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THREAT POSED BY ELECTROMAGNETIC PULSE (EMP) TO U.S. MILITARY SYSTEMS AND CIVIL INFRASTRUCTURE

House of Representatives,

Committee on National Security,

Military Research and Development Subcommittee,

Washington, DC, Wednesday, July 16, 1997.

The subcommittee met, pursuant to call, at 10:20 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. Before I get into the subject of today's hearing, I want to apologize to our witnesses and to the public for our lateness. We do have a Republican conference, which is still going on. That is why there is an absence of Republican members. They will be here as soon as the votes are completed for the leadership positions.

Second, I would like to thank the members of the subcommittee and the staff. We just completed our defense authorization bill recently. I was very proud of our subcommittee, primarily because we had pretty much unanimous agreement in the House on the priorities that we established. The best evidence of that was, we had no major amendments relative to the R&D funding levels and issues in the full committee or on the floor of the House, which I think is a testimony to the cooperation and foresight of this subcommittee.

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Along that line, we have taken great lengths to create an awareness among the members of our key issues through an aggressive set of hearings where we have had excellent attendance from members on both sides of the aisle; but particularly in the area of missile defense, I think the debate has reached a level that we have not seen, certainly in recent years, in the Congress. In fact, this subcommittee over the past 3 months has sent three separate publications to every Member of the House and Senate trying to raise the level of debate on the issue of missile defense and the threats that are out there.

These documents are public documents and they are available for people that would like to get them, but they are an attempt to continue to have our members be on the cutting edge of information relative to the threats that we have to deal with.

Today's hearing, to some extent, is a follow-on to that effort. Earlier this year, I believe in March, our subcommittee held a hearing, I think it was the first major congressional hearing on the issue of information warfare. Both in closed and open session, we went into great detail about the threats that are out there on the horizon, and they are here today relative to our information systems. To a large extent, I think what we are going to hear in closed and open session today is a follow-on to that hearing.

Our subcommittee meets to receive testimony today on the effects of electromagnetic pulse, or EMP, on our military

systems and civilian infrastructure. I have also invited the members of the Procurement Subcommittee to attend the hearing; and many of them have expressed interest, and I assume, will be here today, committee members who were invited to a June 26 classified briefing by representatives of the Applied Physics Lab at Johns Hopkins on the impact of electromagnetic pulse generated by a high-altitude nuclear blast.

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The subcommittee is meeting here today to explore in more detail EMP effects on our military systems and the civilian infrastructure, how confident we are that we can predict these effects, our potential vulnerabilities, what policies and practices guide our efforts to protect our systems, and the steps we have taken and can take to ameliorate these vulnerabilities.

EMP can be generated in several ways, but the widest effects are caused by a high-altitude nuclear blast, although we will ask questions about other than nuclear blasts causing EMP. All of us here understand that the threats posed to our military systems and civilian infrastructure by high-altitude EMP are not new. Atmospheric nuclear tests in the 1950's and 1960's revealed a number of then unanticipated results, including electrical and communications disruptions hundreds of miles from the test sites.

There may be, however, new dimensions in vulnerabilities that we need to look at more carefully. In the 1950's, electronic systems used vacuum tubes, not very sophisticated, but resistant to EMP. Today, computers with more and more microcircuits packed into smaller and smaller chips are key to the efficiency of virtually all commerce in the United States. These have much more computing power, but are also much more sensitive to disruption and more easily disabled by EMP. As our reliance grows, so does our potential vulnerability.

Likewise, potential military vulnerability may be growing. The revolution from military affairs has brought with it a much greater dependence on information technologies. The ability to generate raw data, process it into usable form, and communicate information to the right people and systems is critical to military success, yet the sensors, computers and communications assets essential to this revolution could be vulnerable.

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For example, 95 percent of our military communications go through commercial channels. Are we confident that EMP will not disable or disrupt these commercial communications systems? How confident are we that the military could continue to communicate effectively if commercial systems were disrupted or completely disabled by EMP? How thoroughly do we protect our weapons systems from EMP? Are we confident they will continue to function?

At the same time our vulnerabilities may be increasing, the subcommittee is worried about complacency in this area. It is true the cold war is over and the threat of a deliberate nuclear attack by Russia is much lower. That does not necessarily mean we have nothing to worry about. The proliferation of nuclear weapons and ballistic missiles continues. If we come into contact with a rogue nation in possession of just a very few nuclear weapons, perhaps just one, our adversary may or threaten to use one of those weapons to blind our military or to damage our economy or that of an ally.

Yesterday we invited the intelligence community to provide us with their most up-to-date material on EMP threats. We received documents that were 10 years old, interestingly enough, written at that time by a member of our staff, who now is an expert with us, Peter Pry, who at that time was with the agency and the expert on EMP.

We understand that no NIE has been issued on EMP since the 1980's, and this is 1997. We also understand that some of our EMP testing sets have been dismantled or are in disrepair.

I would like to welcome our witnesses today and thank them for taking the time and effort to help us understand the issues. Before I introduce our witnesses, I would add when we get the appropriate number of members, we will vote to close the session following the public statements, especially when our intelligence community is here to provide

testimony. At that point in time, we will go into more depth with our intelligence representatives here to talk about the threat analysis.

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But that will not come until we have the appropriate number of members of the subcommittee.

To talk about EMP effects, we have Dr. Gary Smith, the director of the Applied Physics Lab from Johns Hopkins University, and Dr. George Ullrich, Deputy Director of Defense Special Weapons Agency. To talk about the impact of these effects on our military systems and commercial infrastructure, we have Gen. Robert T. Marsh, U.S. Air Force, Retired, Chairman of the President's Commission on Critical Infrastructure Protection; the Honorable Gilbert Clinger, Acting Deputy Under Secretary of Defense for Space, and Dr. Lowell Wood of Lawrence Livermore Laboratory.

From the intelligence community we will have Dr. Osias, the National Intelligence Officer for Strategic Systems and Nuclear Proliferation; Dr. Jose Pina from the Central Intelligence Agency; and Dr. Nelson DeGangi from the Defense Intelligence Agency.

Gentleman, we welcome you. Before I open the floor to Dr. Smith, I would ask my friend and colleague, Mr. Pickett to make whatever opening statements he would like to make at this time.

[The prepared statement of Mr. Weldon can be found in the appendix on page 47.]

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

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Mr. **PICKETT.** Thank you, Mr. Chairman. I wanted also to welcome our witnesses here today.

This is an issue that probably has not gotten as much attention as it should have received. I know it is one that concerns everyone in this room and certainly on this committee. EMP is something that has tremendous adverse potential for our Nation as we move more and more into the electronic age.

I welcome the calling of this hearing by you, Mr. Chairman. I think it is way past the time we should have it. I look forward, as you do, to hearing from the witnesses today and also trying to understand what it is we can do from a policy standpoint to improve our Nation's capabilities to deal with this kind of phenomenon.

Thank you, Mr. Chairman.

Chairman **WELDON.** Thank you, Mr. Pickett.

With that, we will proceed to our two witnesses.

Dr. Smith, I turn the floor over to you.

STATEMENT OF DR. GARY L. SMITH, DIRECTOR, APPLIED PHYSICS LABORATORY, JOHNS HOPKINS UNIVERSITY

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Dr. **SMITH.** Thank you, Mr. Chairman. Thank you for the opportunity to testify before this subcommittee.

I am Gary Smith. I am the director of the Johns Hopkins University Applied Physics Lab.

Mr. **WELDON.** Can you move the mike a little closer to you?

Dr. **SMITH.** Thank you very much. The laboratory that I represent is located in Howard County, MD. Before I begin, Mr. Chairman, I would request permission to insert my full testimony into the record and to confine my remarks this morning to just a brief summary.

The Applied Physics Lab operates under about a dozen task order contracts with a number of major sponsors, covering between 200 and 300 separate tasks in any given year. All of our funding is derived from programs. We have no line-item support. About 80 percent of our funding comes from sponsors within the Department of Defense, and about 15 percent from the National Aeronautics and Space Administration. The rest of the funding comes from various Government departments and agencies.

Recently, as you know, Mr. Chairman, Congressman Bartlett asked me to advise him on the subject of this particular hearing, the electromagnetic pulse produced by a high-altitude nuclear explosion, and the implications for defense systems and capabilities and for the civilian infrastructure. My staff has completed a limited assessment based on a review of the literature, an examination of the basic tenets and interviews with responsible and knowledgeable professionals in the field. I am prepared today to present the results of that assessment.

