually not as indicated by the familiar inverse-square-of-the-distance law. Likewise, its severity is generally not well-related to the yield, or total energy production, of the bomb. (The initial sharpness of the EMP actually depends rather sensitively on esoteric aspects of the bomb's design and operation. Low-yield specially-designed bombs may pose as large – or ever larger – EMP threats, at both low and high electromagnetic frequencies, as do high-yield "ordinary" ones.)

***EMP doesn't linger.*** Since it arises from a nuclear explosion's promptly-emitted gamma radiation interacting with the Earth's atmosphere, nuclear EMP goes away very quickly. It is a phenomenon of compelling interest only for time-scales of the order of microseconds – millionths of a second, although its long-time component may be present for milliseconds – thousandths of a second. (Within these time-frames, however, it can be quite dramatic in its effects.) It has none of the lingering characteristics of nuclear radioactivity or fallout.

***EMP isn't sensed by people, and it doesn't damage the human body.*** The nervous system and associated sensory faculties of people are essentially totally insensitive to electromagnetic radiation of the frequency, intensity and the time-duration of EMP. We don't sense it in any way. Because it arises and then goes away so exceedingly quickly, electrical currents due to it do not really begin to flow within our bodies, and no physiological damage of any kind takes place. EMP really "speaks" only to metallic objects, and to things connected to them which are sensitive to high-frequency currents.

***EMP is much more threatening to big electrical systems than to small ones.*** Because metallic objects of many different shapes can effectively gather up and then concentrate the energy associated with EMP, physically large systems comprised of metal – lines, cables, wire and dish antennae – often manifest exceptionally great vulnerability to EMP damage. Their spatially extended components "harvest" the EMP energy broadcast by the bomb-atmosphere interaction, which falls fairly uniformly over wide areas, and bring it to wherever the system's "barn" may be – the often-centrally located components of the extended system which may be quite sensitive to electrical overload conditions. Physically small systems usually don't get EMP "illumination" so well-collected or -focused within themselves, and thus tend to be more durable to its effects. An obvious exception to this smaller-is-safer rule-of-thumb are communications systems, whose antennae and high-sensitivity "front ends" almost unavoidably make them highly vulnerable.

***EMP is much more threatening to modern electronics than to old-fashioned ones.*** Older electrical and electronic systems are generally built out of massive components, which are innately much more tolerant of the effects of EMP. Vacuum tubes, for example, are extremely EMP-rugged, while the ever-tinier transistors which have almost totally replaced them in the U.S. military machine – as well as in U.S. civilian electrical/electronic systems of all types – are ever-more-vulnerable to EMP destruction. (Moore's Law – which states that leading-edge integrated-circuit electronics shrink in area by two-fold every year-and-a-half – assures that this vulnerability will become ever more severe, into the foreseeable future.) The Soviet technological lag behind the Americans has constituted a substantial – and vigorously exploited – advantage in this somewhat perverse respect.

***EMP in space is different from EMP near the ground, and is typically nastier.*** EMP arising in spacecraft due to exposure to nuclear hard-x-ray and gamma radiations – even from great distances – is often extremely tedious to eliminate effectively and with adequately great assurance. (It is assuredly possible to accomplish, however, even against the most severe threats, although it is often quite costly to do so.)

Nuclear EMP thus poses an extremely serious threat to the assured functional survivability of space assets, both military and civilian, the more so as the essential system-level testing always was expensive and currently is effectively impossible.

***EMP defenses are simple, and traditionally have added ~10% to military system costs.*** For typical military systems which do not operate in space, the rule-of-thumb has been that robust hardening against EMP effects adds 3-10% to the total system life-cycle cost – "the cost to the Nation to own" – if such hardening is engineered-in from the outset. For systems which are mass-produced, the EMP hardening cost may be as low as 1%, while few-of-a-kind items such as the MILSTAR spacecraft may have a fractional cost attributed to wartime survivability of a few tens of percent. (To be sure, cost attribution in DoD often is a political art, not an economic science.)

Such hardening consists primarily of *high-integrity* albeit thin (e.g., tinfoil-like) metallic shielding to keep the EMP radiation out of enclosed volumes containing vulnerable systems components and of special electrical devices – e.g., high-tech analogs of lightning arresters – for protecting absolutely essential penetrations of such seamless metallic enclosures from inadvertently admitting significant amounts of EMP energy into the interior "sanctuary." The major fractions of the added-cost for EMP hardening have traditionally been spent in engineering design, prototyping, performance-testing and *life-cycle maintenance* of EMP-robustness, not in the mass-production of the "sanctuary" itself. Indeed, significant economies might be realized in these cost-dominating areas in future efforts by intelligent use of more modern technologies, particularly commercial ones which have been very effectively employed in the past several years. If, on the other hand, EMP hardening is back-fitted to an existing military system, costs have generally been in the neighborhood of 10% of total system cost-to-the-nation-to-own.

Quite notably, substantial EMP hardening of a wide variety of COTS – commercial off-the-shelf – equipment (e.g., personal computers and communications gear) currently being acquired by the Services has been demonstrated to be attainable with a few dollars' worth of parts-and-labor.

SOME FUNDAMENTAL TECHNICO-MILITARY DIFFERENCES. There were several fundamental differences in the technical and military approaches which the Soviet Union and the United States took toward EMP. These differences are reflected in the postures of the two nations' military machines today, and likely will be enduring ones.

The Soviets basically decided that EMP represented not only an exceptionally severe threat to the integrity of their military apparatus and their civilian infrastructure, but also offered extraordinary opportunities to their strategic offensive forces. Relatively deficient in supercomputer-based computational modeling tools with which to understand the quantitative details of EMP generation and interaction with a wide variety of particular structures and systems, they took a generic, highly empirical "belt and suspenders" approach to protection of both military and civilian systems against EMP, deploying protective hardware quite lavishly (as compared to the U.S.) and providing extensive counter-EMP training to both civilian and military personnel involved in the operation and maintenance of these systems. This preparative excellence continues virtually undiminished through the present time.

Soviet strategic strike forces characteristically have featured weaponry well-suited to efficient EMP generation over exceptionally wide areas. ***That EMP strike component exists today in the Russian strategic order-of-battle, moreover likely at its maximum Cold War strength.*** *I very confidently predict that it will be one of the last features of Soviet strategic nuclear weaponry to be retired from the Russian strategic force structure.* It has long been considered highly likely by U.S. strategic war planners that a Soviet first-strike would commence with a multi-explosion "laydown" of high-intensity EMP all over the continental U.S., significantly before any target on the ground is brought under attack, simply because the cost of such an attack-commencement is low and the benefits gained are great. Indeed, recollections of strategic war games long past have as a major common feature the beginning of the game with a massive Soviet EMP laydown all over the U.S., followed immediately by an extended "time-out" while the game's referees rip up huge handfuls of U.S. military capability of all types and throw it away as likely EMP-ruined.

We Americans, in contrast, collectively saw EMP as a major nuisance which could be rather precisely understood, defended against "well enough" – and thereafter largely ignored. The Defense Atomic Support Agency (DASA), succeeded by the Defense Nuclear Agency (DNA) and then by the Defense Special Weapons Agency (DSWA) and currently buried somewhere in the Defense Threat Reduction Agency (DTRA), working in exceptionally fruitful long-term collaboration with dedicated components of American industry (of which the RAND Corporation Physics Department, later re-organized as R&D Associates, and the Mission Research Corporation were particularly distinguished leaders), developed a really outstanding technical appreciation of EMP, how to model and simulate it with high fidelity, and how to effectively defend major military systems against it. Indeed, I estimate that half of DASA/DNA/DSWA's third-billion dollar ('98 $) time-averaged annual budget was expended for purposes of defense against EMP and related nuclear effects, over an interval of three decades.

Programs then came into existence to express and embed this evolving understanding – excellent albeit imperfect – of EMP in major American strategic warfare systems, primarily the offensive ones but also the defensive components. However, because neither supercrats nor senior commanders really understood – or, in some cases, believed in the existence of – EMP and its effects, these EMP hardening programs too often followed uncertain trumpets, and their <u>average</u> effectiveness was not exceedingly high. (At that, U.S. strategic military systems were much better EMP-protected, on the average, than were our tactical ones.)

Some CINCs stand out in my memory as exceptionally diligent in their efforts, the results of which were especially praiseworthy. (A few senior Navy admirals, enjoying unusually great tenure and discretion over the resources of their large commands, did very well by the enduring National interest in these respects.) All too often, though, protecting against a poorly-understood, deemed-unlikely threat of a semi-magical character lost out in the unceasing battles-for-resources, and was deferred, largely or completely, to "next year" – a well-known point-in-time which is never quite attained in DoD-Land. In some notable EMP-hardening programs, sustained and strenuous efforts were made without securing desired results, outcomes which were sometimes obscured to the present day by lack-of-candor leveraged with high security classifications. Case histories abound, but are not appropriate for open discussion.

As a result, the present-day U.S. strategic force structure is a veritable "patchwork quilt" with respect to its EMP durability. The bottom line is that, in "really bad weather", this "quilt" won't keep "warm" the fundamental National interest. *This situation is undoubtedly known, even in many of its details, to our potential near-peer and sub-peer adversaries – and it presumably incentivizes their exploitation-directed efforts.* ***At that, America's strategic forces may be substantially better-postured against EMP attack than are our day-to-day, tactical forces.*** However, I commend to your favorable attention the substantial ongoing efforts of the Services to attain improved EMP hardness levels of tactical military equipments of many kinds, dubious recent coordination efforts from the Joint Staff notwithstanding.

The EMP robustness of the civilian infrastructure of the United States can be summarized far less equivocally: it is entirely non-existent. ***Our civilian telephony, electricity, broadband communications and electronics plants are all naked to our nuclear-armed enemies.*** They were neither designed, nor engineered, nor constructed nor are they operated so as to survive nuclear explosion effects, even at very great distances – for the 'invisible hand' of the marketplace provides no incentives for EMP robustness, nor penalties for failing to so prepare. Large electric power and telephony systems are known to fail under the effects of solar storms, which impose far smaller electromagnetic stresses than are known to arise from high-altitude nuclear explosions of even modest scales. ***Consequently, even a modest, single-explosion EMP attack on the U.S. might well devastate us as a modern, post-industrial nation.***

**PECULIAR ASPECTS OF EMP ATTACKS.** Indeed, a nuclear EMP attack on a nation is, in the large, the *obverse* of what the neutron bomb was asserted (utterly falsely by anti-deployment-directed Communist propaganda, but nonetheless with great political effect) to be in the small: an arch-capitalist weapon which killed people but didn't destroy the capital plant in which the people were located. *EMP weaponry (potentially even in single copy), in acute contrast to this now-ancient canard, potentially destroys in a highly effective manner the high technology electrical/electronic plant of any advanced nation – the heartland of modern civilization – while not directly harming people at all.*

It is profoundly unsettling that ***the electrical/electronic infrastructure of a large modern nation – which may be valued at more than ten thousand dollars per capita, or a few trillions of dollars for a nation such as the U.S. – can be so seriously threatened from afar by a single nuclear explosion, whose marginal cost may be a few million dollars, or a million-fold less.*** That this can be done without harming people – potentially even invisibly, if done in broad daylight – gives real pause for thought, in a still-troubled, nuclear-multipolar world. ***Nuclear EMP is the quintessential asymmetrical-and-unconventional threat.***

<u>**ASPECTS OF THE INTERNATIONAL STATE-OF-PLAY.**</u> Several aspects of the current and likely-future geopolitical state-of-play seem impacted by such considerations.

