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1999

[H.A.S.C. No. 106-31]**ELECTROMAGNETIC PULSE THREATS TO U.S. MILITARY AND CIVILIAN
INFRASTRUCTURE**

HEARING

BEFORE THE

MILITARY RESEARCH AND DEVELOPMENT SUBCOMMITTEE

OF THE

COMMITTEE ON ARMED SERVICES
HOUSE OF REPRESENTATIVES

ONE HUNDRED SIXTH CONGRESS

FIRST SESSION

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APPENDIX:

Thursday, October 7, 1999

THURSDAY, OCTOBER 7, 1999 ELECTROMAGNETIC PULSE THREATS TO U.S. MILITARY AND CIVILIAN INFRASTRUCTURE

STATEMENTS PRESENTED BY MEMBERS OF CONGRESS

Pickett, Hon. Owen, a Representative from Virginia, Ranking Member, Military Research and Development Subcommittee

Weldon, Hon. Curt, a Representative from Pennsylvania, Chairman, Military Research and Development Subcommittee

WITNESSES

Bernardin, Dr. Michael, Provost for Theoretical Institute of Thermonuclear Studies, Los Alamos National Laboratory

Jakubiak, Mr. Stanley, Senior Civilian for Nuclear C3 and EMP Policy, Joint Chiefs of Staff

Graham, Dr. William, Former Science Advisor to President Reagan and Rumsfeld Commissioner on the Missile Threat

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Wood, Dr. Lowell, Member of the Director's Technical Staff, Lawrence Livermore National Laboratory

APPENDIX**PREPARED STATEMENTS:**

[The prepared statements can be viewed in the hard copy.]

Bernardin, Dr. Michael

Graham, Dr. William

Jakubiak, Mr. Stanley

Weldon, Hon. Curt

Wood, Dr. Lowell

DOCUMENTS SUBMITTED FOR THE RECORD:

[The Documents submitted can be found in the hard copy.]

Testimony to the R&D Subcommittee of the House Armed Services Committee—Open Session Testimony submitted by Dr. Michael P. Bernardin

QUESTIONS AND ANSWERS SUBMITTED FOR THE RECORD:

[There were no Questions and Answers for the Record.]

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ELECTROMAGNETIC PULSE THREATS TO U.S. MILITARY AND CIVILIAN

INFRASTRUCTURE

House of Representatives,
Committee on Armed Services,
Military Research and Development Subcommittee,
Washington, DC, Thursday, October 7, 1999.

The subcommittee met, pursuant to call, at 10:30 a.m. in room 2118, Rayburn House Office Building, Hon. Curt Weldon (chairman of the subcommittee) presiding.

OPENING STATEMENT OF HON. CURT WELDON, A REPRESENTATIVE FROM PENNSYLVANIA, CHAIRMAN, MILITARY RESEARCH AND DEVELOPMENT SUBCOMMITTEE

Mr. **WELDON**. The subcommittee will come to order. This morning the Military Research and Development Subcommittee meets in open session to receive testimony on the potential of an electromagnetic pulse attack to disrupt the United States military and civilian electronic infrastructure. Our open hearing will be followed by a closed, classified briefing. The classified briefing will give our witnesses an opportunity to brief Members in greater depth and to respond to questions that may be too sensitive to fully answer in open session.

Before I go into the subject of today's hearing, I want to announce that we can now confirm that on October 26 we will have a very special hearing in this subcommittee. In fact, over the course of the last five years, I have had five witnesses appear before our subcommittee from Russia, including General Alexander Lebed. Twice I have had Dr. Alexander Yablokov. I have had Mr. Lunev, who is one of the highest ranking defectors from the GRU, and on October the 26th of this year, our committee will have Dr. Christopher Andrew, a noted Cambridge scholar, along with Russian—London Chief of Station of the KGB, Oleg Gordievsky, who will appear with Andrew, and they will discuss the recently released book entitled *KGB*, which documents approximately three decades of KGB files that were copied by Mitrokhin, who was the KGB archivist.

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This book has received international attention. It is provocative in terms of what factual information is in here, and it will be the first time in America that Members of Congress will have a chance to see and ask questions of both an outstanding scholar on Russian intelligence, as well as a Russian individual who has, in fact, cooperated with us on some of the patterns that have occurred in the Russian Intelligence Community.

I would also like to announce at this time the release within a matter of several weeks of a new book entitled *War Scare*. This book has been published by a very eminent author, who has documented five very real cases over the past several decades of Russia's movement toward a possible response in terms of their nuclear arsenal.

The author is sitting to my left and your right, Peter Pry, who is a staffer for our committee. We are extremely proud to have him on staff because of his expertise, his former tenure as an agent in the CIA, and this book is extremely provocative. I am also working on a way that we can give visibility to the author Peter Pry's comments, not the staffer Peter Pry's comments, because I think they are relative to the work that is outlined in the KGB book documenting the Mitrokhin archives by Christopher Andrew.

So those events will take place in October, later on, and they should be exciting, and they will be provocative.

Our hearing today, as I said earlier, focuses on electromagnetic pulse (EMP). We first held a hearing on this issue in 1997. To my knowledge, we were the first major committee in the Congress to devote any attention at all to this issue. It has been an ongoing concern of both my distinguished Ranking Member Owen Pickett and myself, and certainly has been at the key of the interests of Congressman Roscoe Bartlett, who, in fact, held kind of a mini-field hearing in his district on this issue at Johns Hopkins earlier this year.

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Being a physiologist himself, Roscoe has a particular expertise here that has been very helpful to this committee in fully understanding the potential threat posed by electromagnetic pulses.

Part of our purpose today in holding an open hearing on EMP is to help educate the public on this still not widely understood threat. Electromagnetic pulse can be generated when a nuclear weapon is detonated at high altitude above the atmosphere. The EMP produced by such an explosion can potentially damage or destroy electronic systems along vast areas of Earth's surface.

Let me say at this point in time, for those who think and for those people who have testified that this could never happen to America, I led a delegation to Vienna on April 30th and May the 1st of this year to meet with a group of Russian Duma officials and leaders to work out the framework for a peaceful solution of the Kosovo crisis. In fact, Congressman Bartlett went on that delegation with me.

In our discussions with our Russian counterparts, all of whom are friends of mine, one of the leaders of that delegation, Vladimir Lukin, the former Soviet Ambassador to the U.S. here in Washington, made this statement, that America needs to understand that while Russia may be in a state of turmoil, Russia still has the capability to do significant harm to our people and our country.

He went on to further outline Russia's capability to conduct electromagnetic pulse laydown. He described it. He said that Russia has this capability, and that if our policies continued along the line that they were going, in that particular case in relation to Kosovo, that that could be the response that could be generated against America.

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So for those who would say that this kind of a threat would never emerge, I can only tell you what came out of the mouth of the former Soviet Ambassador to the U.S. and current Chairman of the International Affairs Committee for the Russian Parliament, the lower House, the state Duma.

The United States is involved in a technologically-dependent society with high potential vulnerability to EMP. The widespread paralysis of electronic computer systems, communications power grids and transportation systems would not be merely an inconvenience. Nor would an EMP attack have only commercial consequences. Our modern way of life and life itself depends upon the functioning of our electronic society.

How severe would the consequences of an EMP attack on the United States be? Some have argued that an EMP event could be like putting the United States in a giant time machine and in the blink of an eye transforming our high-tech society into a primitive preindustrial one, circa the 19th century. Others argue that while the consequences of an EMP attack would be serious, the effects are likely to be much less severe and much more manageable.

The EMP threat may have acquired new and urgent relevance as the proliferation of nuclear weapons and missile technology accelerates. North Korea, for example, is assessed as already having developed one or two atomic weapons and is on the verge of testing an Inter-Continental Ballistic Missiles (ICBM) capable of delivering a nuclear warhead to the United States. North Korea already has missiles capable of delivering a nuclear warhead against U.S. regional allies and U.S. forces based in Japan and South Korea.

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Is it possible that given the small size of North Korea's nuclear arsenal, Pyongyang may consider an EMP attack the most efficient military option; the best way to inflict the maximum damage on the U.S. and its allies in the event of a conflict, or perhaps the best way to blackmail or deter the U.S. in the event of a crisis?

There are differences within the scientific community over just how damaging an EMP attack would be. There are differing opinions among experts over the likelihood that a rogue state armed with a small number of nuclear missiles would prefer to perform an EMP attack as opposed to blasting a city or a military base.

The main purpose of our hearing today is to air and explore these differences of opinion about the EMP threat by receiving testimony from two panels representing different points of view.

On our first panel representing the administration and the Joint Chiefs of Staff are Mr. Stanley Jakubiak, senior civilian for nuclear Command and Control and EMP policy from the Joint Chiefs of Staff; Dr. Michael Bernardin, provost for Theoretical Institute of Thermonuclear Studies, Los Alamos National Laboratory.

Our second panel is made up of Dr. William Graham, former science advisor to the President of the United States Ronald Reagan, and Rumsfeld Commissioner on the ballistic missile threat; and Dr. Lowell Wood, member of the director's technical staff at Lawrence Livermore National Laboratory.

We welcome you all and thank you all for being here. However, before I turn the floor over to you, I want to call upon Mr. Pickett, the Ranking Democrat on the R&D subcommittee, respectfully for his comments.

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[The prepared statement of Hon. Curt Weldon can be found in the Appendix.]

Mr. **WELDON**. Mr. Pickett.

STATEMENT OF HON. OWEN PICKETT, A REPRESENTATIVE FROM VIRGINIA, RANKING MEMBER, MILITARY RESEARCH AND DEVELOPMENT SUBCOMMITTEE

Mr. **PICKETT**. Thank you, Mr. Chairman. I want to join you in welcoming our distinguished witnesses today, and also I applaud the fact that you are holding an open meeting here on this subject that I think will

help inform the public about the seriousness of this threat.

Today's hearing is an excellent opportunity to learn more about the potential effects of an electromagnetic pulse, or EMP, attack. Based on history, there is certainly reason to be concerned. Both nuclear blast tests and simulated scenarios have allowed us to recognize many of the vulnerabilities of our military and civilian systems.

I am particularly interested in examining this issue more closely due to the military's growing reliance on commercial off-the-shelf technologies. While this is neither the time nor the place to dwell on our Nation's efforts to emphasize and rely on diplomacy, early warning capabilities and deterrence doctrine to prevent such attacks, I look forward to learning more from our witnesses today about how such EMP incidents may occur and the likelihood of their possible occurrence. Greater insight into the possibility of an EMP laydown should prove beneficial in our effort to design a more capable, robust and dependable military and national infrastructure and better inform our people about the potential of this particular threat.

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Again, Mr. Chairman, I applaud you for calling this hearing, and I look forward to the testimony of our distinguished witnesses here today.

Mr. **WELDON**. I thank you, Mr. Pickett.

Mr. Pickett, would you be in agreement that perhaps before our witnesses speak we should go complete the journal vote?

Mr. **PICKETT**. Yes.

Mr. **WELDON**. Are there any other Members who would like to make opening statements before we go for the journal vote? If there are, that is fine. If not, we will go over and vote and come back and start our panel.

Mr. Bartlett.

Mr. **BARTLETT**. Just one quick moment. I am very appreciative of the fact that you have called this meeting. This is a discussion of an eventuality that could potentially bring us to our knees or worse. It is very important that the American people understand it and collectively decide what we need to do to prepare for such an eventuality.

Thank you very much for calling the meeting.

Mr. **WELDON**. Thank you, Mr. Bartlett, for your ongoing efforts in this area.

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Mr. Reyes, any comments?

Mr. **REYES**. No.

Mr. **WELDON**. Mr. Hostettler?

Mr. **HOSTETTLER**. No.

Mr. **WELDON**. We will unfortunately have to temporarily adjourn. This is only one vote. We run very fast so we can be back here and start hopefully within about six to eight minutes. So the hearing is temporarily adjourned.

[Recess.]