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In short, we have found that the phenomenon is very real, as you have already stated, and is well understood by the nuclear weapons effects community; that our strategic systems and their command, control and communications infrastructure have been designed and built to survive and operate effectively in such an environment; that there would likely be pronounced effects on the civilian infrastructure from such a pulse; that the magnitude and extent of these effects is difficult even to estimate; and that it is probably not feasible to completely protect the entire infrastructure from the effects of such a pulse.

In this testimony, I will first consider electromagnetic pulse—or EMP, as it is called—phenomenology, and I will identify specific EMP-related vulnerabilities for ground system components of the civilian infrastructure. My full testimony discusses protection against EMP as well as nuclear threats to space-based elements of the infrastructure. It specifically reviews threat environments and the effects of prompt and delayed radiation exposure on satellite systems.

Due to the limitations of time this morning, I will not address those aspects in these remarks.

To begin with, electromagnetic energy is really invisible energy traveling in waves which is capable of doing useful work. Such energy exists throughout our environment, and the basic property allows such things as radio and television to work in a useful manner. But electromagnetic energy, even at low levels, can disrupt our lives if we are not careful.

For example, if we put a wristwatch too close to an electric motor, it may cause the watch to become magnetized and run erratically. Everyone also knows that computer floppy disks have to be kept away from magnetic fields or they can be erased or damaged.

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Figure 1, which my colleague, Mr. Ron Wiltsie, is illustrating, and which is also on page 2 of your copy, shows the basic phenomenology of an EMP event. The detonation of a nuclear weapon produces high energy gamma radiation that travels radially away from the burst center. When the detonation occurs at high altitudes, greater than about 40 kilometers, the gamma rays directed toward the Earth encounter the atmosphere, where they interact with air molecules to produce positive ions and recoil electrons called Compton electrons, after the man who discovered the effect.

The gamma radiation, interacting with the air molecules, produces charge separation as the Compton recoil electrons

are ejected and leave behind the more massive positive ions. The Earth's magnetic field interacts with the Compton recoil electrons and causes charge acceleration, which further radiates electromagnetic energy. EMP is produced by these charge separation and charge acceleration phenomena, which occur in the atmosphere in a layer about 20 kilometers thick and about 30 kilometers above the Earth's surface.

The area of the Earth's surface directly illuminated by EMP is determined entirely by the height of burst. All points on the Earth's surface within the horizon, as seen from the burst point, will experience EMP effects as depicted in figure 2, which is on page 3 of your handout. Note that a burst on the order of 500 kilometers in altitude can cover the entire continental United States.

Mr. **WELDON.** What strength burst would that be?

Dr. **SMITH.** It is not terribly burst-strength dependent; almost any burst will produce that kind of radiation. The strength of the field will change at the various radii from the burst point, but it will cover the same area regardless of the strength of the burst.

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The amplitude, duration and polarization of the wave depend on the location of the burst, the type of weapon, the yield, and the relative position of the observer. The electric field resulting from a high-altitude nuclear detonation can be on the order of 50 kilovolts per meter with a rise time on the order of 10 nanoseconds and a decay time to half maximum of about 200 nanoseconds. It is very fast.

A localized lightning strike, by comparison, 10 meters away, has a higher peak amplitude by about an order of magnitude, but it rises more slowly than the EMP peak, and therefore it may be simpler to protect against.

It is important to point out, however, that the peak amplitude, signal rise rate, and duration of the EMP wave are not uniform over the illuminated area; the largest peak intensities of the EMP signal occur in that region of the illuminated area where the line of sight to the burst is perpendicular to the Earth's magnetic field. At the edge of the illuminated area, that is, farthest towards the horizon as seen from the burst, the peak field intensity will be about half of the maximum levels, and the EMP fields will be somewhat longer lasting than in the areas where the peak intensities are the largest.

The EMP threat is unique in two respects. First, its peak field amplitude and rise rate are high. These quantities depend upon the rate of rise and the energy of the gamma ray output of the weapon. These features of EMP will induce potentially damaging voltages and currents in unprotected electronic circuits and components.

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

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Much of what we depend on today would be susceptible to EMP effects, both in the military and civilian infrastructure. An electromagnetic field interacts with metallic conductors by inducing currents to flow through them. A television antenna, for example, is a collection of metal conductors arranged to facilitate the induced current flow in the frequency range allocated for television broadcasting and to transfer the signal to the receiver.

Other conducting structures, such as aircraft, ships, automobiles, railroad tracks, power lines, and communication lines connected to ground facilities, also effectively serve as receiving antennas for EMP coupling. If the resulting induced currents and voltages, which can be large, are allowed to interact with sensitive electronic circuit and components, they can induce an upset in digital logic circuits or cause damage to the components themselves.

Ground facilities, for example, those housing the large computers central to the functioning of our financial systems, are typically nodes in a larger network and are connected to overhead or buried cables for power and communication. They are also connected to buried pipes for water supply and waste disposal and are typically equipped with communication antennas and distributed security systems of various types. All of these features can direct EMP energy into the facility.

Analyses and simulated EMP testing have shown that currents carried to a facility by long overhead or buried conductors can reach thousands of amperes. Shorter penetrating conductors can carry hundreds of amperes into facilities. Direct EMP penetration through the walls and windows of an unshielded building can induce currents of tens of amperes on illuminated interior conductors.

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

In summary, EMP introduces two collectively unique features to the overall picture of system susceptibility to nuclear effects. These features, taken together, distinguish EMP from all other forms, both natural and man-made, of electrical stress and response. First, stresses induced by EMP can significantly exceed those ordinarily encountered in system circuits and components and can thereby increase the probability of upset and burnout occurring in electrical and electronic systems. Second, EMP can cause this increase to occur nearly simultaneously over a large area, about one million square kilometers for a high-altitude burst.

These unique features, together with the lack of occurrence of EMP-like phenomena in the normal day-to-day environment, cause great difficulty in attempting to deal with EMP as a normal engineering problem. In particular, EMP can induce multiple, simultaneous upsets and failures over this wide area.

The coverage and levels that would ensue from an EMP attack are well understood. However, the overall effects on specific terrestrial systems are not as well understood. How much of the telecommunications systems would fail and for how long, how much of the power grid would be disrupted and for how long, how many cars would stop and/or would not start are things that are extremely difficult to predict.

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However, just consider what would happen if even a small fraction of the cars on the beltway stopped, and expand that to all the roads throughout the country.

It is also clear that the infrastructure, in general, has become more vulnerable to EMP because of the solid state technology proliferation and the increase in more sensitive components.

I hope that I have been able to give you an idea of the phenomenology associated with EMP and the qualitative effects on our civilian infrastructure. This concludes my statement.

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

[The prepared statement of Dr. Smith can be found in the appendix on page 51.]

Mr. **WELDON.** Dr. Ullrich, thank you.

STATEMENT OF DR. GEORGE W. ULLRICH, DEPUTY DIRECTOR, DEFENSE SPECIAL WEAPONS

AGENCY

Dr. **ULLRICH.** Thank you, Mr. Chairman. I am George Ullrich, the Deputy Director of the Defense Special Weapons Agency in the Department of Defense. I appreciate the opportunity to appear before you today on this important issue. I would like to briefly summarize my written statement, and I request that my full statement be made part of the record.

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Mr. **WELDON.** Without objection, all of your statements will be made a part of the record.

Dr. **ULLRICH.** I would be remiss if I did not point out the remarkable coincidence that exactly 52 years ago to the day, on July 16, 1945, the world's first nuclear device was exploded at Trinity site located on an isolated stretch of New Mexico desert in what is now the White Sands Missile Range. Among the team who witnessed that momentous event was Enrico Fermi, Noble Laureate, and perhaps the most brilliant of the Manhattan Project physicists. It has been said of Fermi that he was most likely the last of the 20th century physicists who actually knew all of the physics of his day.

I mention that because it was Enrico Fermi who first, and well in advance of the Trinity event, predicted that a nuclear explosion would generate strong electromagnetic fields and that they would occur over a large spatial domain.

In ensuing years, we have learned a great deal more about nuclear-induced electromagnetic phenomena, and in particular, about the phenomenon of high-altitude electromagnetic pulse, or as we have already referred to it, EMP.

To a layman, a nuclear explosion usually conjures up the image of a mushroom cloud representative of a burst at or near the surface of the Earth. Such a burst creates a variety of immediate effects, most prominently blast and thermal, which fall off rapidly with range, extending up to several miles from ground zero, depending on the yield.

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In stark contrast, high-altitude burst, detonated a few hundred kilometers above the surface of the Earth, has as its salient featured effect the ability to simultaneously bathe an entire continent in EMP. The ability of EMP to induce potentially damaging voltages and currents in unprotected electronic circuits and components is well-known. The immense footprint of EMP can therefore simultaneously place at risk unhardened military systems, as well as critical infrastructure systems to include power grids, telecommunication networks, transportation systems, banking systems, medical services, civil emergency systems and so forth.