Through the end of the Cold War, we Americans could "attribute" any EMP attack on us with exceedingly high confidence to precisely one source: the Soviet Union. Moreover, we usually anticipated that such an attack would merely comprise the precursor of a "mass raid on North America" and, as such, "will be met with a full retaliatory response." Toward the end of the Cold War, American strategic war planners worried about more nuanced Soviet attacks, possibly EMP-intensive ones involving quite limited damage-on-the-ground, and puzzled as to how to most appropriately respond to such damage-intensive but "casualty-poor" attacks. Such perplexities seemed to many observers to be largely obviated by the end of the Cold War and the cessation of such "virtual hostilities" with the Soviets.

*But were they really?* It is widely-known that we Americans contemplated, briefly and in a non-pervasive fashion, a nuclear EMP laydown on Iraq (a Non-Proliferation Treaty signatory legally entitled to immunity from all nuclear attacks) as an exceptionally high-effectiveness commencement to Operation *Desert Storm* – <u>and</u> that two-thirds of the American people polled on the subject in that season explicitly supported the use of nuclear weaponry to protect the lives of American troops. It certainly should not be surprising if other nuclear-capable nations were thereby stimulated – if indeed any such external stimulus was needed – to contemplate employment of a similar tactic against their various politicomilitary adversaries, of which the U.S. may well be one.

***What would the U.S. response be to a nuclear EMP "bolt from the blue" – or even one from a geopolitically overcast sky?*** What if such an attack, e.g., executed with a single rather modest Earth-orbiting bomb, arguably could have been mounted not only by Russia, but also by China or India or Pakistan or Iran – or North Korea? Particularly if none of our fellow citizens died as a direct-and-immediate result of such an attack, what degree of certitude of attack attribution would we require of ourselves before an American President would order a retaliatory strike imposing condign punishment on the suspect nation? Paralyzed as a modern nation, thrown back decades in time in industrial capabilities but still retaining a reasonably full set of nuclear teeth in our national mouth, just how would we Americans then choose whom to bite – if anyone?

That scenarios of this general flavor are currently considered "within the pale" is illustrated by the "Army 2020" war game conducted at Carlisle Barracks two years ago. Especially notable for its openness, this exercise postulated a U.S. expeditionary force in the Ukraine clashing with an invading Russian force, two decades hence. When the Russian force fared poorly in ground combat operations, the Russian General Staff used a set of nuclear explosions in space to effectively destroy the "high eyes and ears" of the U.S. military – and most civilian comsats and Russian space systems, as well – in order to express "national resolve." In addition to the far-distant Russian nuclear explosions giving American decision-makers real pause for thought, the entirely unexpected, abrupt and total loss of the "high ground" conferred by U.S. space assets nearly cost the American expeditionary force its collective skin. Just as this game was ending in a Russian-American armistice, the Chinese, noting America's unprecedented military incapacity, commenced to make their long-expected moves in the Far East . . . .

At that, wafting out of this unusually thought-provoking exercise was a faint aroma of "Blue-preferred Red responses," a well-known key ingredient of politicomilitary folly. The Army's game-designers were willing to postulate nuclear explosions in space of a flavor which acted over time-scales of hours to days to dramatically "burn down" American space assets largely owned-or-operated by the Air Force. However, these game-designers didn't care to consider an arguably equally plausible Russian nuclear EMP laydown over the Ukrainian territory within which the American expeditionary force was operating – which, without inflicting casualties directly, may well have devastated the electrical/electronic sinews of American tactical military assets – ones incidentally almost entirely owned-and-operated by the Army in this particular scenario.

Indeed, EMP laydowns constitute a generically attractive response on the part of any regional nuclear power – not just Russia – to virtually any American power-projection attempt. They exemplify what is termed a "technologically asymmetric response" to the impending *Revolution in Military Affairs*, one in which our adversary acts purposefully to leverage his set-of-strengths and exploit our set-of-weaknesses. (Saddam Hussein fought us entirely on our terms in *Desert Storm*; we must assume that we will not be gifted with a similarly inept adversary for some long time.) ***Because a very small number – potentially just one – nuclear weapon exploded at high altitude over an American expeditionary force attempting forced entry against a major regional power could potentially tip the balance against our efforts, all such powers who contemplate someday possibly confronting us will be incentivized to develop, acquire or retain nuclear weaponry*** *– quite contrary to the goals of ongoing nuclear nonproliferation efforts and to the objectives of the Revolution in Military Affairs.* It might be noted in this context that there are over 10,000 ballistic missiles presently owned by over 30 countries which are potentially capable of lofting a nuclear weapon to high altitudes over proximate U.S. forces – and that ***none of the ballistic missile defense programs of the current Administration aim at military "products" which could defend against such "pre-apogee" nuclear EMP attacks thrown by ballistic missiles against U.S. forces.***

Both as a demonstration-of-military capability and a show-of-national resolve, exploding a nuclear weapon continues to have no peer. (The South African example naturally comes to mind in the current context, both with respect to its motivations and its successful covertness.) If exploded so as to also cripple opposing military forces without also inflicting mass casualties, the potential attractiveness of such weaponry likely becomes quite compelling. A few nuclear weapons and unstoppable delivery systems (e.g., attacking ballistic missiles facing only Clintonesque missile defenses) which can throw them into space, one at a time, over an invader's forces thus naturally rise to the top of the "wish list" of many types of national leader. ***North Korean options of these types relative to American forces deployed in South Korea and Japan come unbidden to mind.***

***<u>The ability of North Korea to attack the continental United States in the very near term with small nuclear weapons thrown with advanced variants of the current Taepo Dong missiles is by now well-known to the Washington national security community, thanks in large part to the efforts of the Rumsfeld Commission</u>***

***Thus, for several reasons, each one good-and-sufficient, the U.S. would be well-advised to manifest far more effective concern than prevails at present regarding EMP attacks against its national territory <u>and</u> against its forces abroad.*** <u>Conventional approaches to threat assessment – i.e., those which typically quite conservatively-and-conventionally assess both the capability and the intent of potential adversaries – may result in **Pearl Harbor-class catastrophes** in the context of EMP attacks.</u>

**<u>EMP ISSUES FACING AMERICAN SMALL BUSINESS.</u>** Against such current and anticipated-future geopolitical backgrounds, then, what are the major EMP-related issue-sets facing the constellation of American small businesses?

First, when a Government-sponsored enterprise such as the DoD with its huge annual budget is still struggling to attain a reasonable level of EMP hardness, moreover after literally decades of large-scale effort, how is it at all reasonable to expect America's small businesses to even begin to cope with such a mysterious and seemingly unlikely threat?

Second, America's small businesses currently have to economically battle competition from all over the world, while operating in an already-very-high-cost business environment featuring some of the most extensive regulation found anywhere on Earth. How is it even remotely feasible for a typical small business to take steps toward greater EMP hardness when its foreign competition won't be burdened with the costs of any such steps?

Third, even if an American small business were somehow motivated to seek greater EMP hardness for its operations and, as pertinent, for its products, how could it possibly do so in a practical manner, since it has no expertise in this arcane area and no spare resources to go out and purchase this in a marketplace inhabited only by the relatively very well-resourced DoD and its captive suppliers?

At the bottom line, it's difficult to understand how America's small businesses can possibly be expected to respond meaningfully to the EMP threat which the United States will face into the foreseeable future. They are simply not resourced, intellectually, materially or in any other way to cope with this problem. Indeed, one might ask why America's businesses should even be expected to respond – after all, isn't providing for the common defense one of the primal reasons why Americans established a Federal government, and why they fund it every year with their taxes? Why should the Government expect America's citizens-small businesspeople to shoulder the same burden twice?

**EMP ISSUES FACING THE CONGRESS.** With all due respect, the only *fundamental* issue facing the Congress in this area is determining the degree of its own concern regarding the EMP threat to the at-risk portions of the Nation's infrastructure.

Once the degree of this concern is determined, the Congress is then in a position to determine what's appropriate to do in the way of leading, guiding, intellectually capitalizing and materially incentivizing America's small businesses to defend capably their respective portions of the privately-owned part of the American infrastructure from EMP threats.

It's of fundamental importance for all such Congressional consideration to realize that ***the ways-and-means for defending against EMP threats are far more readily available, less expensive and more effective today than they were even a decade ago.*** This nearly-qualitative change in EMP-defensive capabilities has arisen as a direct consequence of the proliferation of very high-performance electronics throughout American civilization, i.e., personal computers and telecommunications devices. An unavoidable consequence of the ever-higher performance of these devices is that they *continuously* generate very low-level EMP-like signals; also, due to their very small size, they are exceptionally sensitive to interference in their operations from EMP-like signals.

These considerations have motivated manufacturers of these systems to provide passive defensive means against interference with their normal operation by EMP-like signals coming from outside of them; also, the manufacturers, on their own and due to Government regulations, have constructed these systems so that they emit very little of the EMP-like signals which they generate in normal operation. Together, these passive defenses not only make a substantial fraction – indeed, the most modern fraction – of the American infrastructure more robust against EMP threats, but they also provide the ways-and-means, both technological and intellectual, for extending this relative robustness into many other EMP-vulnerable portions of our Nation's electrical and electronic infrastructure.

These defenses have two basic forms. The first consists of enclosing electronics in high-performance metallic shells, since even quite thin layers of metal essentially completely stop both the most threatening aspects of EMP and the low-level electromagnetic interference resulting from high-performance equipment operation. The second defensive step consists of simple, very low-cost means for suppressing electrical surges on consumer-level electrical power and signal lines, so that feeding electrical power to equipment or connecting telephone or cable signals into it don't also provide pathways for ruinous EMP to damage or destroy its circuitry.

The fundamental reason that significant portions of the American infrastructure are much more robust today than a decade ago against EMP threats is simply due to the now-pervasive use of these two technology-sets in the modern portions of the computing and telecommunications plants of the United States. This constitutes an applicable track and an excellent example for enhancing the robustness of much of the currently unprotected infrastructure of our country.