Mr. **WELDON**. The hearing now will reconvene, and we will now turn to our distinguished panel of witnesses. As I said before, we will start with Mr. Jakubiak and Dr. Bernardin, and then we will move right down the line to Dr. Graham and to Dr. Wood.

Mr. Jakubiak, your statement will be entered into the record without objection, and you are free to make whatever comments that you would like to make. Obviously, if we have questions that you feel are not appropriate for this forum, then they will have to wait until we get into the classified forum. I am sure you will know better than us as to when that line is reached. But we would like to keep as much as possible for the public to consume about this, because there are a lot of misconceptions and misinformation, and we are hoping to clear some of that up today. So the floor is yours.

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STATEMENT OF STANLEY J. JAKUBIAK, DEPUTY CHIEF OF THE COMMAND CENTER'S DIVISION, JOINT CHIEFS OF STAFF

Mr. **JAKUBIAK**. Mr. Chairman, Members of the committee, I am grateful—.

Mr. **WELDON**. Could you pull the mike a little closer to your mouth, please.

Mr. **JAKUBIAK**. Mr. Chairman, Members of the committee, I am grateful for the opportunity to address the committee on the electromagnetic pulse threat environment and to discuss the impact on commercial off-the-shelf or so-called COTS equipment used in military command and control systems.

As you know, the detonation of a nuclear weapon between 50 and several hundred kilometers above the Earth's surface will produce an electromagnetic pulse that can, under certain conditions, damage electronic equipment. We don't know exactly how much damage can be done to commercial equipment. The phenomenon is well-known, but the variances in electronic equipment design, commercial design, and the systems that they are incorporated in, do not provide us with sufficient information to allow us to accurately predict how widespread the damage or disruption will be.

Now, to counter the EMP attack, the military has in the past taken a simplistic approach. We have basically said and assumed that all commercial equipment would fail under an EMP pulse, and therefore we have designed protection into that equipment to withstand the EMP protection or the EMP environment.

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Critical nuclear command and control nodes, critical military nodes that must operate through that EMP environment have been identified. The Chairman puts out policy to the services and also to the Commander in Chiefs (CINCs) identifying what nodes and what systems and what equipment should be protected. That is published in the Chairman of the Joint Chiefs of Staff instructions, which I am responsible for preparing. In fact, some of those selected systems are even provided backup power generators on the assumption that the commercial power grid would fail in an EMP environment.

However, to capitalize on leading-edge technologies, military systems are becoming more and more increasingly reliant on commercial off-the-shelf (COTS) equipment, which are not specifically designed to survive an EMP environment. To ensure that that equipment reliably operates in an EMP environment, what the services do is basically take that COTS equipment and test it in simulators to the projected threat. The failures are analyzed, and modifications are retrofitted to that equipment to ensure that the equipment does perform properly in an EMP environment.

In some cases that retrofitted fix is a very simple fix, costing less than \$10 to make a piece of equipment that is off-the-shelf, commercial piece of equipment, in fact, perform in an EMP environment. However, when we talk about large sensor systems, that inexpensive \$10 part can, in fact, quickly soar to a \$50 million bill to protect that sensor.

The testing of COTS equipment has allowed us to make some observations regarding the vulnerability of COTS equipment to a range of EMP environments that may be of some use in assessing the impact on the commercial infrastructure.

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If I could have that first view graph, please.

On this view graph, you can see that the EMP field strengths between 3 and 8 kilovolts per meter, that there can be some upset on commercial off-the-shelf equipment. When the field strengths get above 8 kilovolts per meter, the risk that there will be upset is more probable. In the range of 7 to 20 kilovolts per meter, there is a possibility that some equipment will be damaged. Above the 20-kilovolt-per-meter range, the damage is most likely probable, although some equipment will even perform above that level.

Results from some recent testing of COTS equipment—can I have the next view graph, please—appear to confirm these levels.

Now, the temporary upset reflected on this view graph indicates that the upset was self-correcting. The equipment, in fact, had an upset, and the equipment self-corrected without any operator intervention. The upset column shows that the equipment, in fact, required an operator to do something to the equipment to bring it back into operation. And then the damage levels are shown on this chart also.

The Office of the National Communications System (NCS) has also done some extensive testing of the commercial public switch network and have found that the public switch network infrastructure is inherently resistant to the effects of EMP. Their studies have shown that the probability of connection of a telephone call under an EMP environment is greater than 90 percent with normal loading, and greater than 70 percent when there is panic loading on that system.

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The NCS results have also been confirmed by AT&T Bell Laboratories, who reported that their testing of the public switch network also showed that some upset could be expected, but that damage to the system in an EMP environment was not a concern.

In conclusion, due to the sensitivity of COTS equipment in various EMP field strengths, we have (the Joint Staff) over the past several years sponsored an effort at the national laboratory of Los Alamos to assess the potential field strengths that can be produced by nuclear weapons. When you receive Dr. Michael Bernardin's assessment in closed session, keep in mind the COTS vulnerability levels that I have addressed in my presentation.

Mr. Chairman, Members of the committee, on behalf of the Chairman of the Joint Chiefs of Staff, I appreciate this opportunity to present the Joint Staff views on EMP environment, and I look forward to your questions.

Mr. **WELDON**. Thank you, Mr. Jakubiak.

[The prepared statement of Mr. Jakubiak can be found in the Appendix.]

Mr. **WELDON**. Dr. Bernardin.

STATEMENT OF MICHAEL BERNARDIN, PROVOST FOR THEORETICAL INSTITUTE OF THERMONUCLEAR STUDIES, LOS ALAMOS NATIONAL LABORATORY

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Dr. **BERNARDIN**. Mr. Chairman, thank you for the opportunity to provide testimony on this issue vital to national security. I speak as a weapons designer with specialized knowledge in electromagnetic pulse. Since 1996, I have been the provost for the Postgraduate Nuclear Weapon Design Institute within the laboratory chartered with training the next generation of nuclear weapon designers.

The issue to be addressed this morning is the impact of a high-altitude nuclear detonation over the United States to the civilian and military infrastructure. A high-altitude nuclear detonation would produce an electromagnetic pulse that would cover from one to several million square miles, depending on the height of burst, with electric fields larger than those typically associated with lightning.

In such an event, would military equipment deployed within the area of EMP exposure be seriously impaired? Would civilian communications, the power grid and equipment connected to the power grid catastrophically fail? The answers to these questions depend on three elements: One, the types of threat weapons deployed; two, the EMP produced by these weapons; and three, the effects that are caused by EMP.

The Defense Intelligence Agency (DIA) and the Central Intelligence Agency (CIA) identify current and projected nuclear weapon threats and provide inputs to the Department of Energy nuclear design labs, Los Alamos and Livermore National Laboratories, who model foreign nuclear weapons. The labs each have over 25 years of experience in performing this type of modeling. The weapon models serve as a basis for

associated EMP threat assessments.

For the purpose of EMP assessment, it is convenient to group the threat weapons into the following five categories: One, single-stage fission weapons; two, single-stage boosted weapons; three, nominal two-stage thermonuclear weapons with yields up to a few megatons; four, two-stage thermonuclear weapons with yields over a few megatons; and five, special technology thermonuclear weapons.

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The reason for this grouping and the threat weapons themselves will be discussed in closed session. The EMP produced by these weapons is also a topic delegated largely to closed session.

It is possible to discuss in an open forum the process by which high-altitude EMP is produced in the atmosphere, its propagation down to the ground, and some of the generic features of the resultant EMP. This information will be discussed briefly in my statement, and detailed information can be found in my written testimony.

I have brought three graphics along to help illustrate the production of EMP. May I have graphic one.

Shown in graphic one is an illustration of the area coverage of direct EMP exposure from a 200-kilometer height of burst over the United States. For this burst altitude, which might be appropriate for a hypothetical multimegaton weapon, the horizon is located at about 1,600 kilometers or 1,000 miles from a point on the ground directly beneath the burst.

For a 50-kilometer height of burst, which might be appropriate for a 10-kiloton fission weapon, the horizon is located at about half this distance, within the circle.

May I have graphic two.

Shown in graphic two is the spatial distribution of the peak EMP fields for a hypothetical weapon detonated over the United States. The directionality of the Earth's magnetic field causes the largest peak field region to occur to the south of the burst point. The large numbers on the plot are peak electric field values in thousands of volts per meter or kilovolts per meter, and the smaller numbers are distance increments in kilometers.

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Note that the peak field ranges from 12 to about 25 kilovolts per meter. Other later time, lower-amplitude EMP components are generated by nuclear detonation. These are discussed in my written testimony.

May I have graphic three. Graphic three illustrates details of some additional specifics of EMP generation, of the generation process, for the early time portion of the pulse. A high-altitude nuclear detonation produces gamma rays, X-rays, neutrons and debris. Some of the gamma rays propagate down into the Earth's atmosphere where they collide with air molecules and produce recoil electrons. The electrons are created with a velocity directed principally radially away from the burst. The electrons are turned by the Earth's magnetic field, which results in synchrotron radiation. The radiation adds coherently to form the electromagnetic pulse.

As the electrons traverse their trajectories, they collide with other electrons creating a sea of ionization. Ionization can be enhanced by atmospheric breakdown or avalanching due to the presence of the EMP electric field. The ionization shorts out the EMP, limiting its value to typically 30,000 volts per meter.

High-energy x-rays are also produced by the exploding weapon and can enhance the ionization in the high-altitude EMP source region. This source of ionization was largely ignored in EMP assessments until 1986. The inclusion of the X-rays lowered the assessed values of the peak field for many weapons.

Note in graphic three that the thermonuclear weapon consists of two stages, a primary stage, which is typically of relatively low yield and is used to drive the secondary stage, which produces a relatively large yield. Each weapons stage produces its own EMP signal, but the primary stage gamma rays, after they go out, leave behind an ionized atmosphere from their EMP generation that is present when the secondary stage gamma rays arrive a moment later. Thus, the primary stage can degrade the EMP associated with the secondary stage.

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You can take down the graphic now.

Given an understanding of the resultant EMP fields from a high-altitude nuclear detonation, the effects of those fields on military and commercial infrastructure must be determined. The effects cannot be quantified simply by drawing upon nuclear test experience. High-altitude EMP was produced on ten nuclear tests conducted in the United States in 1958 and in 1962, and damage or temporary glitches of electronics were noted on a number of the systems. However, these weapons are not truly representative of the foreign nuclear weapons in existence today. Nor are the electronics of 1962 representative of the modern era. Moreover, the U.S. atmospheric tests were conducted over large bodies of ocean, and thus the exposure of extended land line systems to EMP fields was quite limited.

A much more extensive set of vulnerability data has been accumulated over the years through EMP testing and laboratory simulators. Tested items include aircraft, tanks, automobiles, computers, telecommunication equipment, et cetera. Both upset and damage (information) have been obtained for some of the systems at certain field levels, and some of the systems experience no deleterious effects.

A limitation with this type of testing is if the simulators are a finite volume and are not able to expose electric lines of greater length than about 50 meters to EMP. Systems connected to power and communication lines are frequently tested with current injection, but even these tests are limited.

Electronic systems can be protected against EMP, and standard protection techniques include enclosing systems or subsystems in metal boxes and adding surge arresters to power lines, cables, et cetera. Simulator testing has shown that EMP protection is effective. There are costs and practical considerations associated with implementing EMP protection. This is an area of specialty of the military services and the Defense Threat Reduction Agency (DTRA) for military systems, and I suggest consulting them if more detail is desired.

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To address the likelihood of catastrophic damage by EMP from a high-altitude nuclear detonation, one must begin with a model of a historical high-altitude detonation, say the Starfish event that was conducted in 1962, and demonstrate that the predicted EMP environments, the EMP coupling and the effects match observation. Then one must be able to establish that the model retains its fidelity when the warhead model is changed, when the burst location is moved over land and changed in elevation, when the electromagnet coupling pads change, when the vintage of electronics changes, and, with the incorporation of EMP test simulator data, that the results are reliable. While it is conceivable for a model to achieve all of this, any such model that is developed should be thoroughly peer-reviewed before its predictions are to be believed.