Another potentially devastating, but less well-known effect of high-altitude nuclear bursts is the artificial pumping of the Van Allen belt with large numbers of electrons. The bomb-induced electrons will remain trapped in these belts for periods exceeding a year and in fact up to several years.

All unhardened satellites in low Earth orbit traversing these enhanced belts can be expected to demise from the total ionizing radiation dose in a matter of days to weeks following one such high-altitude burst. A knowledgeable adversary, armed with a few nuclear weapons, might seek to exploit any such perceived vulnerability, thereby severely degrading the significant U.S. technological advantage built on a foundation of sophisticated electronic systems.

This year's National Security Strategy for a New Century, issued by the White House, warns against the likelihood of an adversary using asymmetric means that avoid our strengths while exploiting our vulnerabilities.

To quote from the report, "Because of our dominance in the conventional military arena, adversaries who challenge the United States are likely to do so using asymmetric means, such as weapons of mass destruction."

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The mandate is clear. Hardening systems to the pervasive effects of high-altitude explosions must be part of an overall strategy to balance asymmetries and to disincentivize the acquisition and use of nuclear weapons by potential adversaries.

In keeping with your request, Mr. Chairman, I would next like to provide some additional details regarding the phenomenon of high-altitude EMP, how we protect against it, how we validate the hardness of military systems. I will keep this very brief, since Dr. Smith has already done a superb job on the details.

EMP is highly dependent on the gamma ray output of the weapon, as we have seen. The downward-streaming gamma rays collide with the air molecules, producing high energy electrons in a process called Compton scattering. The Compton electrons, in turn, interact with the Earth's magnetic field, producing an intense, coherent electromagnetic pulse that propagates downward to the surface of the Earth. The EMP effect encompasses an area whose perimeter is defined by the line of sight from the detonation point to the Earth's horizon. Any system within view of the detonation will experience some level of EMP.

For example, if a megaton class weapon were to be detonated 400 kilometers above Omaha, nearly the entire contiguous 48 States would be affected with potentially damaging EMP experience from Boston to Los Angeles, from Chicago to New Orleans.

The frequency range of the pulse is enormously wide, from below 1 hertz to 1 gigahertz, enabling the energy to simultaneously couple to individual electronic components, small components, larger system components, as well as distributed long-line conductors.

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One of our earliest experiences with high-altitude EMP dates back to the resumption of atmospheric nuclear testing in 1962 following a 3-year testing moratorium.

During that brief return to atmospheric testing, Starfish Prime, a 1.4 megaton detonation conducted over Johnston Island at an altitude of about 400 kilometers, proved that these effects could have wide-ranging impact on systems. The effects of EMP from the Starfish event were observed in Hawaii, 1,300 kilometers east of the detonation. Street lights and fuses failed on Oahu and telephone service was disrupted on the Island of Kauai.

We have recently learned that Soviet scientists observed similar disruptions following their high-altitude tests. In one test, all protective devices and overhead communication lines were damaged at distances out to 500 kilometers. The same event saw a 1,000 kilometer segment of power line essentially shut down by these effects.

Over the years, we have come to understand how to provide effective protection against the effects of EMP. The basic approach is to envelop the entire system with a integral metallic shield to exclude externally generated electromagnetic fields from the interior. Additionally, all mechanical and electrical penetrations through the shield must be protected.

For example, electrical penetration such as antennas and power connections must be equipped with filters and surge arresters. Windows must be coated with wire mesh or conductive coatings. Doors and utility ports must be sealed with conductive gaskets.

EMP hardening protocols are described in numerous military standards and handbooks. There are user friendly computer codes available to facilitate system hardness design. EMP is well understood.

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A particularly good news story is that EMP protection can be quite affordable. If EMP hardening is built in from the

start, the cost of EMP hardening is a relatively small fraction of the overall system's cost, approximately 1 to 5 percent. Done after the fact, when the unprotected system has been already fielded, it can be significantly more expensive.

To further explore cost reduction opportunities, my agency has an effort under way to develop integrated hardening techniques that provide protection against multiple hazards. Our initial work focuses on integrated protection against both high-altitude EMP and high-power microwaves.

For EMP testing purposes, the DOD currently operates a suite of simulators capable of large area, threat level field illumination. Also employed are direct current injection techniques and continuous-wave low-level illumination to evaluate shield integrity and energy coupling efficiency. While some EMP simulator facilities have been mothballed over the years, those that remain meet both present and projected customer needs.

To summarize, high-altitude EMP is real and well understood. We know how to harden to it—we know how to test it. High-altitude EMP hardening can be achieved at an affordable cost; I mentioned numbers of 1 to 5 percent.

On a final note, high-altitude EMP does not distinguish between military and civilian systems. Unhardened infrastructure systems, such as commercial power grids, telecommunication networks, as we have discussed before, remain vulnerable to widespread outages and upsets due to high-altitude EMP. While DOD hardens their assets it deems vital, no comparable civilian programs exist. Thus the detonation of one or a few high-altitude nuclear weapons could result in serious problems for the entire U.S. civil and commercial infrastructure.

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This is a topic that requires thoughtful attention, and I commend the committee for its interest in it.

Mr. Chairman, that completes my statement. I would be pleased to answer questions.

[The prepared statement of Dr. Ullrich can be found in the appendix on page 69.]

Mr. **WELDON.** Thank you. We appreciate that statement. If you two wouldn't mind, we are going to bring the other panel up and ask you to join them for questions. That way we will get all the testimony in up front and then begin the questioning, and then after that, get into some technical things we will go closed, and at that point in time, listen to our Intelligence Community.

I would ask our other three witnesses from panel two to come forward. We have Gen. Robert Marsh, U.S. Air Force, Retired, Chairman of the President's Commission on Critical Infrastructure Protection; the Honorable Gilbert I. Klinger, Acting Deputy Under Secretary of Defense for Space; and Dr. Lowell Wood from the Lawrence Livermore Laboratory.

Why don't you come over here with us where there is another——

Mr. **ABERCROMBIE.** While our witnesses are getting set up there, I observed that test, Mr. Chairman. I was on Oahu.

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Mr. **WELDON.** I didn't think you were born back then.

Mr. **ABERCROMBIE.** I surely was.

Mr. **WELDON.** You were a young child, right?

Mr. **ABERCROMBIE.** Don't I wish. I did want to say, it was the single most sobering experience in my life,

because it was, in effect, over Johnston Island, as our witnesses stated, and yet the entire sky lit up in Hawaii, even though it was hundreds of miles away, and there were all these disruptions and so on.

Mr. **WELDON.** Do you remember the disruptions?

Mr. **ABERCROMBIE.** That, I don't recall particularly, because everybody was more or less mesmerized by what happened. I think, in the aftermath, there were newspaper observations that were made. But I can tell you that anybody —I know exactly where I was. I know precisely the location on the hill and everywhere when the whole sky lit up. This was, of course, a fairly low-intensity explosion and it made me forever want to participate in some way in seeing that this weapon never got used by anybody for any reason.

Mr. **WELDON.** I thank the gentleman. Now you have that opportunity to follow through on that goal.

With that, we will turn to our distinguished panelists, and we will start with General Marsh.

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STATEMENT OF GEN. ROBERT T. MARSH, U.S. AIR FORCE, RETIRED, AND CHAIRMAN, PRESIDENT'S COMMISSION ON CRITICAL INFRASTRUCTURE PROTECTION

General **MARSH.** Good morning, Mr. Chairman and members of the subcommittee.

My name is Robert T. Marsh, and I am Chairman of the President's Commission on Critical Infrastructure Protection. I thank you for the opportunity to present my views about the potential of EMP effects as a threat to our critical infrastructures. My perspective arises from my service on the Commission established by Executive Order 13010 on July 15, 1996.

This is a joint Government and industry commission charged with assessing threats to our critical infrastructures and their vulnerabilities. The President identified eight infrastructures as our national life support system. They are: telecommunications, electric power systems, oil and gas transportation and storage, banking and finance, transportation, water supply systems, and emergency services such as medical, police, fire and rescue, and continuity of government services.

The first line of the Executive order says it all: Certain national infrastructures are so vital that their incapacity or destruction would have a debilitating impact on the defense or economic security of the United States.

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Our mission is to assess vulnerabilities and threats to the critical infrastructures, identify relevant legal and policy issues and assess how they should be addressed, and recommend to the President a national policy and implementation strategy for protecting critical infrastructures, and, in the process, propose any necessary statutory or regulatory changes.