<u>RECOMMENDATIONS FOR CONGRESSIONAL CONSIDERATION.</u> If the Congress chooses to initiate an EMP defensive program for the non-Governmental portions of the American infrastructure, particularly those involving small businesses, I respectfully recommend that any such initiative should include the following features:

**Mandated Public Information Program.** A reasonably informed American public is the surest and likely-most-effective single means of defense against the EMP threat. A statutory mandate to, for instance, the Small Business Administration and/or the Federal Emergency Management Administration to comprehensively inform – in clear and readily-comprehended language – America's small businesspeople about EMP protection, its significance in National emergencies <u>and</u> its many tangible peacetime benefits, is surely long overdue. If effectively done, such Government-to-citizenry communication would lay a broad and sound foundation for all subsequent corrective actions. It certainly would provide the motivation for a follow-on Government program to incentivize and guide EMP-defensive actions.

**Design-To-Cost Focus and Government-Sponsored Prototyping.** All successful businesses are bottom-line-oriented, and no Government program which aims to enlist the participation of American businesspeople in the late 1990s can hope for success if it's not got effective-and-visible caps on the costs which will be involved – even if the Government underwrites much of the expense of implementing EMP defenses of the American infrastructure. Typical "government gold-plating" must be eschewed in creating "good enough" solutions to EMP threat-issues of very high cost-efficiency and general applicability. I suggest that it's the Government's responsibility to set standards, to resource entirely the development of prototypes which comply with these standards, to test and certify these prototypes in a representively wide variety of civilian equipments and circumstances, and to underwrite commencement of a mass-production program which maintains certifiable quality.

<u>Only</u> after all this is accomplished at Government risk-and-expense should American small businesses be asked to shoulder <u>any</u> significant portion of the cost-at-the-margin of "providing for the common defense" against the EMP threat. [After all, businesses already pay for the Government to "provide for the common defense" via their taxes; if the Government were truly efficient-and-reliable in discharging this arguably-most-fundamental of its responsibilities, there would be essentially no need for Joe Businessman to pay a second time for EMP defenses.]

**Tax Incentives For Widespread Adoption.** In the "real world" in which American business operates, incentives matter, and incentives-at-the-margin matter most of all. Any Government program aimed at defending the American infrastructure from the EMP threat should be based squarely on minimizing the cost-at-the-margin for businesspeople who must decide to whether, when and how much EMP defense to erect in their portions of the infrastructure, whether it be their plants, their stores or their product-lines. One of the most efficient means for doing this is to provide for tax rebates for a large portion of the total cost of purchasing and installing EMP-protective gear. I suggest that equal burden-sharing between Government and business is roughly equitable in most cases, for the Government's responsibility is defense against the common enemy while the businessperson's interest is high-reliability performance-in-peacetime, in spite of electromagnetic interference (EMI), power-line surges, lightning-strike effects, etc. Well-designed EMP-protective gear will provide both peacetime and National emergency benefits of substantial magnitudes.

**Credible Performance Certifications.** Several large-and-venerable investment houses have sustained titanic losses in the past few years by allowing their high-rolling traders to run their own back-offices, with the result that losses were effectively concealed until they ran into ten figures. Government programs that are allowed to monitor, review and appraise their own performance often run into similar difficulties – with the notable difference that these failures are typically entombed discreetly in classified document repositories. Certification of EMP hardness of National infrastructure-protective equipment and systems in transparently-operated UL-type test facilities is a *sine qua non* for programmatic integrity.

**Independent Periodic Assessments.** For nearly three thousand years, the applicable maxim of Western jurisprudence has been "No man is an apt judge of his own cause." Particularly in its oversight of any Congressional initiative – one in which Executive co-ownership might be somewhat lacking – the Congress would be well-advised to commission independent reviews and assessments of programmatic progress made and problems encountered. No honest program will object to a single swiftly-executed annual review by competent-and-objective folks who can be "brought up to speed" without undue effort or delay. For the present purposes, a National Academy of Engineering review group within which pertinent DoD expertise was well-represented might be most appropriate.

**Mandated Government Contractor Compliance.** One of the most frequently exercised Government tools for introducing change into the civilian infrastructure is to require that Federal contractors of one or another types "shall comply" with Government-specified standards. While I personally find most such requirements to be excessively burdensome and borderline-tyrannical as well as often outright silly, assuring National survival against EMP threats while securing robustness against peacetime electromagnetic mishaps is clearly a "good cause" – and so are they all, all good causes justifying coercion by an enlightened Government!

**Executive Managerial Accountability and Stability.** Most Government programs perform as abysmally as they do, relative to the closely comparable people-sets working in American industry, primarily because managerial stability is distinguished by its absence and managerial accountability is correspondingly non-existent. "State property is nobody's property" as the old Soviet saying went, and the U.S. Government's interest in programmatic success of its endeavors is almost invariably "co-owned" by precisely no one, civilian or military. Even a superficial comparison of Soviet and American experience over the past few decades indicates clearly that, without some type of proprietorship, no "property" will be decently looked after, and the long-term consequences of the resulting neglect likely will be telling ones. The Congress would be well-advised to act accordingly with respect to creation of infrastructure EMP defenses: the program's senior managers should be "lashed to the mast" until the programmatic ship weathers the inevitable storms and is safely in the specified port. This is *remarkably* difficult to accomplish, as a wealth of regrettably pertinent DoD experience shows, but it's extremely important.

**Competent, Empowered, Dedicated, Single-Purpose Congressional Staff.** Nothing more clearly-and-convincingly indicates Congressional seriousness regarding any issue as the commitment to its oversight of highly capable Congressional staff. Staff of this rare-but-crucial flavor is dedicated to following Executive performance on statutory specifications, undistracted by other unrelated responsibilities, and manifestly has the confidence of cognizant senior Members. If the Congress should become really serious about protection of the National infrastructure from the enduring EMP threat, it will so commit such staff.

**Continuing Congressional Engagement.** Accompanying all of the above is a need for continuing Congressional engagement with the Executive's best thinking and analysis, of the general character which is traditionally associated with Congressional oversight proceedings which review mandated annual reporting and *ad hoc* certifications. Indeed, and again with all due respect, the Congressional follow-up with respect to the existing statutory demand on the SecDef and the DCI for an EMP posture statement will be quite prognostic.

Congressional oversight with which I'm familiar in the overall National security area has been highly commendable in its peak intensity, its intellectual acumen and its cogency but, again with all due respect, has been less-than-perfect in its regularity and follow-through. *Constancy and perseverance will be crucial in seeing Congressional mandates faithfully and efficiently translated into Executive Branch programs and National infrastructure EMP defenses-in-being*, as cognizant Government officials-and-officers come and go with remarkably high frequency. As just noted, commitment of highly capable, single-task Congressional staff members to such functions would have both symbolic and practical significance.

**CONCLUSIONS.** Electromagnetic pulse (EMP) is a "weapon of mass *hardware* destruction", even one instance of which could not only cripple much of the U.S. military machine but which also can lay waste to most of modern American civilization – without directly harming a single American. Technical means of defense against EMP exist which are of unquestioned technical feasibility and effectiveness; such means already passively defend much of the most modern portions of America's electronics infrastructure.

***Whether such passive EMP defenses are extended to the rest of the electrical and electronics infrastructure of the United States is for the Congress to determine. This matter is ripe for decision now.***

I thank the Committee once again for this opportunity to appear and comment on these matters of enduring significance for our Nation's common defense.

# Some Intelligence Perspectives on the Nuclear Threat and Electro-Magnetic Pulse

A Statement for the Record
by
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for Strategic and Nuclear Programs

for the 1 June 1999 Hearing of the
Subcommittee on
Government Programs and Oversight,
Committee on Small Business,
United States House of Representatives

I understand the interest this Committee would have in an Intelligence Community perspective of the EMP issues outlined in Congressman Bartlett's 13 May 1999 letter to me. Although the questions outlined in his letter focus more on other invitees, I can say a few things in an open forum about proliferation, the emerging missile threats around the world, and the nuclear threat that will likely face the United States in the future. However, I am limited about what I can say regarding various countries' nuclear weapons and missile programs and their concepts for using them in the future. Obviously, you would want us to be able to continue to gain intelligence insight into foreign developments and intentions, so I cannot divulge too much lest countries increase their denial measures.

The United States has faced a significant nuclear threat for several decades from the former Soviet Union and China. We continue to face that threat today, albeit with considerably reduced tension than during the Cold war. Generally, the nuclear threat has been viewed from the perspective of direct strikes, but the potential for electromagnetic pulse (EMP) effects has been part of it as well. I will leave to others more expert than myself to describe EMP and the potential damage its effects could have on US military and civilian equipment. Instead, I will focus my statement on the proliferation of nuclear and missile capabilities and some developments that could affect the EMP threat.

The proliferation of weapons of mass destruction and the missiles that can deliver them has continued to evolve. We saw nuclear testing in India and Pakistan last year, indicating both are positioned to build nuclear arsenals; Iran seems to be pushing its nuclear weapons program forward; and we are concerned that North Korea has a continuing program. Moreover, societal and economic stress in Russia seems likely to grow, raising more concerns about the security of nuclear weapons and fissile material.

The capabilities of the missiles in the countries seeking to acquire them are growing, a fact underscored by North Korea's launch of the Taepo Dong-1 space launch vehicle last August. The number of missiles in these countries is also increasing. Medium- and short-range ballistic missile systems already pose a significant threat to US interests, military forces, and allies, particularly if armed with weapons of mass destruction. We have seen increased trade and cooperation among countries that traditionally have been recipients of missile technologies from others. Finally, some countries continue to move toward longer-range systems, including intercontinental ballistic missiles (ICBMs).

We expect the threat to the United States and its interests to increase over the next 15 years. However, projecting political and economic developments that could alter the nature of the missile threat many years into the future is virtually impossible. The threat facing the United States in the year 2015 will depend on our changing relations with foreign countries, the political situation within those countries, economic factors, and numerous other factors that we cannot predict that far into the future with confidence. A glance fifteen years into the past is illustrative:

- Fifteen years ago the United States and the Soviet Union were superpower adversaries in the midst of the Cold War, with military forces facing off in central Europe and competing for global power. Today, by contrast, the ideological differences that separated us have been replaced by differences expected between modern nation states.

- Iraq is another example; 15 years ago it shared common interests with the United States while it was at war with Iran. Since Iraq's invasion of Kuwait in 1990, Washington and Baghdad have been in numerous military and diplomatic conflicts.
- As a final example, we do not know whether some of the countries of concern in 15 years will continue to exist in their current states or as suppliers of missiles and technology.