Thank you.

Mr. **WELDON**. Thank you.

[The prepared statement of Dr. Bernardin can be found in the Appendix.]

Mr. **WELDON**. Dr. Graham.

STATEMENT OF WILLIAM GRAHAM, PRESIDENT AND CEO, NATIONAL SECURITY RESEARCH

Dr. **GRAHAM**. Thank you, Mr. Chairman, and distinguished Members of the Committee on Armed Services. I appreciate the opportunity to testify today on nuclear EMP, and I am also going to say a few things about nonnuclear electromagnetic effects, which I think are closely related.

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I would like to begin by just mentioning a few examples of the circumstances in which another nation might wish to employ a nuclear-weapon-generated EMP effect against the United States and the benefits that might be sought through such use. The scenarios cover both political and military use and run from tactical to the strategic level.

By way of background, I have worked in EMPs since 1962, when I was a lieutenant at the Air Force weapons lab, handed a dataset taken from the last atmospheric and Pacific exoatmospheric nuclear test series, and asked to try to explain some very strange-looking phenomena that had been observed. Fortunately, we had the benefit of colleagues at Livermore, Los Alamos and other places in doing this, and the theory of high-altitude EMP, and, in fact, all EMP was developed over the next decade or so.

Interestingly, though, like many important scientific discoveries, the intense electromagnetic pulse produced by the exoatmospheric nuclear weapon explosion was discovered by accident. It was first observed both directly and by its effects on civilian systems during the exoatmospheric nuclear test series we had conducted, primarily the FISHBOWL series in the beginning of the 1960s. However, the theory that was being used at the time to predict the effect had been incorrectly derived by a Nobel laureate actually and caused all of the instrumentation on monitoring those exoatmospheric tests to be set at far too low a scale, far too sensitive a level, so that the data on the scope tended to look like vertical lines. We couldn't see the peak amplitudes that were being produced, and it was Conrad Longmeier of Los Alamos National Laboratory who, after looking at the data, figured out what was really happening.

One possible use of EMP against U.S. forces, just by way of a few brief examples, might be against forces

stationed overseas; for example, on the Korean peninsula or in the Persian Gulf. Even if an adversary had only a very few nuclear weapons, by launching even as primitive a missile as a SCUD and exploding a nuclear weapon above the atmosphere, the ability of the U.S. and Allied Forces to make full use of their electronics systems, including communications, fire control, radar systems, missiles and certainly network systems envisioned for our 21st century forces could be degraded to some degree. Depending on the characteristics of the weapon as described here, such degradation—and, of course, the susceptibility of the equipment—such degradation could range from a nuisance to a major hindrance in the employment of electronic systems throughout the theater.

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Another possible use of a nuclear weapon might be against U.S. space assets, particularly low-altitude assets, supporting military forces in a theater. The detonation of a nuclear explosion outside the atmosphere, even if it were a small nuclear weapon, perhaps a few tens of kilotons, could produce sufficient direct and delayed radiation to degrade or destroy satellites in line of sight of the burst, as well as a second effect; that is, producing EMP near the Earth's surface, which could interfere with, among other things, the satellite ground stations on the Earth.

Satellite assets, as you know, are a significant part of our overall military capability and, therefore, would be a desirable target.

Another possibility would be the use of EMP because the adversary does not have confidence in his ability to target precisely with a nuclear attack against forces or infrastructure, populations on the ground. For example, if an adversary is not able to pinpoint a carrier battle group or amphibious ready group, he could produce an EMP effect over the presumed operating area of the group, with only rough knowledge of where it is.

Another possibility might involve an adversary with a long-range but relatively inaccurate ballistic missile or a short-range missile launched from a platform that engenders some inaccuracy itself, such as a ship or a submarine, and have only a relatively low-yield nuclear weapon. In this case, the weapon could be more confidently used for an EMP attack than a direct attack, because the accuracy would not be required for the EMP attack.

And, of course, another reason would be basically a demonstration that a country may wish to make that it had a nuclear capability and could deliver it over our forces and allies. A by-product of that would be an EMP effect, but in addition, it would announce to the world that the country is nuclear-capable and prepared to use it, while at the same time not causing any loss of life among our forces, friends and allies, and, therefore, might impede the strong nuclear response by the U.S.

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I would like to mention one particular effect of nuclear EMP that is, in fact, unique. While all electronics systems fail spontaneously for a myriad of reasons from time to time, in the case of reliable systems, as most military systems are, these failures occur infrequently, and then only at single points or nodes. Therefore, experience has been gained in dealing with single-point electromagnetic and electronic system failures during the normal operation of systems.

However, since the nuclear EMP, even from a single exoatmospheric detonation, covers a wide area of the ground and the atmosphere above it, nuclear EMP can produce electronic system failures at many widely distributed points simultaneously. Unless special nuclear EMP recovery preparation and training has been implemented, system operators will have no experience with recovering the system from simultaneous, widely distributed multifailures and would have to discover how to recover from such failures at the time they occur, which would be a highly stressful time.

I know of no training in U.S. commercial systems focused on multiple, widely spread, simultaneous failures of highly reliable equipment.

Let me turn now to nonnuclear electromagnetic weapons. These are typically high-powered, radio frequency or microwave devices for which there is a great deal of interest in the world today, and there is a substantial history of interest from the Soviet Union's technology and that of others.

These weapons as well, these nonnuclear electromagnetic weapons, have several characteristics that could make them attractive to an adversary of the U.S. On the other hand, they have the potential disadvantage of requiring closer proximity to their targets to be effective than do nuclear EMP weapons. For example, a small radio frequency device might have a range measured in feet, while a relatively large, again nonnuclear radio frequency weapon might produce upset or damage in electronic systems at ranges measured in hundreds of feet and, of course, through basically what we call electronic countermeasures could cause interference up to ranges of 100 miles.

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Radio frequency weapons, however, are more suitable for covert use than are nuclear EMP weapons. A targeted asset might not realize that its problems are the result of a radio frequency or high-powered microwave attack, or even that a radio frequency weapon attack has taken place at all. And if such nonnuclear radio frequency weapons were used simultaneously against multiple sites, they could cause confusion and could slow restoration efforts because of a multipoint failure problem.

The ability of radio frequency (RF) weapons to be used selectively and intermittently as well as to be disguised as ordinary objects from briefcases to trucks could allow an adversary's covert operatives to interfere with U.S. or allied systems in a more controlled manner than a nuclear EMP attack.

And finally, RF weapons provide an opportunity for their users to escape detection, capture and potentially could be used repeatedly against U.S. assets. A truck-mounted RF weapon, for example, likely would be large enough to act from at least a few tens to 100 feet and mobile enough to have a reasonable chance of escaping before detection.

It should be noted, of course, that RF weapons, nonnuclear ones, are not as damaging over a large area as are nuclear EMP weapons. But in regard to a specific target against which they might be employed, both nuclear EMP and RF weapons can produce effects ranging from temporary interference, to the need to shut down and restart a system, to physical disablement of the targeted system by literally fusing or melting sensitive internal components. Especially due to the greater applicability of RF weapons for covert use within the United States, RF weapons, as well as nuclear EMPs, should be given serious consideration.

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Let me describe a range of the type of effects that you can experience from both EMP and RF weapons, and then I will summarize, or I will conclude by describing examples of easy errors to make in doing EMP testing and analysis that I have seen in my experience with this field.

At the lowest levels of field strength, the complex world of electronic warfare involving nonnuclear generation and transmission of signals has been present for many years and, in fact, was a major theme in World War II. I won't address that particular aspect of electromagnetic warfare today any further. As nonnuclear electromagnetic field strengths increase, signal carrier and modulation effects, usually involving continuous wave or nearly continuous electromagnetic field interaction in ways not envisioned in the design of the target system, come into play. In addition to pickup on deliberate system antennas, the most likely coupling mechanisms of these signals and, for that matter, all those that I am going to describe from this point forward is the pickup on other conductors extending from the core of the system and acting like electromagnetic antennas.

Examples of these effects include the use of a conventional warfare (CW) carrier with an audio modulation picked up on telephone lines attached to a computer, rectified by the semiconductor devices in the computer and interpreted as a telephone control signal, thus resetting modems and other features of a computer; and another example, the penetration of a microwave electromagnetic signal into a missile, such as an air-to-air missile or an air-to-ground missile, where the signal is rectified and interpreted as a missile guidance signal and navigation command, causing the missile to go off target.

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At still higher electromagnetic field levels, both nuclear and nonnuclear signals can be induced that are comparable in size to the normal signal levels in a digital system, the one bit versus the zero bit, for example, injecting anomalous bits, corrupting data and/or producing system upset. This injection of erroneous digital information into systems can be as benign as causing a flicker on the screen, or it can also cause a computer to lock up, which is a more typical response, and requires the computer to be restarted, rebooted, as they say. But in relatively autonomous systems like missiles or unmanned aircraft, particularly missiles in powered flight, which require active guidance to maintain their stability, not to mention their navigation, a lock-up of the computer is equivalent to the destruction of the system. There is no time to reset on a missile in flight.

At still higher electromagnetic fields than those that cause digital upset, signals induced on conductors that lead into semiconductor junctions can cause what is called a reverse breakdown of those junctions, and that, in turn, can then dump the power supply connected to the semiconductor through the junction in the wrong direction and cause the junction to fail permanently. This only occurs when the system is powered, but the effects can be catastrophic, and they can be apparent on power supplies, normally very rugged equipment, as well as on signal-processing electronics.

Then finally, at still higher electromagnetic field levels, just the direct EMP or RF weapon-induced signal can have sufficient power and energy to cause direct damage to semiconductor devices even when the system is turned off; and those are at the highest levels.

Let me summarize briefly by describing five common errors I have seen in doing testing and analysis of electromagnetic effects on military and other systems. There is some tendency to regard the item that is responding to the electromagnetic effect as the box rather than the box with all the conductors extending to it,

even fiberoptic conductors, because those designed for outside use and designed to be pulled through conduits inevitably have steel or other conductive wires protecting the fiberoptics. So the antennas are the dominant pickup mechanism for EMP, not the box itself, and even though I have designed simulators for use on things like missiles, which don't tend to have a lot of wires on them once they are launched, use of those simulators for things like telephone switching systems is really not appropriate unless electromagnetic pulsers are attached to the cables. It is not a box response. It is a box plus antennas response issue.

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I have seen systems tested with power off, even though it is clear that having power on the system makes it much more susceptible than having it off, and power off versus power on is a major issue. Clearly, systems would be used with power on, and they should be tested with power on.

I have seen systems tested in a quiescent state where they are not functioning, where subsystems are not exchanging data from one to another, and, therefore, the prospect of corrupting that data is small; whereas if a system is actually functioning, the data exchanges are taking place, and they are more susceptible to EMP.

I have seen systems well-designed with shields, which are operated in the field with the shields open. This is particularly true with personnel access hatches, where you might have an excellent electromagnetic shielding door, but if the personnel find it more convenient to leave the door open, then much of the shielding has been lost, or if wires have been run through the open door, they act as antennas directly into the electronics.

Finally, I have seen the issue of when a failure occurs, confuse EMP analyses, the most likely components to fail are first those near the outside world, near these EMP antennas, the conductors going into a system, and the components most likely to fail first are the weakest ones. I have seen tests where several components failed, and when they were replaced and tested again, they didn't fail, and people would say, well, this must have been a test anomaly. In fact, what they were doing was weeding out the weakest components near the interface and replacing them with statistically stronger components. Now, that is fine if all the operational systems you deploy in the field have also gone through this EMP trial and you have been able to weed out the weakest components as well, but generally that is not done, and, therefore, the weak components are left in the systems that are deployed in the field and will fail at the first high-level pulse.

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So even when tests and analyses have been run on systems, one has to look at the results very skeptically and with the benefit of experience that we have gained in testing systems over many years.