There are two categories of threats to our infrastructures, physical threats to tangible property and threats of electronic, radio frequency, or computer-based attacks on the information or communications components of critical infrastructures. The Commission's report to the President scheduled for mid-October of this year will propose a national policy and implementation strategy to protect these critical infrastructures from both types of threats and assure their continued operation.

The EMP effects of nuclear weapons, as was noted earlier, were thoroughly studied and well understood during the cold war. At great cost, we hardened our strategic nuclear forces and our critical command and control systems against such effects. We built extensive special test facilities and tested these systems to assure their continued operation under attack.

Obviously, the nuclear threat from hostile nations cannot be dismissed today, but we consider it a remote possibility. Likewise, we consider a terrorist acquiring a nuclear weapon and positioning it at the high altitude necessary for the generation of an EMP burst that would debilitate our infrastructures to be a very remote possibility. Consequently, we are not considering any special measures to counter such a threat, though a high-altitude EMP attack could devastate the telecommunications and other critical infrastructures.

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We have also looked at localized radio frequency, or RF, threat innovations and discussed them with RF weapons experts. It is theoretically possible to develop such weapons, but to my knowledge their practicality has not yet been demonstrated. Even if perfected, RF weapons would be targeted at local installations with limited local effect. Nevertheless, progress in this area should be continually and actively assessed. If developments mature as some predict, we will have to address defensive measures.

In summary, there is much promise in this technology, but today I do not see any evidence that suggests capabilities seriously threatening our critical infrastructures.

The present likelihood of a terrorist obtaining a nuclear weapon is uncertain. But even if it happened, generating the high-altitude explosion required to produce a devastating EMP attack would be extremely challenging. There are many easier, less costly, and more dramatic ways for terrorists to use nuclear weapons than delivery to a high altitude. Such an event is so unlikely and difficult to achieve that I do not believe it warrants serious concern at this time. The administration's policy is to prevent proliferation and unauthorized access.

In conclusion, Mr. Chairman, I believe the threat of a major debilitating EMP attack generated by a nuclear weapon is remote at this time. This is also true of the more localized effects of RF weapons, although this area needs to be kept under surveillance and may warrant the development of countermeasures in the future.

This completes my statement, Mr. Chairman. I will be pleased to answer any questions later.

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[The prepared statement of General Marsh can be found in the appendix on page 79.]

Mr. **WELDON.** Thank you, General Marsh.

We will proceed to our next witness.

STATEMENT OF GILBERT I. KLINGER, ACTING DEPUTY UNDER SECRETARY OF DEFENSE FOR SPACE

Mr. **KLINGER.** Mr. Chairman and members of the committee, it is an honor for me to appear before this committee to address issues related to electromagnetic pulse and national security space systems. As you know, I am Gil Klinger. I am the Acting Deputy Under Secretary for Space with the Office of the Secretary of Defense.

I would note in passing that the Office of the Deputy Under Secretary of Defense for Space is the Secretary of Defense's principal staff assistant for space matters. In that regard, we are developing space policies and monitoring and overseeing the development of space architectures as well as acquisition of all DOD space programs.

Let me direct my opening remarks to EMP as it concerns space systems. Hardening guidance is established indirectly by national and DOD space policy and explicitly by the Joint Staff, and space systems are hardened consistent with that guidance.

In the past, national security space systems have been hardened to varying degrees, and that practice continues

today. The fact is that hardening all systems to the maximum possible extent carries with it significant cost implications in light of our assessment of current and projected threats.

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We are now studying a range of protection measures which will enhance the entire national security space constellation and its capability against any projected threat. This review will look at a range of alternative protection measures with cost as an independent variable.

The Joint Space Management Board, the senior level DOD and intelligence community body that reviews space matters, recently received and approved a comprehensive space protection study that was conducted by the Department of Defense space architect and the National Reconnaissance Office. Analysis and specific implementation is being planned of the recommendations contained in this study of current and projected issues.

We recognize the growth in the use of space systems by the Department of Defense and, moreover, the criticality of space systems in implementing Joint Vision 2010, the future blueprint for the conduct of U.S. and allied military operations.

In light of this potential massive use of space capabilities, both dedicated national security and supporting commercial space systems will require a review and study of critical infrastructure components within the overall critical infrastructure protection activities currently under way under the direction of General Marsh. For the space systems at issue, DUSD Space is heading this effort.

As Drs. Ullrich and Smith pointed out earlier, the most common usage of the term "electromagnetic pulse" refers to the complex radio frequency wave form generated by a nuclear device being detonated in the atmosphere. This is also known as high-altitude EMP, or HEMP. Spacecraft are far from an atmospheric HEMP event and are not damaged. The effects of HEMP on satellite ground stations, however, can be more disruptive, and those depend on a number of factors such as the altitude of the detonation, the distance of the ground station from the burst itself, and the design of the ground station in terms of the protections that it affords against HEMP effects.

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Another form of electromagnetic pulse that was previously discussed is system-generated EMP, or SGEMP. This effect happens only in a vacuum and when x rays produced by a nuclear device strike a satellite and displace electrons throughout the spacecraft. Obviously, the movement of these electrons has detrimental effects for the spacecraft components and its functions. The design and testing of military space systems for vulnerability to SGEMP effects is the responsibility of the individual program offices that are in the business of acquiring those space systems. Obviously, we oversee all facets of those acquisitions.

The adequacy of nuclear survivability features within the overall context of a program acquisition is also considered by the Defense Acquisition Board. For space architectures, these issues are developed by the Department of Defense and NRO architects and are also brought before the joint space management board. Again, as part of our ongoing space protection efforts, we will be looking explicitly at the issue, with its cost kept in mind as an independent variable.

I now would like to spend a few moments discussing radiation-hardened microelectronics. The radiation effects discussed earlier are the result of natural and man-made sources. Natural sources include cosmic rays, charged particles trapped in the Van Allen belts, as well as solar flares which are a feature of solar meteorology.

DOD satellite systems must be designed to survive much more severe radiation environments induced either by hostile actions or by operating in high ambient radiation orbits. For example, the global positioning system is one such system that must tolerate these high levels of naturally occurring radiation. Especially designed and manufactured electronic components used in these systems are termed to be radiant heat hardened or simply rad hard.

In December 1996, an integrated product team reported to the Under Secretary of Defense for Acquisition and Technology on the industrial base that designs and manufactures rad-hard components. The IPT found the following: There is an insufficient commercial business base to support a rad-hard industrial capability. The Government, and primarily DOD, is the principal customer in this niche market. Second, Government investment in advanced radiation hardening technology is adequate at the moment, but there is insufficient funding for transitioning these technologies to wide-scale production.

Finally, Government and industry competency has decreased as the industry downsized, predominantly as a function of the end of the cold war. The IPT's rad-hard strategy was to generate economies of scale by providing the seed money for rad-hard parts development and production, thereby assisting the manufacturers to remain in the business while they develop a non-DOD market inasmuch as commercial space system providers also have an interest in some level of radiation protection.

The IPT specifically recommended: first, establishing a DOD level group to oversee and coordinate DOD investment in radiation hardened electronics with a companion interagency coordination group; second, funding an annual radiation hardened investment program at the $60 million to $70 million level of investment; and, finally, creating a graduate level initiative to train more electrical engineers in radiation hardening technology.

In May 1997 the Under Secretary of Defense approved the IPT's recommendations and directed a DOD-wide initiative implementing them. We will update the committee on the implementation of the DOD rad-hard initiative and the progress in creating an interagency coordination mechanism.

All of these issues become more important as DOD transitions to great dependence upon commercial satellite systems to provide cost-effective and affordable ways of meeting mission requirements. We are studying this issue in conjunction with both U.S. Space Command and the NRO. The vulnerabilities of both national security and supporting commercial assets will have to be taken into account. To the extent we migrate critical space functions to commercial providers, we will need to focus on protection and negotiate appropriate hardness levels as part of the acquisition for these programs.

Mr. Chairman, that completes my statement, and I would be pleased to respond to any questions that you have.

[The prepared statement of Mr. Klinger can be found in the appendix on page 86.]

Mr. **WELDON.** Thank you very much for your statement.

Dr. Wood.

STATEMENT OF DR. LOWELL WOOD, LAWRENCE LIVERMORE LABORATORY

Dr. **WOOD.** Thank you, Mr. Chairman.

I appear before you today as an independent technical expert who has worked for the past three decades in both the offensive and defensive aspects of EMP. I am not necessarily representing the positions of the Lawrence Livermore National Laboratories where I work, and I request that my prepared statement be included with my testimony.

Mr. **WELDON.** With unanimous consent, all of your statements will appear in the record.