Recognizing these uncertainties, the Intelligence Community projects foreign ballistic missile capabilities into the future largely based on technical capabilities and with a general premise that relations with the United States will not change significantly enough to alter the intentions of those states pursuing ballistic missile capabilities. By Congressional direction, we make annual assessments of the threat and will be able to take account of any contemporary information that alters our projections.

The new missile threats confronting the United States are far different from the Cold War threat during the last three decades. During that period, the ballistic missile threat to the United States involved relatively accurate, survivable, and reliable missiles deployed in large numbers. Soviet--and to a much lesser extent Chinese--strategic forces threatened, as they still do, the potential for catastrophic, nation-killing damage. By contrast, the new missile threats involve states with considerably fewer missiles with less accuracy, yield, survivability, reliability, and range-payload capability than the hostile strategic forces we have faced for 30 years. Even so, the new systems are threatening, but in different ways.

First, although the majority of systems being developed and produced today are short- or medium-range ballistic missiles, North Korea's three-stage Taepo Dong-1 space launch vehicle (SLV) demonstrated Pyongyang's potential to cross the 5,500-km ICBM threshold if they develop a survivable weapon for the system. Other potentially hostile nations could cross that threshold during the next fifteen years. While it remains extremely unlikely that any potential adversary could inflict damage to the United States or its forces comparable to the damage that Russian or Chinese forces could inflict, emerging systems could potentially kill many Americans, depending on the type of warhead, the accuracy, and the intended target.

Second, many of the countries that are developing longer-range missiles probably assess that the *threat* of their use would complicate American decision-making during crises. Over the last decade, the world has observed that missiles less capable than the ICBMs the United States and others have deployed can affect another nation's decision-making process. Although our potential adversaries recognize American military superiority, they probably assess that their growing missile capabilities would enable them to increase the cost of a US victory and potentially deter Washington from pursuing certain objectives.

Third, the probability that a missile armed with a weapon of mass destruction (WMD) will be used against US forces or interests is higher today than during most of the Cold

War. Ballistic missiles, for example, have already been used against US forces during the Gulf war. More nations now have longer-range missiles and WMD warheads. We have seen missiles used in several conflicts over the past two decades, although not with WMD warheads; nevertheless, some of the regimes controlling these missiles have exhibited a willingness to use WMD.

Thus, acquiring long-range ballistic missiles armed with WMD will enable weaker countries to do three things that they might not otherwise be able to do: deter, constrain, and harm the United States. To achieve these objectives, these WMD-armed weapons need not be deployed in large numbers; with even a few such weapons, these countries would judge that they had the capability to threaten at least politically significant damage to the United States or its allies. They need not be highly accurate; the ability to target a large urban area is sufficient. They need not be highly reliable; their strategic value is derived primarily from the threat (implicit or explicit) of their use, not the near certain outcome of such use. In many ways, such weapons are not envisioned at the outset as operational weapons of war, but primarily as strategic weapons of deterrence and coercive diplomacy.

The progress of countries in Asia and the Middle East toward acquiring longer-range ballistic missiles has been dramatically demonstrated the past 12 months:

- Most notably, North Korea's three-stage Taepo Dong-1 space launch vehicle has inherent, albeit limited capabilities to deliver small payloads to ICBM ranges. Although the Taepo Dong-1 satellite attempt last August failed, North Korea demonstrated several of the key technologies required for an ICBM. However, as a space launch vehicle it did not demonstrate a payload capable of surviving atmospheric reentry at ICBM ranges. We assess that North Korea would be unlikely to pursue weaponizing a three-stage Taepo Dong-1 as an ICBM, preferring instead to pursue the much more capable Taepo Dong-2, which we expect will be flight tested in the near term.

- Pakistan has flight-tested its 1,300 km range Ghauri missile, which it made with North Korean assistance.
- Iran has flight-tested its 1,300 km range Shahab-3—an improved version of North Korea's No Dong, which Iran has produced with foreign assistance.
- India has flight-tested its Agni II MRBM, which will have a range of about 2,000 km.

Thus, the threat to US interests overseas from medium-range ballistic missiles is immediate, serious, and growing. These missiles could use conventional, and in some cases, WMD warheads. Moreover, in a regional conflict, some of these systems could loft a nuclear weapon (if the country had one) over nearby adversarial territory and attempt to create an EMP effect. However, the effects of EMP are not merely based on the height of burst of a nuclear device; the yield and type of nuclear device significantly affect the degree of potential damage the EMP generated would create.

In an unclassified forum, I cannot go into the details of individual countries' nuclear weapon development efforts. However, as we continue to analyze those efforts, we will be able to work with our DoD colleagues to model the potential effects of the types of nuclear weapons North Korea and others would be capable of producing in the years to come. DoD would also be able to examine whether the EMP produced by those weapons would be able to damage US military or civilian equipment.

Also, as additional countries develop ICBMs, the potential to threaten the United States will increase. Thus, the United States has faced a nuclear threat for decades; an inherent component of that threat has been the potential effects of EMP. We project that the nuclear threat will continue into the future, along with the concomitant potential for EMP effects. Nevertheless, from an EMP perspective, the launching country--Russia or someone else--would undoubtedly calculate that the target country, after detecting an incoming missile strike, would not debate whether direct destruction or EMP was the intent; the target country would view a nuclear strike as a nuclear strike. Thus, the launching country would assess that any strike—EMP or not—would risk severe retaliation.

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Before The

House Committee on Small Business

Government Programs & Oversight Subcommittee

Electromagnetic Pulse (EMP)

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U.S. House of Representatives

Mr. Chairman and Members of the Committee.

I am grateful for the opportunity to address the Committee on an issue of some importance to the Department of Defense -- Electromagnetic Pulse (EMP). I will discuss the threat environment and the growing dependence on commercial off the shelf (COTS) equipment in our military systems.

The detonation of a nuclear weapon between 50 and several hundreds of kilometers above the earth's surface will produce an electromagnetic pulse that can under certain conditions, damage electronic equipment operating within its footprint. Although the EMP phenomenon has been studied for many years, its interaction with unprotected electronic equipment, and therefore the effects EMP will cause, is at best uncertain. While we know EMP may couple signals into electronic equipment well beyond those it was designed to safely handle, we do not know what margins or tolerances have been built into the equipment, the extent to which temporary or permanent disruption to the equipment's normal operation will be experienced, or how wide spread the damage or disruption will be.

While EMP is a threat, it is not considered a highly probable threat in today' world. The President's Commission on Critical Infrastructure Protection, led by retired General Tom Marsh assessed threats and vulnerabilities of the national infrastructure including telecommunications, electrical grids, oil and gas systems, banking and finance, emergency services, and continuity of government. The report states that an EMP event would potentially devastate portions of the national infrastructure, but it is one of the least likely threats and , therefore not a serious danger. The report also reviewed the inherent threat posed by radio frequency (RF) weapons, but consider this threat to be very localized. In effect, the report concluded that our adversaries could find easier ways to do more damage then by the use of EMP or RF weapons and that because of this, the potential for such an event was unlikely.

I would like to quickly review some key factors in EMP technology efforts and then discuss several ongoing Department of Defense programs designed to address the EMP problem.

1) EMP testing of consumer electronics indicates that most systems require high EMP levels for damage, but may be upset (but not destroyed) at lower levels. Testing of COTS equipment has allowed us to make some observations regarding their vulnerability to a range of EMP environments. In general, it is possible that some equipment upset can occur when the EMP environmental field strengths are between 3-8 kilovolts per meter (kV/m). When the field strengths reach above 8kV/m the risk that some equipment will be upset becomes more probable. In the range of 7-20kV/m there is a possibility that some equipment will be permanently damaged, and above 20kV/m damage is probable. These results have been reconfirmed in recent 1998 testing of COTS computer equipment. I recommend to you the Los Alamos National Laboratory report by Dr. Michael Bernardin that further describes the impact of EMP on COTS equipment, as well as providing an assessment of the field strengths that can be produced by nuclear weapons.

2) Changes in commercial technology contribute to the hardening of the infrastructure. The two most significant developments are the widespread use of optical fibers and the general electromagnetic shielding of commercial electronics against spurious signals. The evolution of telecommunications cabling from copper wire to silicone and plastic fibers not only provides us the added speed and capacity modern communications demands, but these 'light pipes' are inherently immune to interference from electromagnetic pulse. Unlike copper cables, long fiber cable runs do not act like antenna to collect electromagnetic field strength and route EMP to sensitive devices. As our electronic environment becomes more complicated, equipment manufacturers have been forced to take defensive actions to protect equipment operation and consequently much of our electronic equipment is being manufactured today to tighter tolerances, which permit operations in electronically noise environments. Particularly for industrial quality and medical and laboratory equipment, off-the-shelf electronic equipment can be purchased and installed to meet the toughest electromagnetic environments that can be found in medical imaging, radiology, and high frequency welding environments. In fact, the move towards the digital environment has demanded a certain level of shielding to prevent interference to vulnerable transmission lines.
3) You likely have a form of EMP protection in your home, if you have a home computer or a major investment in home electronics entertainment systems. You likely have purchased a surge suppressor to protect this expensive and somewhat delicate investment from unintended spikes on the electrical power

grid. While in the normal case these transients are caused by natural phenomena such as lightning strikes or other factors such as power switching or transient loads, these devices will "filter out" the transients induced by EMP up to their stated ratings and built-in engineering margins. In many cases, these surge suppressors will also provide protection for equipment attached to telephone lines such as wireless telephone instruments, facsimile machines, and data communications devices. By blocking the out-of-the-ordinary signal levels, these surge suppressors provide some measure of protection from EMP-like events.

4) We know how to protect against EMP and radiation threats. Such protection is affordable, if provided for at an early stage in system design and development. For tactical systems and an anticipated threat environment at the low-to-moderate end of the threat spectrum, the cost can be as little as one percent of the total development investment and for strategic systems, where the worse possible threat environment must be protected against, five percent is reasonable. The typical engineering approach is to provide necessary filtering of the expected EMP energy frequency on wirelines that are connected to the device and to shield sensitive components from the direct effects of EMP energy.

5) State of the art commercial semiconductor processes are designed primarily for performance factors other than EMP. Many of today's semiconductor technologies are highly vulnerable to relatively low levels of electromagnetic

field strength. Protection of these devices requires designs and packaging techniques to prevent effects of EMP.

6) The infrastructure is rapidly evolving into a complex system of networks. At present, there is limited understanding of the implication of EMP vulnerability on these complex systems. We know for example that a large system of systems will only be as resilient as its weakest link. On the other hand, we know that large networks frequently have multiple, redundant paths and failure of an individual component may have little or no effect on the overall performance of the network.