I guess I would finally like to say that I have seen major military systems fail as low as in order of magnitude below the level that Mr. Jakubiak showed there, and not failed at all at the highest levels we could produce, depending on whether they had been hardened or not. Thank you.

Mr. **WELDON**. Thank you, Dr. Graham.

[The prepared statement of Dr. Graham can be found in the Appendix.]

Mr. **WELDON**. Dr. Wood.

STATEMENT OF LOWELL WOOD, MEMBER OF DIRECTOR'S TECHNICAL STAFF, LAWRENCE LIVERMORE NATIONAL LABORATORY AND HOOVER INSTITUTION

Dr. **WOOD**. Thank you, Mr. Chairman and distinguished Members. I am grateful for the invitation to appear today. Like Dr. Graham, my esteemed senior colleague, I also commenced EMP studies in 1962, as my graduate advisor Willard Libby had recently retired from a long term of service as the Commissioner of the Atomic Energy Commission, and he assigned me EMP analysis problems kind of as exercises for the students, as he was then very keenly concerned by them.

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Indeed, electromagnetic pulses, EMP, generated by high-altitude nuclear explosions have riveted the attention of the military nuclear technical community for more than 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 technical mischief throughout the Hawaiian Islands nearly 1,000 miles distant from ground zero.

The potential for even a single high-altitude nuclear 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, "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 a postnuclear attack recovery process, the PONAIST studies of the 1970s. When essentially nothing electrical or electronic could be relied upon to work even in rural areas far from nuclear blasts, it was surpassingly difficult to bootstrap national recovery, and postattack America in these studies remained stuck in the very earliest 20th century until electrical equipment and electronic components began to trickle into a Jeffersonian America from abroad.

For obvious reasons, the entire topic of EMP was highly classified, and congressional oversight was generally circumspect and conducted in closed session. Indeed, this is only the third even partly open session of congressional oversight devoted to the EMP topic of which I am aware, and I congratulate you and your colleagues, Mr. Chairman, for the extraordinary vision and dedication to bedrock, albeit less fashionable, aspects of the Nation's security which are evidenced by this morning's hearing, as well as for the exceptional expertise of your staff on this subject embodied by Dr. Peter Pry.

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The third decade following the high-altitude tests of the early 1960s 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 than this \$5 billion were expended by other components of DOD in order to express this understanding as force in being, primarily to defend especially vital military equipment against EMPs' 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, weren't hardened against EMP very much at all.

I strongly concur with the remark that my colleague Dr. Graham just made, that I know of major military systems, some very important to the Nation's warfighting capabilities, which were documented to have failed at EMP levels in order of magnitude and more below those which Mr. Jakubiak represented to you.

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.

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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 punch of a fight to the death conducted with EMP-hardened means. Indicated responses to any EMP attack then were clear.

To be sure, as you noted at the outset, Mr. Chairman, the maximum Soviet capability to impose such attacks still exist today in the strategic forces of the Russian Federation, and I unhesitatingly predict that it will continue to exist for many decades to come.

Today we also watch the ongoing diffusion by purchase and perhaps by illicit routes, at least as much as by indigenous development; as the Rumsfeld Commission documented in the case of ballistic missile proliferation, we see the ongoing diffusion of nuclear weapons technologies throughout the Third World. Just last week, for instance, former Secretary Perry told the Nobel Institute that he expected to see nuclear weapons in the hands of the Iraqis, the Iranians and the Syrians, in addition to those who already have them.

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 a great deal about the revolution in military affairs and the promise which it extends for far greater effectiveness of a postrevolutionary 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.

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There arises the regrettably real prospect that EMP weaponry, assuredly if nuclear and perhaps, as my colleague Dr. Graham just highlighted for you, even if it is nonnuclear, could abruptly transform a future Desert Storm type of 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 of the character of national scale masochism. It is perverse and irrational, and it is assuredly not necessary or foreordained.

Relative to the two years since I last testified before you on this subject, it is useful to ask what has changed and what has not. The natural laws governing EMP haven't changed an iota, nor has the EMP-oriented Russian strategic war machine. American preparedness against EMP attacks hasn't improved. Rather, the operation of Moore's Law continues to endow our national infrastructure with ever more intrinsically fragile electronics.

Notably, Third World nuclear weaponry capabilities and long-range rocketry both continue to advance rapidly, as the Rumsfeld Commission reported. Specifically, North Korea, a nation which has elected to lose an appallingly large fraction 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 just now on the threshold of ICBM ownership. In short, our previously poor national position vis-a-vis EMP attacks has deteriorated markedly over the past two years, and it is no exaggeration to forecast future major peril.

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It is therefore heartening to see the Congress continue to engage the EMP threat, for too much of the DOD has seemingly resigned itself or, worse by far, is actively deluding itself regarding the nature and severity of EMP.

That said, I must commend those dedicated and competent DOD components and staff, both civilian and military, who continue to labor to harden with respect to EMP crucial national warfighting capabilities, strategic and tactical. While those belittling the magnitude of the consequences of EMP threats should be judged harshly by the Congress, the more so when the shakiness of their technical premise becomes manifest, the many DOD people and organizations of integrity and fidelity to the enduring national interests vis-a-vis EMP are most deserving of praise.

For the sake of America's future in a nuclear multipolar world, I appeal most earnestly to you and your colleagues, Mr. Chairman, 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 or devastation.

Thank you, Mr. Chairman. I will be grateful if my prepared statement can be included in the record. I also ask your attention to the fact that I am here today as a private individual, not necessarily representing any opinions other than my own. I have verified, however, the viewpoints I have expressed and will express in subsequent testimony seem congruent with the community consensus as represented in documentation in the pertinent files of the Defense Threat Reduction Agency. Thank you, sir.

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Mr. **WELDON**. Thank you, Dr. Wood.

[The prepared statement of Dr. Wood can be found in the Appendix.]

Mr. **WELDON**. I thank all four of you, and your statement will be entered in the record as will all the

statements. We appreciate the testimony, and as we had hoped and wanted, and as we have seen and observed, there is a significant amount of difference in the assessment of what the impact would be of an EMP laydown or the EMP threat, and I think also the preparation of response, and I would hope that during our time of questioning, our colleagues would explore those significant differences.

Let me start out by asking the question, is it not true that in the past both the strategic doctrine of the U.S. and the Soviet Union had an EMP laydown at the beginning of a nuclear attack on the other country? Hasn't that been a part of the strategic doctrine of both nations?

Dr. **WOOD**. Yes, Mr. Chairman, it has been. In all of the war games in which I have been present and all the ones which I have studied when I have not been present, the attack, the red attack, always begins with an EMP laydown on blue, that is to say a Soviet laydown on the continental United States by multiple multimegaton high-altitude bursts.

Mr. **WELDON**. Mr. Jakubiak, would you agree with that?

Mr. **JAKUBIAK**. I agree with that.

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Mr. **WELDON**. Dr. Bernardin?

Dr. **BERNARDIN**. I cannot speak to that subject.

Mr. **WELDON**. Dr. Graham, do you concur with that?

Dr. **GRAHAM**. I don't have current information on that, Mr. Chairman.

Mr. **WELDON**. How about in the past, did your experience indicate that that, in fact, was the case?

Dr. **GRAHAM**. Yes.

Mr. **WELDON**. That being said, Mr. Jakubiak, maybe I misread your statement, but it seemed to me as though there was some question as to whether or not EMP was an effective tool.

I guess I would ask the question, why would both major superpowers have an EMP laydown as the key start of a nuclear confrontation if, in fact, there was not a degree of certainty that, in fact, this was a good tool?

Mr. **JAKUBIAK**. In my statement, sir, I basically indicated that, in fact, the U.S. military has assumed that, in fact, unless the equipment is protected against an EMP, it would fail under an EMP environment, and therefore we have taken steps to protect those military circuits to the levels that we feel are the threat levels and provide a protection for those critical circuits.

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My statement basically was geared towards the use of COTS equipment, which is now becoming more

prevalent within military systems, and, in fact, the COTS equipment has been showing up as being surprisingly resistant to EMP effects. To counter any deficiencies that equipment is, in fact, tested on a case-by-case basis. The levels are, in fact, identified that the equipment fails at, solutions identified, and, in fact, modifications are retrofitted to that equipment before they are fielded.

For systems that go into an EMP environment, EMP threat environment, are intended to be used in an EMP threat environment, they are, in fact, protected at the EMP levels that are identified as the threat.

Mr. **WELDON**. Mr. Jakubiak, your statement doesn't seek, was at least my impression—and I certainly could be wrong, I have been wrong in the past—but in the hearings we have held in the past, one of which was an opportunity to have General Clark here, he basically left me with two impressions. One, we were dismissing the potential threat; and, two, we were characterizing the cost as being too excessive to deal with as the reasons why we weren't taking aggressive steps.

Furthermore, my understanding is, and maybe again I am incorrect, that the only systems that have really been hardened are ICBM systems that would be used in the event of an all-out nuclear attack against the Russians, and that, in fact, the rest of our systems are not hardened to any level of certainty that they could withstand an EMP. That may be wrong, and I am going to ask you each to respond to that, but that has been my assessment.

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I guess the specific question is, I think it was in Dr. Woods' testimony, he mentioned that we had spent at one point in time \$5 billion, I think was the figure you used. Is that correct, Dr. Wood?

Dr. **WOOD**. That is what has been spent, just by what is now the nuclear component of the Defense Threat Reduction Agency, sir. That is a small fraction of what has been spent by DOD overall.

Mr. **WELDON**. I don't know of any specific line that is being spent on EMP in our current year's budget, and I have chaired this subcommittee for five years, and I have asked this question frequently. My suspicion is that because no one service has EMP as a priority program, as we have faced a very difficult budget process, that funding and investment in hardening has gone by the wayside. I would ask you all to respond to those statements that I have just made in the positive or the negative. Why don't we start with Mr. Jakubiak.

Mr. **JAKUBIAK**. The requirement for an EMP protection is addressed on a system-by-system basis when you get outside of the nuclear command and control area. The ICBM systems you talked about, they are protected. The SSBN systems are protected. The bomber systems are protected. All of the communications that are used to provide survivability for execution of those forces are, in fact, protected to EMP levels that are specified in a DOD standard that has been produced by, in fact authored by, the Defense Threat Reduction Agency.

When we get to the tactical battlefield, the individual systems that are used in the battlefield come before a requirements panel. The utilization of that equipment as to what environment that equipment might be used, whether it would be—whether it would be used under an EMP umbrella or EMP threat environment is considered, and a decision is made as to whether that equipment will, in fact, be provided EMP protection or designed to EMP standards. For instance, the M-1 battle tank, that is EMP protected. That is a tactical system, not a strategic system. There are several others that I will be able to address in closed session of

tactical systems that, in fact, have been protected to EMP standards.

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Mr. **WELDON**. Would the others like to comment on this statement? Dr. Graham first and then Dr. Woods.

Dr. **GRAHAM**. Mr. Chairman, as far as the cost issue goes, on those systems which have been EMP-hardened, the cost of the hardening is embedded in the system cost.

My experience is that with systems designed from the ground up for military application, if the hardening is taken into account early in this system, conceptual design and development, it can be as small as a percent or two of the system cost.

On the other hand, if the system is completely designed, engineered, manufactured, and then you want to harden it, it can be up in the tens of percents of system cost or higher, and generally is regarded as prohibitive. So when you do it is very important.

I have much less experience with COTS equipment, but my impression is that at least in cases where you are using what might be called global hardening, shielding and penetration control, you are probably going to come into about the same situation, where thinking of it early has a tremendous payoff, including the EMP hardening early is very valuable.

I would also say that when looking at hardened systems, hardened against EMP, you have to look at what was in the design and manufacture of the system, how the system was tested and how the system is maintained.

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It is perfectly possible to start out with an EMP-hardened system, but because the maintenance program and the operational program doesn't incorporate EMP-related issues, the system can become vulnerable very rapidly.