Dr. **WOOD.** Electromagnetic pulses, EMP, generated by high-altitude nuclear explosions have riveted the attention of the military nuclear tactical community for three-and-a-half decades since the first comparatively modest one very unexpectedly turned off the lights over a few million square miles in the mid-Pacific. This EMP also shut down radio stations, turned off cars, burned out telephone systems, and wreaked other mischief throughout the Hawaiian Islands nearly 1,000 miles distant from ground zero.

The potential for even a single high-altitude explosion of a more deliberate character 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 for 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 detail studies of the post-nuclear-attack recovery process. When essentially nothing electrical or electronic could be relied upon to work, even in rural areas far from the blast, it appeared surpassingly difficult to bootstrap American national recovery, and post-attack America in these studies remained stuck in the very early 20th century until electrical equipment and electronic components begin to trickle into a Jeffersonian America from abroad.

For obvious reasons, the entire topic of EMP was highly classified and associated congressional oversight was generally circumspect and conducted entirely in closed session. Indeed, this is the first even partly open session of congressional oversight devoted to the EMP topic which I recall, and I congratulate you, Mr. Chairman, for the extraordinary vision and dedication to bedrock aspects of the Nation's security which this morning's hearings betokens.

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The third century following the high-altitude test in the early 1960's saw the expenditure of 5 billion present-day dollars by Defense Special Weapons Agency and its predecessors to develop a detailed working understanding of EMP and its consequences for both our own and our adversaries' military hardware systems. Substantially larger sums were expended by other components of DOD in order to express this understanding as military force in being, primarily to defend especially vital military equipments against EMP's destructive effects. You have heard excellent summaries of these effort from Drs. Smith and Ullrich.

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 most major military hardware and systems, especially those not considered vital to the conduct of strategic nuclear war, were not hardened against EMP much at all. As a result, at the present time our national profile of vulnerability to EMP attack is highly uneven, with large parts of our military machine and virtually all of the equipment undergirding modern American civilization being utterly EMP vulnerable.

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

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Indicated responses to any EMP attack then were clear. To be sure, the maximum Soviet capability to impose such attacks still exists 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 watch the ongoing diffusion by purchase and by illicit routes, at least as much as by indigenous development, of nuclear weapons technologies throughout the Third World. At the same time, we are compelled to acknowledge the unique opportunities for defeating both advanced U.S. forces abroad and the American Nation itself which are offered to our adversaries by EMP-centered attacks.

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

There arises the regrettably real prospect that EMP weaponry, assuredly if it is nuclear and perhaps even if nonnuclear, could abruptly transform a future Desert Storm type operation from another historic victory to a memorable American defeat. Such EMP weaponry could also be deployed with only slightly more advanced means from space to rip up the electrical and electronic infrastructure in the American homeland.

Thus, the de facto national policy of nakedness to all of our potentially EMP-armed enemies takes on ever more the character of national scale masochism. It is perverse, irrational, and assuredly not necessary or foreordained. It is therefore most heartening to see the Congress engage this issue for most of corporate DOD has seemingly resigned from it.

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With respect, Mr. Chairman, by their recent accomplishments in protecting military and national systems from EMP, not by their undoubtedly splendid policies, their ringing declarations, and their glowing promises for the outyears, should DOD efforts in EMP defense work be known to you and to your subcommittee.

For the sake of America's future in a nuclear multipolar world, I appeal most earnestly to you and your colleagues to remain seized of this vital issue, one of the few which, in and of itself, carries the potential of major military victory or defeat, perhaps even of national well-being or devastation.

Thank you, Mr. Chairman. I will be pleased to respond to questions.

[The prepared statement of Dr. Wood can be found in the appendix on page 94.]

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

If we could bring back our other two panelists from the first panel, we will begin our first round of questions and we will continue with the questioning of these two panels until such time as we get into classified answers, and at that point in time if we do not have a quorum, we will adjourn the public hearing and then I will convene a classified briefing with all of our panelists, including those from the intelligence community. But I would like to keep as much of this in the open for as long as we can, until we get into more sensitive areas.

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First of all, I want to thank you all for coming in and appearing. Excuse my ignorance, but up until this year I really didn't know that much about EMP, and it was largely because of the effort of the gentleman to my right and your left, who encouraged me to take a closer look at what EMP—he himself is a physicist and worked at Johns Hopkins—am I correct?

Mr. **BARTLETT.** Physiologist.

Mr. **WELDON.** A physiologist, OK—and worked at the Johns Hopkins Center and is constantly pushing us, as are other more technical Members of Congress, to look at things that perhaps we haven't looked at in a thorough enough manner. And we have had a couple of classified briefings.

I would ask our physicists especially on the panel to respond because they are the experts. You say that an EMP burst would occur at an altitude of 250 miles? Is that the appropriate or optimum altitude for an EMP burst to take

place? Is that correct, Dr. Ullrich?

Dr. **ULLRICH.** There is no particular optimum. Of course, it depends on yield. You can get EMP at altitudes ranging from 50 kilometers on up.

Mr. **WELDON.** Say I wanted to lay down an EMP over the United States. You said in your testimony maybe 250 miles; is that correct?

Dr. **ULLRICH.** Yes, you would want to be at about 300 or 400 kilometers, 250 miles, and you would be in the megaton class yield. That would probably put a damaging contour, at least the potential for disruption, out to the periphery of the United States.

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Mr. **WELDON.** What would that megaton yieldage range be?

Dr. **ULLRICH.** Let me just say 1 to 2 megatons.

Mr. **WELDON.** 1 to 2. Would the other physicists agree with that assessment?

Dr. Wood.

Dr. **WOOD.** That is certainly a very reasonable estimate. The only remark I would make, in putting that into context, is that component of the Soviet missile force which is believed to be primarily oriented to laying down EMP attacks on the United States had a warhead which was more in the neighborhood of 10 megatons rather than 1, sir.

Mr. **WELDON.** So 1 to 10 would be a range that——

Dr. **WOOD.** One is certainly sufficient to do very much the damage as Dr. Ullrich suggested. I would suggest that the 10 megatons was insurance on the part of Soviet planners.

Mr. **WELDON.** At a 250-mile altitude, that would pretty much cause damage in the United States of the type that you talked about which would include our power systems?

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Dr. **SMITH.** It would put fields that were sufficiently strong to cause potential disruption. The actual disruption is not something that we can estimate with certainty.

Mr. **WELDON.** Well, would you say with a fairly high degree of certainty that we would have impact in our utility systems and our communications systems?

Dr. **SMITH.** Yes.

Mr. **WELDON.** Would you agree?

Dr. **WOOD.** Sir, we have substantial impact on our communications and utilities systems from solar magnetic storms which impose far, far lower fields on the long transmission lines and communications systems than, you know, are involved in EMP. And so there would undoubtedly be impact. I believe that Dr. Smith and Ullrich would agree with me that it is difficult to forecast in detail exactly what the impact would be at any specific point.

Mr. **WELDON.** How about automobiles? We mentioned that before because of the use of microprocessors and all. Do we have any studies done on the impact on automobiles and vehicles?

Dr. **WOOD.** Because of exactly what you said, sir, the fact that modern automobiles are very semiconductor- and microprocessor-intensive, the likelihood that they would suffer catastrophic damage so that they could not operate is much larger than it was back in the sixties when some automobiles, at least in anecdotal reports, were shut down due to the Starfish explosion. These were automobiles in the Hawaiian Islands.

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Dr. **ULLRICH.** If I might add, the fact that all of these systems depend on complex electronic subsystems and components certainly makes them vulnerable. But even commercial products in many cases have a certain amount of protection devices built in. There is the concern of electromagnetic interference, and some of the fixes there are similar to what you would do to protect against EMP.

So I think it is premature to say that every car would go belly up under these kind of field conditions. It is certainly safe to say that there is a threat for upset and damage, but I think it is very difficult to predict system response to these kind of insults.

Mr. **WELDON.** I think a couple of you have alluded to the fact that this type of EMP burst would not necessarily have to be nuclear generated, that there are, in fact, efforts under way that have used nonnuclear sources; is that correct?

Dr. **WOOD.** Nonnuclear sources would necessarily involve much smaller aerial coverage, sir, simply because there is so much available energy in a nuclear explosion to convert to electromagnetic form. Systems that were powered, for instance, by conventional explosives would have correspondingly much smaller coverage areas. Damage within those smaller areas could potentially be as severe.

Mr. **WELDON.** I guess the frustrating thing for me in trying to understand, having been briefed by a number of physicists—and I also consulted with physicists at the University of Pennsylvania and Drexel University privately before this hearing, and I might say that all the physicists that I talked to are in general agreement about the impact of EMP and what it would cause, is our assessment of the potential for this type of thing to occur either at the United States or that would impact the United States, and I would like to get into that, because there I see some contradiction, at least in my own mind, among the statements that have been brought before us today.