7) To capitalize on leading edge technologies, military systems are increasingly using COTS equipment that has not been specifically designed to mitigate the effects of an EMP environment. Our goal is to transition from a 25% COTS / 75% MILSPEC equipment ratio in military systems to 75% COTS / 25% MILSPEC. This has several ramifications. There will be fewer DoD investments in built-to-specification military systems to meet unique DoD requirements. At the same time, with our growing dependence on commercial-of-the-shelf technologies, our concerns for robustness in an electronically noisy environment must be addressed in the equipment we purchase and these improvements will be available to other hardware purchasers.

8) The ban on underground nuclear testing requires the development of new designs, test protocols and procedures that ensure system survivability.

9) Life cycle maintenance of EMP protection must be addressed so the highest levels of protection can be assured. This means that modifications, inspections, repair actions, and operations must take into account the EMP integrity of the individual equipment and the networks they serve. A system that is engineered, installed and initially tested to guarantee its EMP hardness must be periodically retested and continuously "surveilled" to ensure that day to day operations and maintenance have not left it vulnerable to electronic attack. This EMP hardness surveillance and hardness maintenance process must be built into the system. This additional operations and maintenance burden must be addressed whenever a decision is made to protect against EMP vulnerabilities.

At this time I would like to discuss three ongoing efforts to address this threat that are underway as part of the DoD's Reliance program. The Science and Technology (S&T) directorate of the Office of the Under Secretary of Defense for Acquisition and Technology (OUSD(A&T)) established the Reliance program as a mechanism for coordinating and integrating DoD-wide S&T programs, reducing redundant capabilities, and eliminating unwarranted duplication. Although Nuclear Technology investments are addressed in the Defense S&T Reliance processes, the nuclear technology programs are unique in the level of integration built into the program. Since the establishment of the Armed Forces Special Weapons Project -- the first defense agency -- more than a half-century ago, joint technical programs have been emphasized within DoD Nuclear Technology activities. Currently all DoD Nuclear Technology S&T programs are accomplished under a single DoD component, the Defense Threat Reduction Agency (DTRA), which began operations on October 1, 1998. DTRA's establishment was one of the primary actions directed by the Defense Reform Initiative in November 1997.

Goals of the Reliance survivability assessment efforts are to perform operability, survivability, vulnerability, and connectivity assessments for current and proposed systems in combined nuclear effects environments. The identification and capture of relevant system data is the starting point for these assessments. This baseline program applies DTRA expertise in support of warfighting Commanders in Chiefs and service needs for affordable and responsive solutions to meet survivability requirements. This program responds to requirements identified by the Joint Chiefs of Staff, combatant Commanders in Chiefs, services, and other DoD organizations. These are efforts to conduct timely, accurate, and relevant assessments of components, systems, networks, and systems of systems. Funding for these particular efforts are roughly $25 million a year with DTRA as the lead agency.

The first effort I would like to describe is the Defense Technology Objective for Balanced Electromagnetic Hardening Technology. Its goal is to develop and demonstrate innovative and affordable technologies and methodologies for integrated hardening and testing of military systems against high-power microwave (HPM) and high-altitude electromagnetic pulse (HEMP) effects. Specific technology objectives include developing a personal computer (PC)-based EMP environment and coupling software model; a PC-based electromagnetic (EM) protection tool; a generic and simple-to-install hardware "kit" for hardening COTS computers; a radio frequency (RF) attack detector

(Witness Chip); and complete development of a unified EMP/HPM protection and test methodology.

It is anticipated that integrated hardening against multiple battlefield threat environments (i.e., HPM and HEMP) will reduce hardening cost, size and weight, reduce procurement costs (design and test time), and provide residual protection against other EM threats (e.g., indirect lightning). Hardening cost reductions of up to 30% can be achieved if composite shielding materials become realizable. Cost savings of 20-25% over the life of a system are also expected with the improved testing and maintenance/surveillance methodologies developed under this program. In Fiscal Year (FY) 1998, a prototype hardened alternating current (AC) power cord was designed to enhance COTS equipment survivability and reduce life-cycle costs up to 20%. A second effort was initiated to develop field-expedient methods for characterizing COTS immunity to EMP and HPM environments.

The second effort is the Electronic System Radiation Hardening Defense Technical Objective. Its goal is to develop enabling technology to support the fabrication of radiation-hardened electronics and photonics and develop test/design protocols to validate system survivability using aboveground tests. The payoffs from this program include hardened electronics and cost effective protocols to support system hardening and survivability verification. During 1998, this program demonstrated radiation hardened 0.5 micron silicon-on-insulator microelectronics for a 4X reduction of weight and power.

The third effort I would like to describe consists of a specific Army Small Business Innovative Research (SBIR) solicitation for EMP protection. Since this effort is currently soliciting proposals I can only refer to the official announcement currently advertised in the Commerce Business Daily (CBD). The effort has the title "Mitigation of Magnetohydrodynamic [MHD] Electromagnetic Pulse Effects on Long Lines for Missile Defense System and Infrastructure Protection." The objective of the SBIR program is to identify, develop, and demonstrate low-cost techniques to protect military and critical infrastructure systems with long power and communication lines from the effects of MHD-EMP. We hope the results of this and similar efforts will assist in our understanding of how best to address the potential EMP threat to our military capability and our national infrastructure.

In summary, EMP is a wide area event that can be caused by high altitude detonation of nuclear weapons. The energy they impart on transmission lines and electronic equipment is similar to certain natural phenomena. We know EMP could inflict damage on the national infrastructure and have tailored several government programs to address the hardening of commercial equipment against a broad spectrum of potential electromagnetic and RF threats. We have taken measures to ensure the critical command and control structures the nation depends on to respond militarily to such an event are resilient to these threats. There is concern that a combination of commercial power grids, telecommunications networks and computing systems remains vulnerable to widespread outages and upsets due to EMP. Detailed analyses of critical civil systems would be useful to better understand the magnitude of the problem.

Mr. Chairman and Members of the Committee, on behalf of Office of the Secretary of Defense, I appreciate this opportunity to present these insights on these EMP related programs and look forward to your questions.

# Vulnerability Assessment of RF Program

**BACKGROUND**

- **The Congress Has Become Increasingly Concerned About These Asymmetric Threats to Our Military Systems and Supporting Infrastructures**

# Vulnerability Assessment of RF Program

**OBJECTIVE**

- **"To Expand Threat Vulnerability Testing and Evaluation to Include the Threat of RF Weapons"**

--National Defense Authorization Act for FY 1999

# BAA - Vulnerability Assessment of RF

- The Goals of the Program Are:

  - To Continue the Test Program which Was Initiated Previously

  - To Acquire New Test Data on Modern and Future Military Systems, Support Infrastructure, and Systems under Development Using COTS Technology in Regards to Their Vulnerability, Susceptibility, and Survivability to Degradation, Disruption, Upset, and Damage from RF Devices

# BAA - Vulnerability Assessment of RF

- The Offeror May Purchase or Fabricate the RF Devices
- Conduct the Testing and Evaluation of the RF Devices
- Both Endeavors

# BAA - Vulnerability Assessment of RF

- The Design of the RF Devices Should Be Based upon the Representative Threat(s)

- Be Characteristic of what a Rogue Nation or Terrorist Could Build

- Be Fabricated Using "Open Source" Information and Commonly Available Hardware Components

# BAA - Vulnerability Assessment of RF

- The RF Devices Should Be Capable of Providing Wide Band and Ultra Wide Band Transient Signals

- RF Devices Capable of Providing Narrow Band High Power Microwave or Nuclear Electromagnetic Single Pulses Are Not Desired

# Please Contact Us.
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PART: U.S. GOVERNMENT PROCUREMENTS (MODIFICATION)
SUBPART: SERVICES
CLASSCOD: A--Research and Development
OFFADD: Defense Supply Service-Washington, 5200 Army Pentagon, Rm. 1D245, Washington, DC 20310-5200
SUBJECT: A--RESEARCH AND DEVELOPMENT BROAD AGENCY ANNOUNCEMENT
SOL DASW01-99-R-0900
DUE 061599
POC Mr. Harry W. Shatto, Jr. (703) 614-4579
DESC: Broad Agency Announcement (Modification) Solicitation No. DASW01-99-R-0900. This action was previously published in the CBD, 13 April 1999 as Research and Development Broad Agency Announcement for Radio Frequency Devices and Asymmetric Threats by the Naval Surface Warfare Center, Dahlgren, VA on Solicitation No. N00178-99-Q-1021. Amendment 001 on 6 April 1999 by Department of the Army, Defense Supply Service - Washington, and the original on 29 March 1999 by Naval Surface Warfare Center, Dahlgren, VA. This modification is hereby issued to reflect the following changes in this announcement: The revised subject/title is hereby changed to read "BROAD AGENCY ANNOUNCEMENT - **VULNERABILITY** ASSESSMENT OF RADIO FREQUENCY." The Office of the Secretary of Defense, Operational **Test** and Evaluation, **Live Fire Test** and Evaluation (OSD/OT&E/LFT&E) is concerned by the potential adverse threat posed to current and future United States (U.S.) weapons and supporting defense systems by emerging, non-traditional threats such as those posed by low, medium, and high energy lasers and by weapons capable of generating a high-power electromagnetic pulse. These weapons might be used by an adversary to exploit a specific area of **vulnerability**, such as communications, information warfare, or other selected areas, to attack U.S. forces more effectively and efficiently, and thereby achieve an asymmetric advantage. BACKGROUND: A field **test** was performed during August 1998 on selected infrastructure **test** items with a high power transient electromagnetic device (HPTED) provided by a contractor. The contractor was asked to design and build a device characteristic of what a rogue nation or terrorist could fabricate using only "open source" information and commonly available hardware components. BROAD AGENCY ANNOUNCEMENT OBJECTIVES: OSD/OT&E/LFT&E is seeking qualified sources and soliciting research and development proposals which are capable of providing services in the achievement of development, **test**, and evaluation of radio frequency (**RF**) devices and asymmetric threats. The goals of the program are to continue the **test** program which was initiated last year and to acquire new **test** data on modern and future military systems, support infrastructure, and systems under development using commercial off-the-shelf (COTS) technology, which could or will have military application, in regards to their **vulnerability**, susceptibility, and survivability to degradation, disruption, upset, and damage from **RF** devices. The offeror may purchase or fabricate the **RF** devices and conduct the testing and evaluation of the **RF** devices against the military systems and COTS technology. It is expected that a series of devices will be fabricated that will escalate the knowledge of **RF** device design by using past experience to improve each new device. The Department of Defense (DOD) may provide some weapon systems and COTS technology as Government furnished equipment. The design of the HPTEDs should be based upon the representative threat(s) and be fabricated using "open source" information and commonly available hardware components. The **RF** devices should be capable of providing wide band and ultra wide band transient signals. (HPTEDs capable