Finally, I would like to say that you mentioned strategic missiles. There are other systems that have been designed for EMP hardness. For example, the best example, the best case of an airplane being hardened to EMP, I know, is the Navy and Strategic Command's EA-6B Tacamo aircraft, which is a highly modified 707, which has been very extensively hardened to EMP, and there is still some maintenance program associated with EMP ongoing.

Mr. **WELDON**. Dr. Wood.

Dr. **WOOD**. It is indeed the case, Mr. Chairman, as you said, that the strategic war machinery of this country has received by far and away the greatest attention with respect to EMP hardening, and, at that, the unhappy fact of the matter is that these efforts have been incompletely successful. I obviously can't speak to details except perhaps in closed session.

The situation that Mr. Jakubiak seems to be emphasizing is concerned with tactical capabilities and, in particular, with COTS equipment involved in tactical circumstances.

It should be pointed out that there is essentially no COTS equipment in the strategic war machine, both because the strategic war machine has not seen significant amounts of upgrading since the emphasis on COTS equipment utilization in DOD, and also because of the very special nature of much of the equipment, it is really not conducive to use of COTS gear. So most of the—most all of the use of commercial off-the-shelf, or COTS, equipment is necessarily confined to tactical systems.

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Because of the disagreement which first surfaced when Congressman Bartlett held a discussion along these lines in his office most of a year ago, I went out to the Defense Threat Reduction Agency and spent most of the day reviewing the studies and the associated documentation that was referred to by Mr. Jakubiak in these previous discussions, and I discovered several things that were pertinent in their fundamentals to the points that have come up.

First of all, the studies, and in particular the Army study to which Mr. Jakubiak made extensive reference, has in its notes an indication that cables were not connected to the study during the EMP testing. As my colleague Dr. Graham has pointed out, it is not sufficient to analyze the box. It is required to analyze the box and the cables whenever you are looking at the EMP hardness of any equipment, because it is the cables that intercept most of the energy of the electromagnetic pulse and drag it into the equipment where it then does damage. If you don't have cables connected during EMP testing, you really haven't tested under circumstances which are at all realistic. It is a little bit like showering in a raincoat. The water flows, and it trickles down the drain and so forth, but the body doesn't see much water.

The second point is that the study notes also indicated that the equipment was sometimes powered up and sometimes was not powered up during the testing. Again, as Dr. Graham has pointed out, reverse breakdown of semiconductors depends very strongly for its effectiveness in damaging equipment with the equipment being powered up. If it is not powered up, there is no energy in the power supply that then flows into the semiconductors that have undergone reverse breakdown, and there is no damage along that mechanistic line.

On the other hand, if the equipment is powered up, it is the power supply itself whose energy tends to destroy the compromised semiconductors. So it is extremely important if you are doing a full-up EMP vulnerability assessment to have the equipment not only have its cables connected, but to have it powered up, and that was not always the case in these studies. It apparently was not a subject that was given a great deal of attention by the people conducting the study.

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Indeed, the people conducting this study documented their statement that it was hastily constructed test equipment, that the systems were using only very small data sets, and their manifest and declared orientation was to find specific problems and see how they could fix them on particular pieces of equipment with insertion of more or better components.

From a physics standpoint, probably the most striking thing about these tests was that they used only the lowest frequency component of the EMP threat spectrum, the so-called E-3 component. They did not use what I think Dr. Graham and I would both tell you in most circumstances is the most threatening portion of the EMP spectrum, namely the E-1 component, the high frequency component that tends to be especially

penetrating of enclosures, especially unforgiving of cracks and other sort of deficiencies in these protective enclosures, and what, in tests conducted by the Defense Nuclear Agency over the decades, has been the most damaging to most types of electronic equipment.

It is the low-frequency component, the E-3 spectrum, against which protective compartments, protective decoupling devices and so forth is most effective. It is not a blunder on the part of the people doing the tests. Under some circumstances the E-3 threat spectrum may be the most interesting to look at, but it is not the most threatening to look at.

So for these reasons, I found the tests that were done by the Army chemical and nuclear laboratory to certainly be commendable in that they were looking for inexpensive, quick ways to upgrade COTS equipment to the point where it might possibly be useful, but they were in no sense up to DOD standard with respect to how you thoroughly evaluate the EMP vulnerability of equipment, and, therefore, I would caution you that the results which Mr. Jakubiak presented to you in summary—and I am certainly not suggesting it was anything other than in good faith that they were presented, but I must caution you that those results from a technical standpoint can be impeached from several directions.

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Mr. **WELDON**. Thank you.

One final quick question, and I would like you to try to narrow this down to a simplistic answer in what is a very complicated and difficult subject, I realize, but I am going to try and do this. We are doing this public hearing for the American people.

North Korea, possessing, let's say, a low-complexity SCUD missile, puts a nuclear warhead on the top, puts it on a ship so we don't know it is North Korea, fires that missile into the atmosphere off of our coast and detonates it. How prepared is America, from a military systems standpoint and a civilian standpoint, to respond? Would we be able to handle it with no problem? Would it create some degree of problem for perhaps the military, or would it wreak havoc on the people of our country?

I would like to go down the row and ask each of you what you think would be the impact today if North Korea, which both has the SCUD missile capability and a warhead capability of a low-yield capacity, if they, in fact, deployed an EMP, what would be the impact on America both militarily and civilian? Mr. Jakubiak? Would it be significant or nonsignificant?

Mr. **JAKUBIAK**. A single weapon off of the coast of the U.S. would be—naturally it would be a concern, but it would not be a drastic or catastrophic event that would wipe out the civilian infrastructure. That is my personal opinion. I think that the people you would have to talk to to see the more analytical approach as to what the impact on the infrastructure would be would be the national communications systems, the Office of National Communications System, which is responsible for overseeing the survivability of the public telephone switching network infrastructure. Their results have shown that, in fact, that infrastructure would survive, no problem; that, in fact, your phone calls would get through. In fact, even in a panic calling environment, where people repeatedly would try to redial again, they have shown that, in fact, the infrastructure would survive, and your calls would get through at a 70 percent rate, which by no means is a catastrophic event.

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In the area of the military communications systems, our nuclear command and control system would continue to operate properly. We would be able to detect that launch. We would be able to advise the President as far as what his options were, in fact, from a nuclear command and control perspective. And, in fact, if any activation of nuclear weapons was, in fact, required on the U.S., that could still occur after the EMP occurred.

Mr. **WELDON**. Who would we attack?

Mr. **JAKUBIAK**. I am just saying that, in fact, the President would be advised of his options as far as what nuclear capability he has to respond if he wants to respond.

Mr. **WELDON**. So even if it was an EMP laydown where no damage was done to individuals, you think perhaps we would think that was justification to have a nuclear response against another country?

Mr. **JAKUBIAK**. The President is always advised of what his nuclear capability is as far as the scenario.

Mr. **WELDON**. Dr. Bernardin, what would be the impact of that kind of a one, single warhead detonation would be?

Dr. **BERNARDIN**. Mr. Chairman, I am only able to speak to the field levels that would be produced on the ground, and, in fact, I have in closed testimony some presentations to show on what North Korean weapons would produce.

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Mr. **WELDON**. Let's say a 1-kiloton warhead that is fired on a low-complexity SCUD off of our eastern coast, what would be, in your personal professional opinion, the impact of that? Could we handle it, no problem, minimal problem, significant problem, civilian and military today?

Dr. **BERNARDIN**. The effects on our civilian and military infrastructure I am not prepared to speak to. That is outside my area of expertise.

Mr. **WELDON**. As a professional. You are a physicist.

Dr. **BERNARDIN**. I am. My impression would be that we would have low effects due to a 1-kiloton-type weapon detonated over the United States.

Mr. **WELDON**. Dr. Graham.

Dr. **GRAHAM**. Mr. Chairman, I don't know the answer to your question, and I—.

Mr. **WELDON**. Let's increase that to 10- to 20-kiloton.

Dr. **GRAHAM**. Either way it turns out the fields more or less are logarithmic in the nuclear weapons yield,

so they vary fairly slowly with the yield, and I don't believe the analysis has been done which would give a definitive answer to that question.

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However, pieces of the analysis have been done and other systems looked at that while I think the United States would survive such an event, there are such a large number of capabilities, both in our military forces directly and even more in our civilian, supporting infrastructure that we need, that it is quite possible that the effects could provide a major disruption and delay in our activities.

As you know, to deploy military forces in an expeditionary fashion overseas, we require massive logistics to get them there, equip them and sustain them there, and that requires a heavy use of the civilian infrastructure, air transport, surface transport, telecommunications, computing capability. Monetary flows in the United States are primarily electronic today and throughout the world. All of those capabilities depend heavily upon civilian electronics and somewhat military electronics. All of those would be subject to disruption and confusion. None of the civilian infrastructure that I know of has been designed with EMP threats in mind, and, therefore, is likely to experience some degree of disruption. So if we were in a time-critical situation where we have to get men and women to a theater rapidly, such an attack could cause us a significant delay and, therefore, a military problem.

Mr. **WELDON**. Dr. Wood.

Dr. **WOOD**. Mr. Chairman, the question or the set of questions that you posed are certainly the most pertinent ones. They also elicit answers which not only are a bit extended, but really is—some portions of them would have to be made in closed session.

But to speak to the issue as much as feasible in open session, the North Koreans certainly have the ability to deliver a small nuclear explosive to the U.S. at the present time. The ballistic missile capability which they have demonstrated could deliver a warhead weighing substantially more than a tenth of a ton and substantially less than one ton anyplace that they chose to in the United States, including any height of burst that they choose over the continental United States.

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So that is something which I think the Rumsfeld Commission predicted would happen. It is something of which the test of last August 31, 1998, indicated they indeed had that capability.

The press reports are saying that they could strike Alaska or they could strike Hawaii. That is striking in reference to a 1-ton warhead. With a fractional-ton warhead, that same missile could deliver that warhead to any point over the continental United States, over the 48 contiguous states. It is not necessarily the case that the referenced 1-ton warhead is what the North Koreans would use. It is very well known that U.S. strategic warheads that are in stockpile at the present time have masses of tenths of a ton, and not very many tenths of a ton. So if the North Koreans had access to a single sheet of paper, whether it could come to them in a fax from a Soviet nuclear weapons laboratory, they could use the materials that they are known to have in hand to create a warhead, not, Mr. Chairman, that was one kiloton or even ten kilotons, but substantially higher yield than that.

My colleague Dr. Graham has said that the EMP yield of a warhead is very weakly dependent on its energy yield. That is true, but it is true in spades. Special purpose nuclear warheads, on a kiloton scale, can have much more of EMP effect than ordinary nuclear warheads on the megaton scale. Less than ten kilotons properly employed in the type of warheads which have actually been examined, both in the Soviet Union and in the United States experimentally, warheads of less than 10-kiloton yields can put out very large EMP signals. So it is necessary to understand that it doesn't take a megaton to do an awful lot of damage. You can do an awful lot of damage in ten kilotons or less.

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Mr. **WELDON**. What would be the damage done by that, in your opinion? That is what I am trying to get at, and I know there are all kinds of variations. Are we prepared, militarily and civilian, for the kind of capabilities North Korea has?

Dr. **WOOD**. In order to be noncontroversial, I will just quote a CIA estimate that has been briefed by a senior cognizant CIA national intelligence officer on the Hill here during the last year, on an unclassified basis, where he considered a hypothetical laydown of the type that could be posed by a Taepo Dong missile over the central United States and presented the unclassified calculations of what the EMP yield or the EMP consequences would be at the coasts of the United States; in other words, most distant from the explosion. The EMP field strengths that were calculated there—and nobody seriously questions these calculations, they are with tool sets that are community tool sets that have been around for decades—with the field strengths that were demonstrated at the coasts, the maximum distance, you would see upset or damage to a wide variety of civilian equipment that has been documented to fail at these field strengths, and you would see some damage to military equipment.