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Believe me, I know this issue is also getting the attention of the Speaker of the House. In fact, at about 3:45 p.m. today he wants me to bring over as many of you as I can get to brief the Speaker personally on this issue. Roscoe has talked to the Speaker about this, and he is personally concerned about the issue. So it is going to get more and more attention in this Congress, I can assure you.

But let me say, anyone who knows my record, I don't think that the threat of an all-out Russian attack is higher today. I think the concern of an accident is there, and I think what really concerns me are the rogue nations, not necessarily the terrorists, and I don't see that being brought out in the testimony. And, General Marsh, I am going to get into your statement in a moment.

I want to ask you all to respond, as physicists and as policy people. If I am the commander of North Korea and I have one nuclear weapon and that weapon is in the range of 1 to 10 kilotons, which I assume it is, and if I have the capability of a Nodong or Taepodong 2, system which I assume can reach an altitude of 250 miles quite easily, General Marsh—at least that is the testimony that has been give to me—and I want to do something to hurt the United States, I think the weapon of choice is to launch that device in the air and wipe out our smart capability and then dare us to respond, because we haven't killed anyone, we haven't hurt any buildings, and we, being a moral Nation, what is our President going to do? Is he going to set off a nuclear strike against North Korea, when they have not killed one person in this country, but it would devastate our entire infrastructure? That is what concerns me.

And maybe I am reading your statement wrong, but your statement appears to me at least—and correct me and say that I am totally wrong—but I believe it appears to me to dismiss it and say that I believe that the threat of a major attack is remote at this time.

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And I compare and contrast it to the statement made—I guess it was the statement made by Dr. Ullrich, where he says, as outlined in the National Security Strategy for a New Century—I am quoting him—the White House, May 1997: Our national military strategy also emphasizes the importance of responding to asymmetries. That is unconventional approaches that avoid or undermine our strengths while exploiting our vulnerabilities.

Well, that to me is what EMP is. Here is a White House document in May of this year coming out and saying this is a major concern for us, and, to quote from the report, it goes on to say, because of our dominance in the conventional military arena, adversaries who challenge the United States are likely to do so using asymmetric means such as weapons of mass destruction, and—to continue to quote—to preserve our technological advantage as DOD develops radiation hardened systems and tests them to assure survivability, end quote. Which leads me to believe that it is being taken seriously by DOD.

And then I go on to read the testimony, which I have done, of retired general—Lt. Gen. Robert Schwitzer, who testified before Congress on June 17, and let me read part of his statement into the record. I quote: To help set the stage, recognize, with experts like a former NSA Director, that we are the most vulnerable Nation on Earth to electronic warfare. This thought is echoed by a former CIA Deputy Director and a former Deputy Attorney General who forecast that we will have an electronic Pearl Harbor if we do not accept a wake-up call. Our vulnerability arises from the fact that we are the most advanced Nation electronically and the greatest user of electricity in the world, end quote.

Now those statements seem to be pretty strong indicators that we need to look at this issue seriously and understand. And the only thing I would say, General Marsh, I would ask to provide for the record the appropriate backup intelligence assessments that support the conclusion that the likelihood of this occurring here is remote.

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When we asked the intelligence community to respond and give us their assessment, as I told you, the two documents they sent to us were 10 years old. In fact, they were written by our staffer who worked for the CIA at that time. It indicates to me, in their sending information over in preparation for this hearing, nothing has been done of substance by the intelligence community in a written report form in the last 10 years. At least, they didn't send it to us and we asked for it.

So I would ask you to respond to what appears to me to be a contradiction in the potential severity of the threat of EMP on this Nation.

General **MARSH.** Well, Mr. Chairman, in response, I am not challenging that EMP would have very devastating effects if employed. So that is not the question. I am saying that the employment is, in our judgment, very remote, and even in the scenario of the North Korean, to put a high-altitude missile of any kind over the central part of this country at 250 miles, to me, seems to be quite an extension of practicality.

Mr. **WELDON.** And all I would say in response, would you provide for the record in a classified context the intelligence information to back up that statement?

[The information referred to is classified and is retained in the committee files.]

General **MARSH.** I can attempt to do that, Mr. Chairman. I am not sure that I can get anybody to foreclose any

possible scenario, but I believe I can support it being a remote possibility.

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Mr. **WELDON.** But the point I am making, general, is we usually respond to threats based on national intelligence estimates and what the intelligence analysts see as emerging threats around the world. And I have just written, in fact, to the head of the CIA to ask why we don't have an updated NIA on this issue.

But my point is, you have made a pretty strong statement and all I am asking for the record is to give us in a classified setting the appropriate backup intelligence documentation to back up your assertion. That is all.

General **MARSH.** Yes, sir.

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

Mr. **PICKETT.** Thank you, Mr. Chairman.

We seem to have quite a range of opinions here on this issue, and our role in this is trying, from a policy standpoint, to make sure that appropriate action is taken on behalf of our Nation to do what is realistically doable in the economic and technological environment to protect ourselves against the results of EMP. And I suppose this is a very broad question, but from a policy standpoint, what needs to be done today, in your respective opinions, that is technologically feasible and economically realistic to do to counter the EMP threat to our Nation that is not now being done?

Dr. Smith, we can start with you and go down the line.

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Dr. **SMITH.** At this point in our understanding of the phenomenon and its effects, my recommendation would be to—if, in the judgment of the Congress and the administration, this threat deserves increased attention, the attention should be devoted to tests and analysis to try to understand better what the impact would be before we embark on any kind of corrective measures.

Mr. **PICKETT.** If I just make sure I understand this, because I am not a scientist and you are probably talking way over my head, but you are saying that we know that there is a certain phenomenon that we can identify but what we don't know is what the actual impact may likely be if, in fact, it develops?

Dr. **SMITH.** Yes, sir, that is it exactly.

Mr. **PICKETT.** Thank you.

Dr. Wood.

Dr. **WOOD.** Sir, the basic point is that essentially all of our conventional military capability and all of our civilian infrastructure is highly vulnerable to EMP damage. The dollar numbers in the civilian infrastructure alone can be conservatively estimated at several trillion dollars' worth of infrastructure which is at risk potentially even from a single pulse—several trillion dollars. So the Congress might properly or appropriately be minded to engage the issue on the basis not only that defeat of our conventional military forces but a very, very profound economic damage to our civilian infrastructure is possible.

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And what I would suggest as a particular policy initiative, if there was to be only one, would be the mandating of

the assessment, the quantitative assessment, of the EMP vulnerability of major national systems, both civilian and military. Just go out and measure how vulnerable these systems are so that you have numbers to inform the subsequent debate with respect to what should be done about it.

Mr. **PICKETT.** So you are coming down pretty much where Dr. Smith has come down on what we can do from a policy standpoint?

Dr. **WOOD.** It is certainly feasible, I believe, from a policy standpoint to mandate the measurement of the levels of vulnerability in both civilian and military systems. Once you know that, then there doesn't have to be this groping in the dark sort of problem that I believe we face at the present time of how much is at risk and how great is the problem involved in fixing it.

We will find that some of our problems, as was implied in Dr. Ullrich's statement, can be fixed very cheaply and very quickly. We will find in other things that we may care about, a lot are quite difficult to fix, and we will then be able to face up to our vulnerabilities and face up to the costs involved in fixing them, but doing so in an informed fashion.

Mr. **PICKETT.** All right.

Secretary—I am sorry; forgive me; I can only see part of your name.

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Mr. **KLINGER.** I have been called infinitely worse in the Pentagon.

I would emphasize two things before giving you a substantive response. One is that I am not a physicist. I am, in fact, by background a policy person. The second is that my comments will really be focused on the space part of the business of the Department of Defense, not on other defense activities and most assuredly not on the broader civilian infrastructure. So that I would couch the boundaries for the comments I will make.

I think there are a couple of things that have to be kept in mind here from a space perspective. We are a work in progress. We have several hundreds of billions of dollars of ground infrastructure and space systems on orbit right now, tens of billions of dollars' worth of systems that are somewhere in the pipeline.

The design freezes for at least many of these systems occurred in the middle of the cold war. Indeed, as the committee is aware, most of these systems were optimized for a conception, a set of circumstances that now have, at least to some degree, either ceased to exist entirely or whose complexion has changed dramatically.

In other words, as the committee is aware, many of our space systems were optimized to operate in an environment in which, once the nuclear threshold were crossed, it would be crossed willfully and not by accident and crossed on a massive scale, not by a rogue nation, and not by accident.