OPTIONAL FORM 99 (7-90)
FAX TRANSMITTAL
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Fax # 416-2773 — Fax # 697-1AWA
NSN 7540-01-317-7368 5099-101 GENERAL SERVICES ADMINISTRATION

of providing narrow band high power microwave or nuclear electromagnetic single pulses are not desired.) Each RF device to be utilized in testing should be fully characterized and documented in regards to frequency, bandwidth, waveform, power, modulation, and rise and fall times prior to conducting any testing to obtain vulnerability and susceptibility on DOD weapon systems and associated infrastructures. The offeror should discuss in his proposal his preliminary specifications in regards to the rise times, pulse widths, repetition rates, and power levels at specific ranges for the HPTEDs. Ideally, the testing should be conducted in the open air with no restriction on frequencies or power levels. An analysis should be conducted on each system identified for testing prior to the initiation of the test cycle to determine what effects will most likely be generated during the test and what hardware/software will experience the effects (i.e., in live fire terminology, "pre-shot" predictions should be made). The offeror should identify the metrics to be used during the testing and the following evaluations. Each system subjected to a test should be fully analyzed to determine all effects generated by the testing. A report shall be produced to document any effects identified and provide recommendations as to the consequences of these effects and impacts to the system under test. PROPOSAL INSTRUCTIONS: Proposals will be accepted for test and evaluation of the RF devices, fabrication of the devices, or both test and fabrication of the RF devices. If desired, multiple proposals addressing different areas of research and development may be submitted. Proposals and all related correspondence shall reference Broad Agency Announcement Number DASW01-99-R-0900. Offerors are encouraged to submit a one to five page "white paper" summarizing the proposed effort(s) and a rough order of magnitude-of-cost to obtain a preliminary indication of potential OSD/OT&E/LFT&E interest. White papers shall be submitted in an original and four copies to Mr. Richard C. Carter, Operational Test and Evaluation, Office of the Secretary of Defense, Room 1D730, 1700 Defense Pentagon, Washington, D.C. 20301-1700. Offerors who submit white papers that are of interest to OSD/OT&E/LFT&E and found to be consistent with the intent of this broad agency announcement will be invited to submit full, in-depth proposal(s). Such invitation does not however assure that the offeror will be awarded a subsequent contract. A white paper is not a requirement for submission or selection of a proposal. Regardless of the recommendation, the decision to submit or not submit a proposal is the responsibility of the offeror. The technical portion of the proposal should be limited to 30 pages (8.5" X 11" paper, double spaced, in no less than 11-point size, and any font), not including cover page, appendices, and curriculum vitae. Foldouts will be counted as a single page. The contents of the appendices shall be limited to figures that directly support items discussed in the text of the proposal. The technical portion should include: a cover page including proposal title, submitting organization, office code and address, principal investigator's name, mailing address, telephone number, electronic mail address, and facsimile machine number, and administrative/contracting representative mailing address, telephone number, electronic mail address, and facsimile machine number; a one page executive summary; a section on company history specific to this broad agency announcement and relevant capabilities, accomplishments, and past and/or contemporaneous related work by themselves and others, along with the qualifications of proposed subcontractors; a one-page task milestone chart; and a multipage specific scope of work, with numbered tasks. The last item will become the body of the contract and should be identified as "scope of work" in the proposal. The offeror's management/cost proposal has no page limit and shall be submitted as a separate document. The cost section of the proposal shall include a breakdown of the proposed effort described in the technical section (inclusive of any subcontractor costs, as applicable). A schedule for period of performance should be included that shows progress reviews and report milestones. Management/cost and technical proposals shall be submitted in one signed original and four copies. Offerors are requested to provide their commercial and government entity (CAGE) number with their submission. This broad agency announcement shall be open through 15 June 1999. Proposals may be submitted at any time during this period and contract awards may be made at any time through fiscal year 1999. White papers received within the first 30 days will have the highest probability of funding. EVALUATION CRITERIA: (1) Overall scientific and technical merit: the technical approach of the offeror should address all critical aspects of the effort. The nature and sequence of the work outlined by the offeror will be evaluated. This evaluation factor will include: feasibility, practicality, thoroughness, and clarity of the proposed work. (2) Offeror's capabilities: the offeror's experience is a critical factor. The facilities, personnel, and equipment available for performance of the proposed work are also important indicators of the offeror's capability to perform the desired work. The Government reserves the right to award on all, some, one, or none of the proposals received. Offerors shall identify proposed contract type in their white paper submissions. Although no portion of this announcement is set aside for HBCU or MI participation, proposals are invited from all interested sources. Any negotiations that may be necessary will be conducted between the offeror and the Contracting Officer at Defense Supply Service-Washington (DSS-W) or her representative. Only full proposals submitted by the closing date of the broad agency announcement will be considered. All proposals must either be submitted by mail (post-marked no later than 15 June 1999) or be hand-carried; proposals sent by facsimile or electronic mail will not be accepted. Proposals will be evaluated by OSD/OT&E/LFT&E. The offerors may be required to make a concise (30 minutes) presentation of their proposals, probably in the Washington, D.C. metropolitan area. Principal investigators of the recommended offerors may attend. OSD/OT&E/LFT&E will provide specific guidance for this presentation, including date, time, and location. DSS-W will make contract award(s) within a reasonable period of time. This broad agency announcement should not be construed as a commitment or an authorization to incur cost in anticipation of a resultant contract. Information provided herein is subject to modification and in no way binds the Government to award a contract. It is the policy of OSD/OT&E/LFT&E and DSS-W to treat all proposals as competitive and proprietary information and to disclose the contents only for the purpose of evaluation. The Government may use selected support contractor personnel as special resources to assist in administering the evaluation of the proposals. These persons are restricted by their contracts from disclosing the proposal information or using it for other than performing their assigned administrative tasks. Questions regarding this broad agency announcement should be forwarded to Department of the Army, DSS-W using Internet addresses: Mr. Shatto - harry.shatto@hqda.army.mil; Ms. Dobeck - dobeckj@hqda.army.mil; via facsimile at (703) 695-9746 or (703) 697-9440. This notice constitutes a broad agency announcement for DSS-W as authorized by FAR 6.102(d)(2).

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# DEFENSE ELECTRONICS

THE DUAL-MARKET MAGAZINE FOR DUAL-USE TECHNOLOGIES

GPS: The Ultimate Dual-Use Technology?

Satellite Survivability In Space: Don't Count on It

Spatial Data Comes to the Battlefield

*Plus*

Product Spotlight: Imaging Products

# The Commercial and Military Satellite Survivability Crisis

## *Whether it's natural radiation or radiation from a nuclear blast, can satellites survive? Unless you harden it, the Defense Nuclear Agency doesn't think so.*

*Since Secretary of Defense Perry's memo to buy commercial off-the-shelf products over milspec, questions have been raised about what the impact would be. Defense Electronics has addressed this important issue in previous articles. DE continues this focus with an exclusive article written by key individuals from the Defense Nuclear Agency who share their concern over the impact of radiation on both commercial and military satellites.* —*The Editor*

**By R.C. Webb, Les Palkuti, Lew Cohn, Lt. Col. Glenn Kweder and Al Costantine**

Global information exchange has rapidly become the cornerstone for ensuring the vitality of worldwide economic, as well as military interactions. The commercial satellite industry has rapidly grown to support this demand for near instantaneous information exchange around the world. The military has leveraged these commercial assets in recent conflicts and plans to respond to future military conflicts by an even greater exploitation of satellites under an evolving doctrine known as "Information Warfare." Quite simply, the use of commercial satellites is now so tightly woven into the fabric of our commercial and military endeavors that the consequences of the loss of these assets is unthinkable, yet such a loss is a very real possibility.

Studies by the Defense Nuclear Agency (DNA) show that the explosion of a single high-altitude low-yield nuclear weapon could destroy $14 billion worth of low-earth-orbit satellites that would transit through the enhanced radiation belts produced by such a nuclear event. This paper discusses the threat to commercial satellites from the natural radiation environment and a credible, yet conservative, Third World nuclear threat, the role that radiation tolerant microelectronics plays in satellite systems, the impact of the post-Cold War budget realities on the radiation tolerant microelectronics and satellite industries, and concludes by describing what is required to ensure the long term availability of radiation tolerant microelectronics through domestic suppliers.

### Background

Satellite designers are continually constrained by the demands for increased capability, decreased power consumption and lower launch weight. Thus, they choose the latest state-of-the-art microelectronics to increase the performance of their systems under these constraints. Unfortunately, as microelectronics devices grow in sophistication (increased integration density and higher operating speed) they become increasingly vulnerable to radiation, as illustrated in figure 1.

To meet the demands of the harsh natural radiation environment, radiation tolerant microelectronics must be used in space systems. During the Cold War the need to harden strategic systems against the deleterious effects of nuclear explosions resulted in government research and development programs that, in cooperation with commercial semiconductor vendors, developed radiation hardened semiconductor devices that followed the rapidly evolving commercial semiconductor market. This continuous development cycle supported military needs and commercial satellite requirements. With reduced DOD budgets resulting from the end of the Cold War, this development cycle has dramatically slowed and the devices presently in use are rapidly becoming obsolete. The combined effects of reduced industrial and government-sponsored research and development, and the reduced market for radiation-tolerant integrated circuits has resulted in the erosion of domestic radiation tolerant vendors, (i.e. the 20 vendors available in 1990 have been reduced to 4 today). This vital domestic resource is in peril of disappearing. DOD support will be required to ensure that future generations of microelectronics are radiation tolerant. Lack of this support and potential unavailability of future generations of radiation-tolerant microelectronics from domestic sources also will jeopardize the vital U.S. satellite industry.

The Van-Allen radiation belts, and solar and galactic high-energy particles

| Category | Effect |
|---|---|
| Total Ionizing Dose | Degradation and/or failure as a function of ionizing radiation accumulation (i.e., months — years). |
| Single Event Effects | Relatively instantaneous device upset or destruction (e.g., latchup, burnout or gate rupture). |
| Displacement Damage | Degradation of solar cells, charge-coupled-sensors, fiber optics, etc. over a period of time due to lattice effect is less severe than SEE or total ionizing dose effects. |

Table 1. Effects of space radiation on semiconductor devices. (Table courtesy of the DNA)

present a hostile environment to microelectronics in space. The primary radiation effects are total ionizing dose from trapped protons and electrons and single-event-effects from galactic cosmic rays, solar enhanced particles and energetic protons and neutrons. These effects, which degrade or destroy unhardened microelectronics, are summarized in Table 1.