The consequences of such a laydown are very strongly dependent on what you assume is the nature of the explosive, as well as what you assume is the vulnerability of the equipment, but with documented equipment vulnerability of the type that has been measured for sensitivity to these threat spectra during the last two to three decades, you would see major damage as far out as the coasts to civilian gear. You would also see it to a substantial amount of military gear.

It must be said, sir, that Mr. Jakubiak is vastly more optimistic than I am with respect to the vulnerability and survivability of civilian infrastructure. He said the telephone companies said that their equipment would just come through unscathed, or essentially unscathed; that you would not notice the difference essentially. Well, this is the same telephone company that can't carry my traffic when I try to call my mother on Mother's Day. And they aren't out 70 percent or 30 percent of the time, they are out for hours at a time, where I get an all circuits are busy now, please place your call again next weekend.

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The Defense Department didn't believe that the telephone company would survive a nuclear EMP laydown. They built an independent telephone system during the Cold War to carry vital strategic traffic, and they did all kinds of things that the telephone company doesn't do in the hopes that that system might actually survive a nuclear laydown. But neither the Strategic Air Command, nor the Joint Chiefs of Staff, nor the Defense Communications Agency during the Cold War believed that the civilian telephone or telegraph or whatever infrastructure would survive a nuclear laydown in any fraction. They thought it would be knocked down completely and forever, and this was extensively documented, Mr. Chairman, in the studies, the Post Nuclear

Attack Survivability and Recovery Studies (PONAST) of the 1970s. There was nothing left. It was totally burned down, and statements by AT&T or whoever else may be making such statements that they are in vastly better shape today are very, frankly, sir, hogwash.

Mr. **WELDON**. Thank you.

Mr. Pickett.

Mr. **PICKETT**. Thank you, Mr. Chairman. I guess what we are all really concerned about here is the basic question—we are the government policymakers here, and we are trying to get an assessment of whether or not there has been an adequate determination of what the threat is to our country, and then whether or not we have developed an adequate response to the threat.

So you all know that we as elected representatives operate in an environment where we have to somehow make an assessment of the technology involved, the economics involved and the response that is fashioned for our country, and we have to bring all of this about in a political environment where we have to persuade the public that what we are spending that money for is justified.

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So my question is, first of all, do you on the panel believe that there has been an adequate assessment of the threat to our country from EMP; and, secondly, if there is a threat there that requires a response, has enough been done by our country to respond to the threat, and, if not, can you make some suggestions about what addition would have to be done in order for our country to have an adequate response to the threat that we have identified?

Dr. **WOOD**. Mr. Pickett, by far and away the most effective thing that could be done in terms of cost efficiency to see that our country doesn't suffer damage from the EMP threat is to make sure that nuclear explosions never occur over our country.

Mr. **PICKETT**. You are alluding to an adequate missile defense system; do I understand you correctly?

Dr. **WOOD**. That is one approach to it, sir.

Mr. **PICKETT**. Yes. Okay.

Dr. **WOOD**. There are others that take exceedingly dire retaliatory threats that would presumably have something—some efficacy along those lines, if those threats were considered credible.

Mr. **PICKETT**. Anyone else? Yes, Dr. Graham.

Dr. **GRAHAM**. Well, I agree with Dr. Wood about the importance of trying to prevent nuclear weapons explosions over the U.S. Using every diplomatic, economic and military capability we have or can develop, I believe we would still face the possibility that it might occur. For example, one of the ways an offensive nuclear weapon on a missile can be armed is in what is called a sympathetic or a salvage fusing mode, so that even if you intercepted above the atmosphere before it reaches its target, once it knows it is being attacked, once the offensive nuclear warhead knows it is being attacked, its fusing system may choose to detonate itself

there to get at least the EMP and space radiation effect of the weapon.

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So it is very hard to eliminate that possibility completely, although we should certainly take every action we can to do so.

I think from the point of view of the Congress, it would prove an interesting exercise to ask the Defense Department and officials in the national security area to review the systems which they think should function through a possible at least high-altitude nuclear attack, and then to describe which of those systems were designed to be hard to it, which were tested to be hard to it, which are being maintained to be hard to it, with some description of what is transpiring in each of those areas, and then to do the same thing in the civilian area.

I am familiar with some of the civilian telecommunications tests, in particular a number five electronic switching system test that was done in the Aries simulator, which I did the preliminary design for in 1968. The cables that normally extend hundreds of miles into that system were represented by cables coiled up and placed under the mobile vans it was carried in. So, as we mentioned earlier, that is certainly not a good representation of the stress that the system would receive.

I am not trying to say that this is the complete work that has been done, but it is indicative of the concerns that a review of the subject by your committee might find both informative for you and beneficial for the defense authorities.

Mr. **PICKETT**. Dr. Bernardin.

Dr. **BERNARDIN**. I would like to respond to your question, Mr. Pickett. I believe that the United States is investing quite adequate resources in studying the threat; that is, studying what countries are out there that are trying to develop nuclear weapons through the intelligence agencies, and what those weapons might look like through the national laboratories. In terms of identifying how serious is that threat that requires EMP testing, I would point out I believe one of the panel members may have left a misimpression, that there is quite extensive testing that has been done of military systems, and it has been to the E-1, the high-frequency EMP. Dr. Graham just mentioned he tested at Aries facility. That is an E-1 simulator of high-frequency EMP, and as you fly into the airport in Albuquerque, you can't help but notice these EMP simulators that are taking up large areas of space, on the order of a football-sized field. Those are E-1 simulators.

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So the military has done quite a bit of testing of EMP for vital equipment, as Mr. Jakubiak talked about which equipment really needs to be EMP-protected.

As far as civilian systems go, I can't speak to that, and I don't know what our vulnerability is on the civilian side.

Mr. **PICKETT**. Mr. Jakubiak, can you respond?

Mr. **JAKUBIAK**. Let me endorse what Dr. Bernardin just said, that the military has, in fact, invested quite

a bit of money into assessing what the threat is over the years and the changing threat. The threat is different from what it was back in 1970. The threat today is different, and we are looking at that threat on a continuing basis. That is why we have funded the effort at the national laboratories to continuously look at the threat, to tell us if the threat is getting worse or if it is getting better, and designing our EMP programs and equipment to meet that threat in today's environment and in the environment of the future.

As far as the commercial infrastructure is concerned, the military—and I am not involved with assessing what the commercial infrastructure vulnerability is, I have access to the reports that have been done by those that are responsible for that. It is not just the telephone companies. It is the National Communications System, which is a Federal agency that, in fact, oversees the survivability of the commercial telephone infrastructure. It is their reports and their testing that I am quoting here, and it is their performance under EMP environment that I am speaking to when I mentioned that the phone system will work at a 90 percent level with normal loading and at a 70 percent with panic loading under EMP environment. They have tested that to the EMP levels that, in fact, we test military equipment to, and that has been their result. So if you would like to have more information on the commercial infrastructure, I would strongly suggest that you get a representative of their survivability program, the National Communications System, and have him provide a briefing also on the work they have been doing and are continuing to do.

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In fact, it is my understanding, from a phone call I had this morning with the National Communications System, the person in charge of the survivability effort, that they are continuing to provide testing on survivability of the public telephone system, and, in fact, their current testing is more concentrated along blast damage than it is EMP, because they feel their system will survive an EMP event.

Mr. **PICKETT**. Okay. Thank you very much.

Dr. **WOOD**. Mr. Pickett, you should be advised that the national capability to do EMP testing is basically in shambles relative to 10 or 15 years ago. For instance, the system that Dr. Bernardin referred to that you see when you fly into Albuquerque Airport is the wreck of the trestle system. It has been decommissioned. It has been completely nonfunctional for a number of years. It would take many tens of millions of dollars to bring that back into operational capability.

The national capability to test against EMP vulnerability of satellites and system-generated EMP died when the U.S. ceased to do underground nuclear testing. There are very few of the major facilities that existed 20 years ago, sir, that are in operational condition today, and the ones that are in existence are used very seldom.

This is a Potemkin village of an EMP vulnerability and hardening program that exists at the present time, sir. I strongly suggest that this committee would be well advised, in all respects, to ask for documentation along these lines. You will find that there is nothing behind the facade to a first approximation.

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Mr. **PICKETT**. Thank you.

Mr. **BARTLETT** [Presiding]. Thank you very much. We must recess briefly for another vote, and it will

be very brief this time.

I would just like to pose a question that I would like you to be thinking about while we are gone. Our last real life experience in EMP effects was Starfish, 1962. There was essentially no electronic equipment in Hawaii. It was electrical equipment. There was massive, relatively massive, disruption of those crude, crude systems in 1962.

I am having a lot of trouble with the simulations today that can't come even close to that real-life test. I mean, what you are telling me is that these highly vulnerable systems that we have today, because we are so sophisticated, would be far less affected by EMP than these crude systems that we had in Hawaii that shut down their telephones, turned off their street lights. I am just having trouble with the validity of your tests.

We have to go to the real world sometimes to get a validation of your tests. I am just very skeptical of the validity of these tests when they can't come even close to predicting the kind of damage that you had in the only real life experience that we have had, and I don't know how you can be sanguine about your tests when they can't verify what, in fact, you know happened in Starfish in 1962.

I would like a brief discussion of that when we return, and we must now recess our committee briefly, and we will return shortly.

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[Recess.]

Mr. **WELDON**. [Presiding.] If we could reconvene, I would return to my distinguished colleague Mr. Bartlett.

As an editorial comment, I understand in response to Mr. Pickett's questions, that there was a statement that was made that was said could be refuted in a classified session. For the public that is here and the media, I will say this on the record, we will have a classified session after this, and we will have a chance for that data to be refuted, but I will also give those who are criticizing the opportunity, and I will let the public know whether or not there has been a refutation of the claims made by the administration in this case on that data. I can't get into the details of the data, but it is unfair, I think, to just use the item that we are going to do that in classified session, which I understand your reason why, but I also understand that in classified session there may be disagreements over that data, and I plan to make that known to the public if there is disagreement in a classified session between the panelists that we have here.

So I don't want anyone to read the fact that we can supposedly refute something in a classified session that the public will not know. The public will not know the specifics of it, but they will know whether or not Dr. Wood and Dr. Graham, and perhaps Dr. Lunt, disagree with the assertions made in terms of refuting certain items by Mr. Jakubiak.

Mr. Bartlett.

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Mr. **BARTLETT**. Thank you.

Let me come first to the question I posed just before I recessed, and that is how can you be sanguine about your simulation results when they, as I understand, come far short of predicting what we know happened in 1962 at Johnston Island? If I believe your simulation results, then what happened in 1962 didn't happen.

How do you explain that?

Dr. **WOOD**. There is a fairly noncontentious way to begin to understand that difference, Mr. Bartlett, and that is that the simulations necessarily do not fully represent what happens in the real world. One of the mechanisms or one of the distinctions along those lines that came up during the break, so the break was actually useful for clarifying this, is that when people put these boxes like the large telephone switches into an EMP simulator, as Dr. Graham pointed out, they curl up the cables and set them underneath, and it is kind of like sitting on your hands, if you will, and they then test to see if the equipment inside the box is vulnerable or not.

But in the real—and they sometimes find out that, hey, it survived the test, but in the real world those cables, as Dr. Graham says, extend out for hundreds of miles. They pick up the real, honest-to-goodness EMP, and they haul it into the box through the penetrations, through the protective enclosure, through the back door, if you will, and it is that aspect of EMP which damages equipment inside the box.

Well, if you are working with strategic systems, and your boss, the general, has said, I want you to make absolutely certain that thing is going to survive in a real EMP environment, what you do is you not only set the box inside the EMP simulator, but you inject current representing the EMP into those cables that in a real system go out for hundreds of miles; you inject current pulses into them to see—which is known to represent the EMP that the cables pick up, and you see if it survives under those circumstances.

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You often find out that, oh, with current injection the thing died. However, if I just curl the cables up and set them underneath, it came through fine.

So a lot of the difference between the tests and what is seen in the real world is how rigorous the tests are, how close to the real world they are made to be.