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Therefore, a lot of our space systems, the good news is, are very hard against a lot of these threats; as I mentioned in my opening statements, less so for the ground segments, but again it depends on the specific system.

And yet what has happened? We are in a very difficult stage, which is a transition from operating, building, acquiring, and designing systems that have to make the transition from maintaining compatibility with the systems that are on orbit to adapt to a world that has changed fairly dramatically.

I am not making excuses for those vulnerabilities that exist, and there are some, but the fact of the matter is that the Department, those authorities responsible for policymaking and acquisition with regard to space, are cognizant not only

of the threats associated with the EMP phenomenology you heard discussed earlier, but in fact we have to place that discussion in a much broader context, which is bounded by two things. One is very heavy constraints on the amount of money that is available to spend on space systems; second is that EMP is one of a range of potential threats with which our space systems have to contend.

The committee is aware, Mr. Weldon, you made mention earlier about the potential of information warfare threats. That is a whole panoply of threats that we have to contend with, and, quite frankly, from an acquisition standpoint, from a policy standpoint, we are charged with a difficult responsibility, which is doing our best to assess the nature of the threats, how real those threats are, quite apart from their technical feasibility, and then taking a look at the amount of resources that we have to spend against the various threats that we agree are credible and are the most likely or, as Dr. Wood points out, whose downside consequences are so dramatic, so catastrophic, that even at a low level of probability we must do something against them.

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Now, I would emphasize, with regard to DOD space systems and with regard to the EMP effects you have seen discussed here, you have heard discussed here, my assessment is that we are in reasonable shape. Our space systems are hardened precisely because many of them were designed to operate and pass nuclear command and control information in the very scenario which was the massive nuclear exchange scenario of the cold war. Other systems, that is not the case because their intended use was not designed to obtain in those circumstances.

And, again, when we talk about the communications segments themselves, as well as the ground systems that support those satellite systems, it depends on the system. But this is neither—I would emphasize from a policy perspective, this is very much not an all or nothing situation; it is very much a situation in which, regardless of the threats that we consider, we gauge what we do against our best assessment, and one can call it—the cynic would say it is a guess.

Hopefully, it is a well-informed guess, based on our best intelligence estimates, the best inputs of our engineers and physicists, what is the most likely threat? What are the downside consequences? How much money is available to address them, given that those same moneys have to be expended to provide on-orbit capabilities? And that presents us with a series of tough choices.

As I mentioned in my opening statement, I believe it is a good news story that the Department and the intelligence community have recognized that we must take a much harder look at the security and protection of all of our space systems against the full range of threats, hence the overall study that was just done by the two architects and for which specific implementations will now be carried out.

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In addition, from a policy perspective, we will be developing an explicit DOD space system protection policy, coordinated with General Marsh's activities, coordinated throughout the Department. So there is a lot of activity going on.

I believe that we are taking the prudent set of steps in the national security space area to try and fix those areas that we believe need remedial attention, continue those practices that have made sense up to now, and, in fact, try and cope with the new environment in which we operate.

Mr. **PICKETT.** Thank you.

General Marsh.

General **MARSH.** Sir, the catastrophic effects of nuclear weapons are not new to this Nation. We have grappled with them in the past, and we have chosen the path of deterrence, and we, in the face of the tremendous expenditure

that would have been required to provide asset defense of the Nation and its critical assets, we have decided best to prevent the occurrence and we have put all of our energies and treasure to that purpose. That worked, and it worked very successfully.

And I recognize that there is the possibility of a rogue nation or, for that matter, a rogue terrorist group attempting to perform an EMP attack. I think that is very, very remote, and I would say if we have the treasure to put to this problem, even though it be very, very remote, we ought to prevent it from happening. We ought to deny the access to those rogues and do everything possible to prevent such a happening, rather than to undertake the almost unthinkable task, in my judgment, of protecting against this very, very severe threat, protecting all of our systems.

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And I say that in light of many other vulnerabilities that we need to be concerned about in our systems, and we have vulnerabilities to a full spectrum of threats that need attention, need serious attention by this Nation. I view the EMP threat as being at the uppermost and most remote corner of that threat spectrum.

Mr. **PICKETT.** You are the chairman of the President's Commission on Critical Infrastructure Protection, General Marsh, and you have heard the statements made by Dr. Smith and Dr. Wood about the policy direction they suggested as a way to begin the congressional involvement in this process, and that is to try to identify and quantify the potential impacts of an EMP attack, if I am correctly paraphrasing you, Dr. Smith and Dr. Wood. Would you concur with that view?

General **MARSH.** Sir, I haven't thought a lot about that. I don't quarrel with any—in fact, I strongly support any rigorous vulnerability analysis of our systems as they incorporate more and more of advanced electronic technology. I think we have to have a continuing vulnerability assessment under way and point to the type of measures that ought to be undertaken to cope with those vulnerabilities. I would not focus it exclusively on EMP if I had that choice.

Mr. **PICKETT.** I understand there are other threats, and I noticed that the report of your Commission is scheduled to go to the President in October of this year.

General **MARSH.** Yes, sir.

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Mr. **PICKETT.** And that report will deal, not exclusively but to some extent, with the EMP threat?

General **MARSH.** The full range of threats as we see them; Yes, sir.

Mr. **PICKETT.** Thank you.

And Dr. Ullrich.

Dr. **ULLRICH.** Mr. Pickett, I believe the Department has acted responsibly in the past in dealing with nuclear survivability issues related to military systems. Many of our systems are hardened to operate in these type of environments. However, most of us have had most familiarity in dealing with this peer adversary threat.

I do believe, as pointed out by the chairman, that these new nuke type scenarios in regional conflicts deserve scrutiny, and I think we need to place renewed emphasis and ask the questions of what systems are really expected to operate in these kinds of environments and assess as to whether or not they can do so.

Likewise with civilian infrastructure, before we undertake any expensive fixes, I think the first requirement here is to do an assessment, is to understand what protection mechanisms that are already built in, how they might play against this new environment, and what additional things might ought to be done. So I think some network analysis

would be in the offing before we declare that the sky is falling and before we pronounce that everything will demise.

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Mr. **PICKETT.** Do you want to comment on that?

Dr. **WOOD.** If I might just very briefly, Mr. Pickett, to follow up on that and to extend slightly my previous recommendation to quantitatively assess what our vulnerabilities are.

I think it would be very valuable to, in the same process, task a red team of experts to look at the results of these vulnerability analyses and see how easily different adversaries of different classes of our country might possibly exploit those vulnerabilities. Is it easy? Is it hard? Is it available to 3 nations or 10 nations or 20 nations? How much would they have to spend? And so forth.

One of the striking things that came out of the 1995 Defense Science Board Summer Study on the Revolution of Military Affairs was that while we Americans might have to spend something of the order of $10 billion a year to bring about the revolution, that very effective counters to American capability that would be gained through the Revolution of Military Affairs could be gained by Third World major regional powers for perhaps $1 billion a year. That is to say, their leverage in economic terms against us was as large as 10 to 1.

This summer study, in which I participated, also found that one of the most striking responses that a major regional superpower can make to an American force projection was the use of EMP to counter a U.S.-led expeditionary force. It was not among the most remote possibilities that the Defense Science Board considered; it was among the most likely.

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Mr. **PICKETT.** All right.

Then, finally, Mr. Chairman, if you will just allow me one other item here.

Mr. Klinger, you stated in your testimony that, for example, electromagnetic pulse policy and standards are established by the Office of the Assistant to the Secretary of Defense for Nuclear and Chemical and Biological Defense Programs. Is that a person we should hear from on this committee to gain additional insight into what action may be taken in the Defense Department with respect to EMP?

Mr. **KLINGER.** Sir, I can only answer that and give you a personal opinion about that. When it comes to nuclear matters in general, especially the technical matters associated with nuclear weapons and their effects, that office has the lead responsibility within the Office of the Secretary of Defense. That individual is currently Dr. Harold Smith.

Mr. **PICKETT.** Thank you very much, gentlemen. And thank you, Mr. Chairman.

Mr. **WELDON.** Thank you, Mr. Pickett.

And before I turn to our colleague, Mr. Bono, Mr. Pickett, on your line of questioning—well, I will pick that up when we go to our second round.

Mr. Bono, I will turn it over to you now.

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Mr. **BONO.** Thank you, Mr. Chairman. I appreciate you calling this hearing, and I am pleased that we have a chairman who looks, to use your word, at indicators. I think that is the key word. There are so many times, if we look at history, where we haven't paid attention to indicators, and it has been very costly, and we have a chairman that stays

on top of that and sometimes displays more knowledge about equipment and things than those that inform us, and I think that is to his credit and makes me feel very comfortable.