Figure 2 depicts the amount of total ionizing dose, in rad(Si), that accumulates as a function of time and altitude from the natural environment. The calculations were performed using the NASA AE8 and AP8 codes assuming 100 mils of aluminum shielding. When referenced to a typical 10 krad(Si) survivability limitation for an unhardened part, we see just how deleterious the effects of the natural space environment on spaceborne microelectronics are for a typical satellite system mission that can last from 3 to 15 years.

The National Geophysical Data Center maintains a data base on anomalous satellite behavior. Since 1971, over 4500 incidents of satellite malfunctions traced to the natural radiation environment have been recorded. Table 2 depicts a partial listing of some of the more publicized satellite incidents and their most probable causes.

| Satellite | Anomaly | Probable Cause |
|---|---|---|
| Anik E-1 & E-2 (Comsats) | Attitude control failure | Electrostatic discharge |
| GOES 5, 6 and 7 (Weather) | Solar array problems | Single event upset |
| Hubble (Astronomy) | Computer problems | Single event upset |
| NOAA-11 (Weather) | Attitude control problems | Single event latchup |
| ERS-1 (Earth Resources) | Sensor failure | Single event upset |

**Table 2. Examples of satellite failures due to natural radiation. (Table courtesy of the DNA)**

Most U.S.-built commercial satellites operate normally in the space radiation environment because they use hardening techniques developed for DOD programs. In 1994 two Canadian communications satellites suffered attitude control system (momentum wheel control electronics) failures which were attributed to space craft charging caused by a severe magnetic storm. A nearby Mexican satellite, Solidaridad, was unharmed by this same magnetic storm. The primary difference between the Canadian and Mexican satellites was that the attitude control system for the undamaged satellite was manufactured using more stringent radiation hardening methods especially in the area of space craft charging. Both Canadian satellites have been restored to operation. However the impact of the outage, coupled with restoration costs, loss of profits, new control facilities and additional insurance etc., exceeded $66 million for the Anik E-2 alone. In addition, Anik E-2's mission life was shortened by more than one year. The cost to harden a satellite to the natural environment is about 1 percent of the total system cost. This represents a relatively modest investment when considering the risks associated with depending on less hardened satellites, such as Anik E-2 and Anik E-1, which cost $286 million each.

## Third World Nuclear Threat

In addition to the natural space radiation environment, a credible Third World nuclear threat exists due to nuclear weapons proliferation. A Third World country could detonate a high-altitude nuclear weapon at 100-200 km and disrupt and destroy hundreds of U.S. satellites in low earth orbit in a few months to a year. Such an incident, if performed in the general vicinity of the aggressor country, would probably not invoke a military response from the U.S. because the Third World country could always deny any knowledge of adverse effects on satellites and claim that they were only doing a weapons test. The resultant enhancement of the Van Allen belts by electrons, from the nuclear event, would result in premature satellite failures. Since the U.S. depends critically on satellites for a variety of military and civilian functions, such an incident would have a drastic effect on the U.S. and minimal, if any, impact on the Third World country.

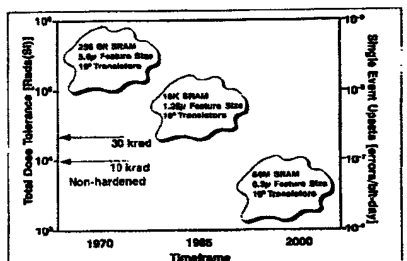


**Figure 1 shows the increased sensitivity of electronics to radiation. (Figure courtesy of the DNA)**

Evidence exists to show that enhanced electron belts produced by a single high-altitude nuclear explosion can significantly degrade the onboard electronics and result in the ultimate demise of satellites exposed to this environment. For instance, in the early 1960s high-altitude atmospheric tests conducted by the U.S. and the former Soviet Union created enhanced radiation belts similar to those expected from a Third World detonation. These tests led to the electronic destruction of a number of low-earth-orbit satellites.

Figure 3 illustrates the total ionizing dose environment encountered by satellites at various altitudes due to the natural environment and a Third-World nuclear weapons detonation. The triangle, square and diamond curves describe the natural environment for half-geosynchronous, geosynchronous (GEO) and low-earth-orbit (LEO) satellites, respectively. The added lines represent the enhanced radiation environment that would be encountered on two LEO orbits as a result of a single 50 kT nu-

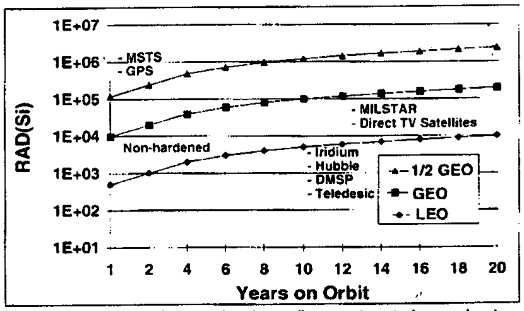


**Figure 2 represents the total ionizing dose that satellites experience in the natural environment. (Figure courtesy of the DNA)**

clear burst at 120 km altitude. The chart plots the accumulated dose versus the satellite time on orbit. The half-GEO orbit presents the most severe environment because of an intense electron belt at that altitude (20,000 nautical miles). The Global Positioning Satellites (GPS) reside in this orbit. These satellites have about a 10-year lifetime and thus must be able to survive $10^6$ rad(Si) of total ionizing dose. At the present time, most communications satellites reside in GEO orbits, while the new mobile communications satellites such as Iridium and Teledesic will have LEO orbits. GEO communications satellite lifetimes are about 10-18 years and must survive about 100-150 krad(Si). The LEO satellites normally encounter a relatively benign environment. A typical lifetime of 5-8 years means that these satellites only need to tolerate about 5 krad(Si). Note that if LEO satellites are only designed to survive the natural radiation environment, they would be highly vulnerable to a nuclear threat. If these satellites were hardened to GEO natural radiation levels, they would survive this threat. Other viable regional threat scenarios evaluated by DNA produce environments up to 100 times greater than this scenario.

The effect of a low-yield, low-altitude nuclear detonation would be to rapidly "pump" the Van Allen Belts such that satellites would begin to fail in a few months (the majority fail within two years). The enhanced belts maintain a high radiation state for over a year, thus precluding the launch of replacement satellites. Figure 4 depicts the impact on satellite lifetime of detonating the same 50 kT low-yield weapon shown in figure 3. The resultant reduction in satellite lifetime from this nuclear event is shown for a number of LEO assets. Specifically, the life of Hubble would be reduced from 15 years to 22 months. The other assets depicted in this chart have 4 to 7.5-year lifetimes which also will be dramatically shortened, as shown. Thirty krad(Si) accumulated ionizing dose was used as the metric to establish satellite lifetime. This value is based on the known susceptibility of the onboard microelectronics (including shielding) for these satellites. In reality, many unhardened systems have parts that fail well below this conservative value.

Currently there are over 40 unclassified LEO satellites performing a variety of military, commercial and scientific missions that would be affected by the nuclear threat previously described. In addition, four future commercial LEO communications satellite systems (Iridium, Teledesic, Orbcomm and Globalstar) are planned. These systems or constellations are scheduled to begin operation within the next 4-6 years and will greatly increase the number of assets vulnerable to a Third World nuclear event. The anticipated number of new satellites per system are: Iridium, 66; Teledesic, 840; Orbcomm, 26, and Globalstar, 48.

### World Wide Satellite Market

In calendar year 1994, the worldwide satellite market was valued at $12.5 billion and growing at about 10 percent per year. The U.S. has dominated this market with a $7.5 billion market share. This dominance has been ascribed to the long term U.S. commitment to space exploration and its preeminence in radiation tolerant microelectronics technology. Greater competition is anticipated from both Europe and Japan, as well as Russia in the near future.

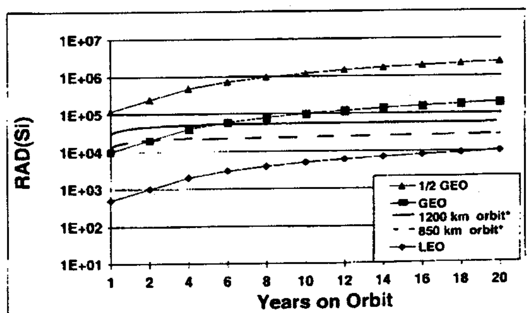


**Figure 3 depicts total ionizing dose for the natural space environment and threat environment. (Figure courtesy of the DNA)**

In order to maintain their market share, U.S. satellite manufacturers must continue to provide systems with higher performance and longer lifetimes than their competitors. The mission lifetime of high-valued assets can be expected to increase from the current 10 years to 15-18 years. Lower valued assets, such as those involved in high density LEO communications systems will have lifetimes from 5 to 8 years. These satellites will need increased capability due to more complex mission requirements.

The key to obtaining higher performance, longer lived, satellites is advanced (higher performance and integration density) microelectronics. However, as the performance and density of electronics increases, so does their susceptibility to radiation effects. With the current technology base used to harden microelectronics becoming obsolete, new technological solutions must be developed to support these modern devices. As each new semiconductor generation evolves, so also must the radiation hardening science and technology. Although this evolution is a costly process, past funding by government research and development programs provided the enabling technology which ensured the availability of radiation tolerant and hardened microelectronics for the commercial satellite manufacturers.

## Semiconductor Sales

Currently, the U.S. radiation-tolerant semiconductor sales are a mere 0.4% of the total world semiconductor market. To remain competitive, semiconductor manufacturers invest research and development dollars in their commercial lines and products. The ongoing annual cost of developing new radiation tolerant enabling technology required for each new generation of semiconductors is approximately 10 percent of the total radiation-tolerant semiconductor annual sales. Unfortunately, market realities constrain the manufacturers' ability to meet this need. In the last several years DOD investment in radiation-tolerant microelectronics technology has decreased from over $50 million in 1989 to less than $20 million in 1995. This dramatic drop-off speaks for itself. Currently, no articulated plan exists to reverse this trend.

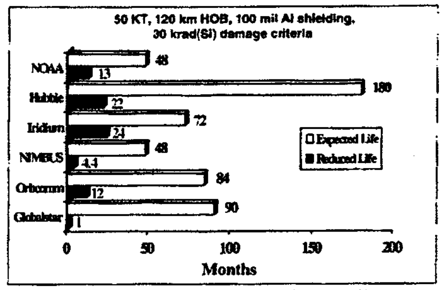


**Figure 4 shows the lifetime impact for a 50 kT, 120 km height of burst. (Figure courtesy of the DNA)**

## Consequences

The consequences of decreased DOD support of radiation-tolerant microelectronics enabling technology development are the loss of domestic sources for this critical technology and a dependence on foreign sources of radiation tolerant microelectronics. In the last five years TI, Intel, TRW, LSI Logic and AT&T have exited the radiation hardened microelectronics market. This trend will place satellite suppliers at risk by reducing their competitiveness against foreign suppliers of satellites. This erosion of the U.S. satellite industry will certainly impact national security requirements for assured access to space.