There is just an enormous difference between what you can say happened in an EMP simulator and what happens in the real world if the EMP simulator is not realistic. You might as well, in some circumstances, not have done the test at all.

Mr. **BARTLETT**. Dr. Graham.

Dr. **GRAHAM**. Particularly concerning the Starfish event, which was above the horizon, but over 1,000 miles from Oahu, the Hawaiian Islands, and approximately that distance from the other islands, a number of events were observed on the islands that were almost certainly related to the EMP from the event. Of course, the EMP wasn't understood at that time, and, therefore, the phenomenon that occurred wasn't understood in any but the vaguest possible way as being something that happened at about the same time as the Starfish event.

However, there was a body of anecdotal data of things that had happened that were unanticipated, coincident with Starfish, and I must admit we were probably a little slow on this, but it wasn't until about a decade later that we made a systematic effort to collect all of that data and describe it. We undoubtedly missed some things that had been lost in the intervening decade, but we had a list of phenomena that were observed, and by that time, say around 1972 or so, we understood the high-altitude EMP effects much, much, much better than we did in 1962.

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I don't know of any effort to go back and deliberately simulate those effects by applying electromagnetic fields and currents to the equipment that was affected during Starfish. However, I believe most—the effects that were observed, as best I can recall them, were in generally what I would call generally at least qualitative accord with the electromagnetic field levels from Starfish that were incident on the Hawaiian Island chain.

So it is really a case of not having done all of the simulation and perhaps not even all the analysis we might, but having, I think, a generally plausible agreement between what we discovered had happened on the event and the electromagnetic field strength we expected in retrospect at Hawaii from Starfish.

Mr. **BARTLETT**. It is fair to say then, I gather, that we do not know the extent of our vulnerability because of our inability to test whole systems and even complements of systems realistically under the kind of environment that would exist with an EMP laydown? Is that a fair statement?

Dr. **GRAHAM**. I don't think it is quite fair. I would say it is slightly differently. I think you can do reasonably good simulation even on systems that are quite extended, cables running off everywhere, antennas, power lines and so on. All of those systems seem to have the characteristic that the really complicated stuff, like electronics and computers, is in one or a few nodes, and all the stuff that goes off great distances is things like wires and cables and antennas, which are relatively simple.

It is not possible to simulate the EMP field effect by directly subjecting long, long wires to that field. The generators, the EMP generators, would have to be too big to do that. However, by directly injecting the current that we predict would be picked up by those cables, antennas and wires, and possibly simultaneously simulating the fields on the more compact and complex parts of the system, I believe you can do a reasonably good job of an overall EMP effect simulation. Interestingly enough, I think, as we mentioned before, the effects on the wires, that is the current injection tests, will have greater effects than the field simulation tests in most cases.

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Mr. **BARTLETT**. Dr. Wood.

Dr. **WOOD**. The ability, sir, to simulate EMP for reasonably compact systems that definitely have existed in the past to a regrettably good approximation doesn't exist at the present time. Perhaps the single largest such facility was the trestle facility to which Dr. Bernardin referred to at Kirkland Air Force Base. That could actually take and was built to take an entire B-52 bomber and could subject it to quite realistic of an EMP environment, and was built specifically for that purpose. The comparable facilities existed and were created typically on special-purpose bases at the Nevada test site in underground facilities for testing of exceedingly important spacecraft that had to survive during nuclear explosions in space in a strategic environment, and

those facilities were made to be exceedingly realistic because it was discovered that unless you were exceedingly realistic, you got results that were off by a country mile; and they were off, and off in an optimistic direction. That is to say, unless you did the job very realistically, you concluded that your spacecraft would survive, but when you are honest about it, you discovered that they would not. Those facilities ceased to be used nearly a decade ago when the U.S. entered the current testing moratorium.

So when you have sufficiently compact systems, yes, you can do very realistic testing. It is necessary to, in some circumstances, people being just human, to confront folks with the prospect of realistic testing in order to elicit candor from them.

We heard at the present time the telephone company says that the telephone infrastructure would survive extremely well. However, when they were asked formally, less than two decades ago, if they could provide service to the Defense Department during a nuclear war situation, they said, not a chance. So the Defense Department went off and spent well over a billion dollars creating a hardened telephone system of an exceedingly extensive geographic nature, but an extremely limited nature as far as service, to connect the national command authority with the strategic war machine here in North America.

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That money was spent not because people were so eager to go out and spend money on a hardened telephone system. It was spent because the telephone company said that there is no chance at all that their systems could survive because they were confronted with a prospect of realistic testing.

The same situation pertained to the electric power system. Three decades ago the electric utilities of this country formally assured the government that the power system would ride through a nuclear war; that because there would be so much load lost as cities were vaporized, that there would always be an excess of electric power generating capability relative to what was needed throughout a nuclear war and afterwards.

Then came the 1965 blackout in the Northeast, followed by large-scale blackouts in this country that were attributed to the effects of solar magnetic storms; that is to say, exceedingly weak EMP of the type that God generates when the sun fluctuates in the output of solar wind. The Earth's magnetosphere rattles around as a result. As a result, there are very low-frequency but, over large geographic scales, large-amplitude electric field disturbances around power systems, and the power systems fall apart; not believed to do so, but they have done so, repeatedly. You know, you actually read in the newspapers occasionally that such and such a blackout was attributed to a geomagnetic storm.

Well, after these events, the power—the electric utilities became much more realistic and in the PONA studies of the 1970s they told the government that they should assume that due to EMP effects, not due to blast and heat or elimination of cities, but due to EMP effects, they should assume the power systems would go down nationwide, and it would be very difficult to reconstitute for the reasons that Dr. Graham said, namely that when a power system goes down, if a piece of it goes down, the rest of the power system can be used to pick it back up and make it operational again. But when the whole system goes down, when a whole interconnection goes down, it is exceedingly difficult to bring it back up. In the case of the northeastern blackout in 1965, in some places it took two or three days to bring it back because people had never brought a power system back before that had gone down over such a wide scale.

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So as people are confronted with the prospect of realistic testing, or sometimes they are just humbled by natural phenomena such as large geomagnetic storms, they become much more realistic about whether their systems can survive, and in particular can survive EMP.

So I would suggest to you that the primary reasons why people are thumping their chests now, are reportedly thumping their chest and saying we are so robust against EMP, is they simply know they won't be tested.

Mr. **BARTLETT**. Let me see if I can get an answer to my concerns another way. The three of us here were sitting in a hotel in Vienna just a few months ago with Vladimir Lukin, Ambassador from Russia to the United States, at the end of Bush, at the beginning of Clinton, who is now the chairman—.

Dr. **WOOD**. I remember him well.

Mr. **BARTLETT**. Sir?

Dr. **WOOD**. I remember him well. He was the final Soviet hardliner.

Mr. **BARTLETT**. Yes, and he was one of the Duma members who was negotiating with us a resolution of the Kosovo fiasco; we were discussing a resolution of that debacle.

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He said, during those deliberations, if we really wanted to hurt you, we would detonate a nuclear weapon at high altitude over your country—by the way, he started out to say, if we really wanted to hurt you without any fear of retaliation, we would detonate a nuclear weapon at high altitude over your country and shut down your entire power grid and your communications system for a month or two.

Did he not know what he was talking about?

Dr. **WOOD**. That is probably a realistic assessment of the time that it would take to reconstitute the power system in this country. When the most vulnerable portions of a power system die, and these are usually the very high-powered transformers in major switching stations, when they go out, the time scale to replace them, if only one is lost, is about 90 days. If you lost 100 of them or 300 of them or whatever, it might be as long as a year or more before you could reconstitute a large portion of the major interconnect points that switch and convey electric power in this country.

It is certainly true that the type of EMP levels that the Soviet Union, or nowadays the Russian Federation, could lay down on this country without killing anybody would be easily sufficient to bring down the entire power grid.

So with respect to how long would it take to come back up, that is a little bit problematic. But with respect to their ability to do it, they could do it today or any time they chose, and if they did it in the middle of the day, on a sunny day, you might not even see the bomb go off.

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So, yes, it represents a way that the Soviet Union could impose pain—or the Russian Federation could impose pain, and indeed in my prepared statement I suggested that they will retain that particular whip hand over the planet for as long as that government is still in existence.

Mr. **BARTLETT**. Mr. Jakubiak, why would he say "without fear of retaliation"? This was Vladimir Lukin. He said "without fear of retaliation."

Mr. **JAKUBIAK**. I do not know what—.

Mr. **BARTLETT**. You can't figure out that?

Mr. **JAKUBIAK**. I can't understand what his thinking was behind that.

Mr. **BARTLETT**. You see, if this came from the homeland, there is no reason to launch it from your homeland because then we would know where it came from. You would have to be pretty dim-witted to launch a nuclear device on our country from your homeland. It is a big ocean. There are a lot of ships out there and submarines on their part. But if it was launched from the ocean, how would we know who launched it in today's world? In the old Cold War world, we knew who would have launched it. It would have been the Soviets. But in today's world, how would you know who launched it?

Mr. **JAKUBIAK**. I don't feel qualified to discuss that.

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Mr. **BARTLETT**. Sir, even if we did know, if all they had done is electronic warfare, they have knocked out your power grid, they have knocked out your communications, they have not hurt one person or broken one window, are we then justified in incinerating their grandmothers and babies?

Mr. **JAKUBIAK**. I think that is a decision that the national command authority would have to make.

Mr. **BARTLETT**. Who would it incinerate if it came from the ocean?

Mr. **JAKUBIAK**. Sir, I don't feel qualified to address that question.

Mr. **BARTLETT**. The point I am trying to make is that we face a real vulnerability here, and I think that this is such a hard question, there are military people that would rather not discuss it, which is why we are discussing it today, because I think it has to be discussed.

What would be the effect on our satellites, both prompt and delayed effects on our satellites? How many of them would survive a high-altitude blast?

Dr. Wood, can you tell us how many would survive?

Dr. **WOOD**. It would depend quite critically, sir, on where the blast occurred, and the total fission yield of the blast. The satellites would die promptly due to gamma ray effects, so-called system-generated EMP, and

other satellites that were not necessarily even in the line of sight of the blast would die at a timescale of hours to weeks due to the so-called pumping up of the Van Allen Belts, the radiation belts surrounding the Earth, by the beta decay products from the fission products of the explosion.

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So the extent of the damage to satellites in space is difficult to say without specifics, but it was demonstrated by the U.S. in the Argus test series in the late 1950s that even very modest nuclear explosives detonated in the Van Allen Belts created large and enduring fluxes of radiation which are confidently expected to be of magnitude such that they would destroy satellites at low- to medium-level Earth orbits.

Mr. **BARTLETT**. Two satellites that would assuredly survive are the MILSTAR satellites?

Dr. **WOOD**. MILSTAR is deployed very far from the Earth, and it represents reasonably hard satellite technology, so MILSTAR—if any satellite survived, the MILSTAR satellites would probably be among them.

Mr. **BARTLETT**. But the other \$50 billion of our satellites are vulnerable?

Dr. **WOOD**. To varying degrees depending on their orbits, sir, they are vulnerable. The ones close to the Earth and in medium Earth orbit in the inner Van Allen Belts would be highly vulnerable to a nuclear explosion at most any location above the Earth's atmosphere.

Mr. **BARTLETT**. Let me ask one additional question, then I will save the rest. We are told that recent hardware procurements are waiving EMP-hardening. That adds on to our discomfort. Can you tell me that that is not true? We are told that we are now waiving both chemical and EMP-hardening because the ten percent roughly, maybe less than that, extra cost buys more weapons systems, and the budget is so tight that our military is making the judgment that they would rather have the more weapons systems than have the lesser number hardened. Is that true as far as you know?

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Mr. **JAKUBIAK**. Well, let me caveat. The answer to that question is that the systems that are waived-EMP go through a process of reviewing what the requirement is, where that system might be used under an EMP environment, and what the risk is associated with not having that EMP protection on that system.

Mr. **BARTLETT**. I understand.