## What is Required

DNA has taken the lead in an effort to make the DOD aware of the severity of this issue and the need to establish a program designed to ensure the long term presence of domestic suppliers of radiation-tolerant microelectronics for both military and commercial applications. The basic assumptions underlying this program are: 1) the commercial space market is sufficient to maintain 2 to 3 suppliers of radiation-tolerant microelectronics, and: 2) if the government invests in the development of enabling technology which allows these suppliers to provide radiation-tolerant advanced product lines, the satellite market will sustain these product lines.

## Why a DOD Program

The DOD's mission calls for the fielding and maintenance of radiation-tolerant systems; its radiation tolerance needs are the most stringent. Commercial satellite manufacturers and NASA simply leverage off the DOD technology development programs. Because of future needs, DOD must ensure that the radiation tolerant pipeline remains open and evolves as advances are made in semiconductor technology. The radiation parts available today are rapidly approaching obsolescence. Future DOD programs will require state-of-the-art radiation tolerant semiconductors but the semiconductor industry is not investing in this development. Only a centralized government "clearing house" can coordinate with DOD program offices to develop a common technology road map to focus industry efforts. Such a program would ensure that DOD funds provide the "technology push" while commercial satellite manufacturers provide the "market pull." Thus, even though DOD purchases a decreasing percentage of the radiation-tolerant production line outputs, these special lines (and facilities) would remain commercially viable because the chips will be procured for commercial satellites.

## The Bottom Line

The U.S. dominance of the commercial satellite market is the result of its preeminence in radiation-tolerant technologies and the U.S. production of radiation hardened microelectronics. The harsh natural space environment and the existence of a credible Third World nuclear threat dictates that the U.S. maintain its preeminence in the development of hardened satellite assets.

However. development of future generations of radiation tolerant microelectronics and the U.S. dominance of the satellite market are dependent on the availability of research and development resources to provide the enabling technology. U.S. microelectronics suppliers are unable to make any significant investment in this area since they must support development of new generations of high-volume commercial electronics to remain competitive. Government (DOD. DOE. NASA. etc.) support is required if future generations of radiation tolerant microelectronics are to be available from domestic suppliers.

Current microelectronic devices now in use were developed with DOD support in the 1970s and 1980s. These programs emphasized the development and demonstration of electronics which could survive and operate in a nuclear weapons disturbed environment. However. in the current post-Cold War environment. funding of similar programs has greatly diminished. Therefore. the long-term availability of hardened parts from domestic suppliers is in jeopardy for two major reasons. First. without access to advanced technology. domestic suppliers will not be able to compete effectively against government-subsidized foreign suppliers and thus eventually will be forced from the market. Second. the life span of microelectronics technologies is finite and today's radiation tolerant/hardened devices will become unavailable in the near- to mid-term (3 to 5 years) as they are phased out of production.

To address these issues. DNA is currently working with the Services to establish a government effort to develop the enabling technology to harden future generations of microelectronics. This effort will ensure the survival of the domestic radiation tolerant electronics industry. and maintain the U.S. leadership in the worldwide satellite industry.


**About the Authors:**

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# Some Intelligence Perspectives on the Nuclear Threat and Electro-Magnetic Pulse

A Statement for the Record

by

Robert D Walpole,

National Intelligence Officer

for Strategic and Nuclear Programs

for the 1 June 1999 Hearing of the

Subcommittee on

Government Programs and Oversight,

Committee on Small Business,

United States House of Representatives

I understand the interest this Committee would have in an Intelligence Community perspective of the EMP issues outlined in Congressman Bartlett's 13 May 1999 letter to me. Although the questions outlined in his letter focus more on other invitees, I can say a few things in an open forum about proliferation, the emerging missile threats around the world, and the nuclear threat that will likely face the United States in the future. However, I am limited about what I can say regarding various countries' nuclear weapons and missile programs and their concepts for using them in the future. Obviously, you would want us to be able to continue to gain intelligence insight into foreign developments and intentions, so I cannot divulge too much lest countries increase their denial measures.

The United States has faced a significant nuclear threat for several decades from the former Soviet Union and China. We continue to face that threat today, albeit with considerably reduced tension than during the Cold war. Generally, the nuclear threat has been viewed from the perspective of direct strikes, but the potential for electromagnetic pulse (EMP) effects has been part of it as well. I will leave to others more expert than myself to describe EMP and the potential damage its effects could have on US military and civilian equipment. Instead, I will focus my statement on the proliferation of nuclear and missile capabilities and some developments that could affect the EMP threat.

The proliferation of weapons of mass destruction and the missiles that can deliver them has continued to evolve. We saw nuclear testing in India and Pakistan last year, indicating both are positioned to build nuclear arsenals; Iran seems to be pushing its nuclear weapons program forward; and we are concerned that North Korea has a continuing program. Moreover, societal and economic stress in Russia seems likely to grow, raising more concerns about the security of nuclear weapons and fissile material.

The capabilities of the missiles in the countries seeking to acquire them are growing, a fact underscored by North Korea's launch of the Taepo Dong-1 space launch vehicle last August. The number of missiles in these countries is also increasing. Medium- and short-range ballistic missile systems already pose a significant threat to US interests, military forces, and allies, particularly if armed with weapons of mass destruction. We have seen increased trade and cooperation among countries that traditionally have been recipients of missile technologies from others. Finally, some countries continue to move toward longer-range systems, including intercontinental ballistic missiles (ICBMs).

We expect the threat to the United States and its interests to increase over the next 15 years. However, projecting political and economic developments that could alter the nature of the missile threat many years into the future is virtually impossible. The threat facing the United States in the year 2015 will depend on our changing relations with foreign countries, the political situation within those countries, economic factors, and numerous other factors that we cannot predict that far into the future with confidence. A glance fifteen years into the past is illustrative:

- Fifteen years ago the United States and the Soviet Union were superpower adversaries in the midst of the Cold War, with military forces facing off in central Europe and competing for global power. Today, by contrast, the ideological differences that separated us have been replaced by differences expected between modern nation states.

- Iraq is another example; 15 years ago it shared common interests with the United States while it was at war with Iran. Since Iraq's invasion of Kuwait in 1990, Washington and Baghdad have been in numerous military and diplomatic conflicts.

- As a final example, we do not know whether some of the countries of concern in 15 years will continue to exist in their current states or as suppliers of missiles and technology.

Recognizing these uncertainties, the Intelligence Community projects foreign ballistic missile capabilities into the future largely based on technical capabilities and with a general premise that relations with the United States will not change significantly enough to alter the intentions of those states pursuing ballistic missile capabilities. By Congressional direction, we make annual assessments of the threat and will be able to take account of any contemporary information that alters our projections.

The new missile threats confronting the United States are far different from the Cold War threat during the last three decades. During that period, the ballistic missile threat to the United States involved relatively accurate, survivable, and reliable missiles deployed in large numbers. Soviet--and to a much lesser extent Chinese--strategic forces threatened, as they still do, the potential for catastrophic, nation-killing damage. By contrast, the new missile threats involve states with considerably fewer missiles with less accuracy, yield, War. Ballistic missiles, for example, have already been used against US forces during the Gulf war. More nations now have longer-range missiles and WMD warheads. We have seen missiles used in several conflicts over the past two decades, although not with WMD warheads; nevertheless, some of the regimes controlling these missiles have exhibited a willingness to use WMD.

Thus, acquiring long-range ballistic missiles armed with WMD will enable weaker countries to do three things that they might not otherwise be able to do: deter, constrain, and harm the United States. To achieve these objectives, these WMD-armed weapons need not be deployed in large numbers; with even a few such weapons, these countries would judge that they had the capability to threaten at least politically significant damage to the United States or its allies. They need not be highly accurate; the ability to target a large urban area is sufficient. They need not be highly reliable; their strategic value is derived primarily from the threat (implicit or explicit) of their use, not the near certain outcome of such use. In many ways, such weapons are not envisioned at the outset as operational weapons of war, but primarily as strategic weapons of deterrence and coercive diplomacy.

The progress of countries in Asia and the Middle East toward acquiring longer-range ballistic missiles has been dramatically demonstrated the past 12 months:

- Most notably, North Korea's three-stage Taepo Dong-1 space launch vehicle has inherent, albeit limited capabilities to deliver small payloads to ICBM ranges. Although the Taepo Dong-1 satellite attempt last August failed, North Korea demonstrated several of the key technologies required for an ICBM. However, as a space launch vehicle it did not demonstrate a payload capable of surviving atmospheric reentry at ICBM ranges. We assess that North Korea would be unlikely to pursue weaponizing a three-stage Taepo Dong-1 as an ICBM, preferring instead to pursue the much more capable Taepo Dong-2, which we expect will be flight tested in the near term.

- Pakistan has flight-tested its 1,300 km range Ghauri missile, which it made with North Korean assistance.
- Iran has flight-tested its 1,300 km range Shahab-3—an improved version of North Korea's No Dong, which Iran has produced with foreign assistance.
- India has flight-tested its Agni II MRBM, which will have a range of about 2,000 km.

Thus, the threat to US interests overseas from medium-range ballistic missiles is immediate, serious, and growing. These missiles could use conventional, and in some cases, WMD warheads. Moreover, in a regional conflict, some of these systems could loft a nuclear weapon (if the country had one) over nearby adversarial territory and attempt to create an EMP effect. However, the effects of EMP are not merely based on the height of burst of a nuclear device; the yield and type of nuclear device significantly affect the degree of potential damage the EMP generated would create.

In an unclassified forum, I cannot go into the details of individual countries' nuclear weapon development efforts. However, as we continue to analyze those efforts, we will be able to work with our DoD colleagues to model the potential effects of the types of nuclear weapons North Korea and others would be capable of producing in the years to come. DoD would also be able to examine whether the EMP produced by those weapons would be able to damage US military or civilian equipment.

Also, as additional countries develop ICBMs, the potential to threaten the United States will increase. Thus, the United States has faced a nuclear threat for decades; an inherent component of that threat has been the potential effects of EMP. We project that the nuclear threat will continue into the future, along with the concomitant potential for EMP effects. Nevertheless, from an EMP perspective, the launching country--Russia or someone else--would undoubtedly calculate that the target country, after detecting an incoming missile strike, would not debate whether direct destruction or EMP was the intent; the target country would view a nuclear strike as a nuclear strike. Thus, the launching country would assess that any strike—EMP or not—would risk severe retaliation.