Let me interrupt you just a moment, and then I will pass on because I don't want to consume all the time. At a hearing just like this when our field people were in here, I asked one of them how much of his capability would remain after an EMP laydown, and he told me, he told the committee, it is on the record, five percent. He would lose 95 percent of his capability with an EMP laydown.

Now, you know if that is true, I don't know how effective we are with five percent of our capability remaining, and, therefore, should we not look carefully at policies of procurement which waive EMP-hardening?

Mr. **JAKUBIAK**. I think one would have to look at his understanding of the EMP environment before you

make the judgment.

Mr. **BARTLETT**. Mr. Chairman, let me yield back.

Mr. **WELDON**. Thank you, Mr. Bartlett.

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Dr. **WOOD**. Mr. Bartlett, if I might respond very briefly to the hypothesis that you had in your question which I didn't speak to. Some might consider your suggestions with respect to EMP-based launches from the sea to be somewhat exotic, and along those lines I would just like to bring to the committee's attention the statement made by former Defense Secretary William Perry last Saturday speaking to the Nobel symposium in Stockholm and as quoted by the Associated Press. He said, quote, last year's India test ruptured the fragile barrier of the nonproliferation treaty. Not surprisingly, Pakistan quickly followed suit, and my expectation is that we will see Iran, Iraq, and possibly Syria go nuclear as well, end quote.

Now, the significance of this, other than pointing out that, hey, everybody is getting them as fast as they can, is that it has also been reported in *The New York Times* that the Iranians have been seen testing the launch of SCUD-type missiles from barges in the Caspian Sea, and so they are not waiting to develop ICBMs, Shahab-5 and so forth; that the CIA has publicly said they will likely have in well under a decade, they are looking to a possibility, one which was identified by the Rumsfeld Commission and tabled before the Congress, of shipping their short-range ballistic missiles presumably with weaponry of mass destruction in them as close to the U.S. as they can get in tramp steamers or barges or whatever and launching them from there.

This is not a conjecture anymore. They have been seen testing such equipment in the Caspian Sea.

Mr. **WELDON**. It is the intent of the Chair that we will finish the public section with Mr. Saxton. The three of us have to be at an event at 1:30. We need time to clear the room. So it would be the Chair's intent to reconvene at two o'clock. So I will turn over to you, and so if you will adjourn it—recess it at when Jim is finished, and then we will come back at 2:00 for the closed session, and then the staff will have a chance to clear the room.

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Mr. **SAXTON**. [Presiding.] Thank you, Mr. Chairman. First let me thank all of you for being with us today and for helping us understand the technical aspects of this very important subject. I would like to look at it from a slightly different angle for a few minutes, if we may. Let me begin by saying that earlier this week, the United States Commission on National Security for the 21st Century was here with us to present us with their report on phase one of their three-phase study. And, of course, in that report they draw some conclusions. And I found the conclusions very interesting because they, in part, go hand in hand with what we have been hearing from you this morning.

But there is a theme through their conclusions, and I would like to try to summarize that theme by reading part of their conclusions to you, if I may.

They say that America will become increasingly vulnerable to hostile attack on our homeland—a scary

thought and similar to some of the things that we have been hearing from you this morning—and our military superiority will not entirely protect us. States, our traditional adversaries as well as terrorists and other disaffected groups will acquire weapons of mass destruction and mass disruption, and some will use them.

And then they go on in another part of their conclusions and say, foreign crises will be replete with atrocities and deliberate terrorizing of civilian populations. The essence of war will not change. What will change will be the kinds of actors and the weapons available to them.

We talked about some of the weapons that are—that will be available to them. They include nuclear EMP. They include radio frequency weapons. It includes weapons used in cyberattacks, chemical weapons and biological weapons of warfare. All scary thoughts.

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And when I saw this theme running through their conclusions, it reminded me of something that I think about often, and that is the fact that in today's world we no longer have the luxury, if you will, of being able to identify our foe as we did during the Cold War. Funny thing to call a luxury. But in a sense at least it gave us a pretty clear idea of what we had to deal with.

But today, I think, at least beginning in the early 1990s when we demonstrated to the world that we had the kind of conventional capability which very few around the world can compete with, there emerged, I think, an enhanced determination on the group of people who want to influence world events through other means to use terroristic types of activities in order to accomplish those goals. They proved, for example, in Afghanistan that those kinds of guerrilla warfare tactics and terrorist tactics were pretty effective.

My question to you is can you help us understand with regard to radio frequency weapons which have been discussed here to some extent this morning, and, of course, EMP as well, what kind of capability this might offer in a nonstrategic—I don't know what we call it today. There is probably—as far as I know, there has not been a phrase termed or developed to really describe this issue—but in terms of terrorists, small groups of people, guerrilla-type warfare, what kind of capability and what kind of attack does this type of technology—what kind of capability does that give these other types of groups that are nontraditional types of adversaries? May I just ask each of you to respond? Dr. Wood, would you start?

Dr. **WOOD**. Very substantial capabilities, sir, to impose damage, and in some circumstances perhaps impose very considerable pain and even loss of life.

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The means for generating very large pulses, electromagnetic pulses, without nuclear explosives have been published in the technical literature for over three decades, and they are of the nature and scale that would suffice to attack in a very effective fashion an entire urban industrial complex like, for instance, greater New York City in an attack that, for instance, might be mounted from a light aircraft, privately-owned light aircraft.

It is obviously not appropriate to provide technical detail in open session, but I would be happy to expand on the possibilities in closed session. There is no point in coaching the bad guys. But the possibilities basically are very substantial ones.

We saw what could be done by incompetent amateurs with deadly intent in the Tokyo subway attacks using neurotoxins. Just a little bit more competence on the part of those people in dispersing the material that they had prepared, and instead of killing a dozen people and permanently injuring a couple of hundred, the likely casualty levels would have been about two orders of magnitude higher. They probably would have killed on the order of 1,000 people and crippled 100,000 just with the materials they had if they had used them in a more effective manner.

So the prospects for terrorists imposing really wide-scale damage by a variety of means these days are peculiarly potent, and EMP just happens to be one of the more technically advanced ways to do the job.

The low-tech stuff would be what was done at the World Trade Center. The story that Jim Woolsey, former CIA Director, relates there was that the guy who masterminded that particular attack was being taken by helicopter over Manhattan by Federal agents for arraignments, and one of the Federal agents pointed to the World Trade Center and said, it is still standing, and Ramsi Yosef said, yes, but if I had had \$5,000 more materials, it wouldn't be.

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If they had knocked over the World Trade Center, they would have killed 100,000 people. That is the super low-tech garden fertilizer approach. The medium-tech is the Tokyo subway approach. The high-tech way would be just to destroy the electronic and electrical infrastructure in large part over an entire urban industrial complex with an EMP weapon, a nonnuclear EMP weapon of the type that a very small terrorist group could build.

Mr. **SAXTON**. When you speak of a nonnuclear EMP-type weapon, are you referring more to the radio-frequency-type weapon-type situation?

Dr. **WOOD**. I would recommend, if it is agreeable to you, that we speak about this in closed session.

Mr. **SAXTON**. Any of you other gentlemen? Dr. Graham? Dr. Bernardin?

Dr. **GRAHAM**. You asked a question that is both very broad and very deep as to how we respond as a country and a society to the growing range of potential threats that we face at different levels.

Mr. **SAXTON**. Let me try to narrow it down because we are going to run out of time, and I didn't mean to ask that broad a question.

With regard to nuclear EMP and with regard to radio frequency weapons, are these effective weapons that can be used by small groups who want to effect political change?

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Dr. **GRAHAM**. Certainly they both, and the nuclear the most, can send dramatic messages to the U.S. We implicitly have an insular mentality, because it has been so long since we have been attacked to any substantial degree. I believe any kind of an attack against us which has either a major infrastructure, military, or population effect will have the same effect on our country as Sputnik had on our science and technology in

1957. It—1956, I guess. It will cause us to think about the world in a different way than we think about it now.

Mr. **SAXTON**. Could an individual or a group of individuals use an radio frequency weapon to, say, shut down significant parts of Wall Street?

Dr. **GRAHAM**. I would prefer to address the specifics in closed session, if that is all right. But certainly attacks against our infrastructure using radio frequency weapons as well as the possibility of the other threats that you mention is a definite possibility. Steps we can take, of course, to counter that are first to have a coherent, consistent national policy on how we are going to approach such concerns; second, on being able to tell if such an attack is, in fact, being mounted against us not just by our intelligence to anticipate it, but, when it is actually being put into effect, to be able to know what is happening; and then third, having plans to respond to it.

And I believe we can make a great deal of progress in each of those areas, and certainly some very careful thought in that is warranted.

Mr. **SAXTON**. Dr. Bernardin?

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Dr. **BERNARDIN**. I am a nuclear weapon expert and speaking on nonnuclear matters, nonnuclear type of weapons, I have limited knowledge. I know that both our laboratories have explored the technology in the past, both Livermore and Los Alamos.

Mr. **SAXTON**. Let me ask you a nuclear question then.

Dr. **BERNARDIN**. Okay.

Mr. **SAXTON**. Mr. Bartlett a short time ago asked the question about the Koreans potentially detonating a nuclear device off one of our coasts and what kind of damage that would do. Is it feasible in your mind that someone like Osama Bin Laden, who reportedly has a wealth of about \$7 billion, could acquire the necessary equipment, ships, SCUD missiles, to detonate such a device? Is that within the realm of feasibility?

Dr. **BERNARDIN**. I think it is within the realm of feasibility to acquire the launching equipment like a missile. Acquiring the special nuclear materials in order to fashion a nuclear weapon is something that the intelligence agencies would have to address.

Mr. **SAXTON**. You don't think he would buy one?

Dr. **BERNARDIN**. That is another possibility. A loose nuke is certainly a scenario that has been postulated.

Mr. **SAXTON**. Tough question, I understand.

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Dr. **BERNARDIN**. It is.

Mr. **SAXTON**. Mr. Jakubiak?

Mr. **JAKUBIAK**. The military has always looked at various scenarios, and that includes situations such as loose nukes appearing and being detonated over the U.S., and we play those scenarios in war games and see what the impact would be on military systems.

Mr. **SAXTON**. I am going to stop.

Dr. **WOOD**. Mr. Chairman, if I could just give a very brief personal example that ties some numbers to your question, last year a few of my colleagues and myself, as a demonstration along these lines, offered to take a vanload of equipment which we estimated would cost less than \$10,000 and go out and in a fashion that would be totally fingerprint-free destroy a government facility that cost about \$1 billion to build, could not possibly be reconstituted now, and would punch a very major hole in the national strategic capabilities, and do so at no risk to ourselves. And the equipment was specifically EMP weaponry. But it obviously didn't involve nuclear energy, and as I said, it packed into a rental van—I mean, an ordinary passenger van.

Mr. **SAXTON**. Thank you. We really have to stop because we have some people waiting for us at 1:30. But I have, as some of you know, been interested in this general subject of nonconventional attack by smaller groups for quite some time, and now the United States Commission for National Security for the 21st Century has come to the same conclusion. And this is very serious and something that we as a committee and we as a governmental institution and we as a society need to be more aware of and need to be able to deal with more effectively, and so I thank you for helping me to make these points in public. Thank you.

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Mr. **BARTLETT** [presiding]. I want to thank Mr. Saxton for joining us. He is not a member of our subcommittee, and we are very pleased that he is here with us because of his concern in this area. Because a number of our Members could not be here and are very interested in this, I would ask unanimous consent that the record be held open so that they can make comments or pose questions to which I hope you will give answers.

Hearing no objection, so ordered.

We now need to adjourn technically. We need to adjourn this because this is a hearing. The next event will be a briefing, and so a recess would not be appropriate. We need to adjourn this, and then we will reconvene at the briefing, our committee Chairman said, at two o'clock. This meeting is adjourned.

[Whereupon, at 1:32 p.m. The subcommittee was adjourned.]

APPENDIX

October 7, 1999

[This information is pending.]