I feel the same way he does about looking at indicators, and I think that if we don't pay attention to indicators and follow up, that that is where we will be most vulnerable.

Excuse me if I am elementary on EMP, because I am, and I don't have really any knowledge, so if I can ask just a basic question. You refer to EMP in conjunction with space. Is this a weapon, if you will, that can only be used in a space-type circumstance?

Anyone? Mr. Wood? Mr. Smith?

Dr. **SMITH.** Well, I think the effect that we have been talking about is largely a space-based effect, yes. And as has been mentioned by other of the people at the table, there are other ways in which electromagnetic pulses can be generated. It is not only required that the explosive be discharged in space, but to have the kind of global reach to have the kind of coverage, geographic coverage, that we are imagining, in fact, it has to be a high-altitude burst.

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Mr. **BONO.** In the situation of a war, if somebody wanted to employ it under those circumstances, like the war in the Middle East, could they pull out EMP and use that as an aggressive weapon or as a defensive weapon to knock out some of the smart stuff that we have?

Dr. **SMITH.** Ground air bursts also produce electromagnetic pulses, but they are of more limited geographic extent.

Mr. **BONO.** But that could happen?

Dr. **SMITH.** Yes, sir.

Mr. **BONO.** That is a possibility?

Dr. **SMITH.** Yes, sir.

Mr. **BONO.** Mr. Wood, did you want to comment?

Dr. **WOOD.** The particular scenario that you just raised, Mr. Bono, is one of very real concern, because in those circumstances, very modest, very short-range rocketry could be used to loft a nuclear explosive over our forces in a force projection situation and impose preferential EMP damage on our forces before they had engaged adversary forces. So there in a sense, are the exceptions.

The only type of capability that is at all advanced would be a small nuclear explosive. You are not interested in covering an entire continent, but rather than stretching 4,000 kilometers, you might only be interested in EMP damage over 400 kilometers, which is a major theater of operations. And in those circumstances, quite modest nuclear explosives on very modest rockets, Scud-type rockets, would suffice to potentially impose very severe damage—as I said in my opening statement, the damage sufficient to make the difference between American victory and American defeat in the military sense.

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There is also the prospect, as Dr. Smith has alluded, to using nonnuclear means.

Mr. **BONO.** I am sorry?

Dr. **WOOD.** To using nonnuclear means of generating very strong electromagnetic pulses over much more restricted areas, and those potentially operate not just above the atmosphere but deep down in the atmosphere. They are the type that might even be deployed from small civilian planes.

Mr. **WELDON.** Would the gentleman yield on that point?

Mr. **BONO.** Yes.

Mr. **WELDON.** When we get to the classified session, you can ask about the status of weapons held by adversary, nations including Russia, in this area. Is there anything you all can say on the public record about what we know the Russians do have now?

Dr. **SMITH.** I am not informed on that, sir.

Dr. **WOOD.** The information which has been published by the Department of Defense on the Soviet military threat, sir, indicated that there were more than a dozen Soviet SS–18 ICBM's which carried large unitary warheads in the 10 megaton class that were believed to have the primary function and military role of conducting an extremely severe military laydown.

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Mr. **WELDON.** I was talking about battlefield capability.

Mr. **BONO.** I guess it is nonclassified. We are all aware that Russia is extensively involved in R&D. I was just wondering whether they have included researching or perfecting EMP as part of their R&D program that they are involved in now.

Dr. **WOOD.** They have known about it for every bit as long as we have, sir, and their basic capabilities, intellectual capabilities, and so forth, are in every sense peer ones relative to we Americans.

The technology base on which they operate is well known to be grossly inferior. On the other hand, because of that inferior technology base in many areas of military technology, they have been inclined to be much more innovative and looking toward breakthrough sort of approaches. These have often come a cropper, but every once in a while they have come up with something that represented a very large advance relative to what we expected.

Mr. **KLINGER.** I think the only thing I would add: We see a lot of reports which obviously we are monitoring on a fairly intense and close basis, as is the intelligence community, about what capabilities were in various stages of development within the Soviet Union and what is still available and the state of those capabilities. There is a tremendous amount of uncertainty about a lot of these things.

Yes, sir, much of my experience is that much of the physics, as you have heard, is well understood. Our experience base is more limited. Our knowledge of effects is more limited. Our knowledge of what the Soviet general staff may have actually taken from the blackboard to operational, fielded, military capabilities is far more limited, far more limited. And thus far, the promises and advertising, which unfortunately is what we frequently see coming out of the former Soviet republics, at least with regard to space systems, has not been backed up by reality. That is not to say they don't exist, but they have not been backed up.

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Mr. **BONO.** Most of the questions that I want to continue with, I guess, should be classified.

I share the chairman's concern that when we have indicators of this nature, that we do not look at these as closely as we can and employ whatever we have to employ as a defensive mechanism, because I am new to this committee, but

prior and still before in committee, I have served on a task force under the chairmanship of Mr. Saxton, and the chairman again used the word "unconventional" warfare. And it seems logical that if they do not have the dollars that we do, and we bring out this big equipment, the B–2's and what-have-you, that if they can find a way to immobilize all of this big stuff, that they are going to focus in that area rather than spend a lot of money on hardware.

And in that committee, we found a tremendous amount of activity that is going on in more of a covert line. And to not accept that as a projection for the future in warfare I think would be a big mistake on our part.

I would hope, as the chairman does, that we would pay far more attention to this unconventional activity and defensive activity that is going on to neutralize the kind of dollars and hardware we are spending.

And I thank you, but I would like to go into this more when we do get into closed session. Thank you, Mr. Chairman.

Mr. **WELDON.** I thank my colleague, and before turning to Mr. Reyes, I would say, just to set the record straight for our witnesses who may think we are looking at this in a vacuum, it was this subcommittee along with the procurement subcommittee that held a lengthy hearing on the issue of information warfare. We heard testimony from, I believe it was Duane Andrews, among others, who chaired the Defense Science Board on that issue, and his recommendation that we should spend $3 billion of additional resources on information warfare above what the President has asked for.

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This subcommittee did begin in a very small way to address that concern by plussing up the request in the information warfare technology area by $88 million in the authorization bill. That is not much, but it is a recognition of the fact that we have to provide more assets than we are currently providing in response to the administration's own analysis.

With that, I will turn to Mr. Reyes.

Mr. **REYES.** Thank you, Mr. Chairman. I don't have any questions for the public portion of the hearing.

Thank you.

Mr. **WELDON.** Thank you.

Mr. Bartlett, who really is the instigator of this initiative. And we have also been joined by our other physicist in Congress, Mr. Ehlers, who is not a member of this committee but who we are happy to have with us.

And at the appropriate time, Mr. Ehlers, we will give you time for questions.

Mr. Bartlett.

Mr. **BARTLETT.** Thank you, Mr. Chairman.

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I would first like to start by trying to get a consensus on some of the fundamental concerns. First of all, it is my understanding that EMP is an unavoidable consequence of a nuclear detonation; is that correct?

Dr. **WOOD.** At high altitudes, sir, is where the effects are particularly striking.

Mr. **BARTLETT.** Well, the effects are always there, except at a ground burst, the area of incineration is roughly the

same size as the area of EMP laydown, and so you are not much concerned about EMP laydown if everything has been incinerated because it is just line of sight.

It is my understanding that about 500 kilometers, a 1-megaton burst would lay down an EMP blanket over the entire contiguous 48 States that at the margins—that is at San Diego and Maine—that we would have about 10-kilovolts of energy, that that gets increasingly higher as you come near the ground zero point, which would be, if it were optimized—it would be over what, northeastern Nebraska would be the detonation site?

Dr. **SMITH.** Yes, sir, except it is 10 kilovolts per meter field strength.

Mr. **BARTLETT.** That field strength is adequate to cause what kind of damage in which of our systems? Dr. Wood.

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Dr. **WOOD.** Ten kilovolts per meter is where you begin to see substantial damage in all kinds of unprotected semiconductor systems, sir, both civilian and military. This is not to say that you won't see it at much lower field strengths, but I don't know of any major military system that has ever been tested unhardened that hasn't suffered widespread damage at 10 kilovolts per meter of EMP equivalent.

Mr. **BARTLETT.** If we are looking at our civilian infrastructure, what does this 10 kilovolts per meter do to our power grid, for instance?

Dr. **SMITH.** I don't think that we can honestly say what the effect will be in any given area. We know that there will be large currents, there will be large voltage gradients induced. These will cause some disruption in power systems, but the extent and the duration of these power outages I don't think we have a good handle on, Congressman.

Dr. **WOOD.** Sir, this is primarily—the uncertainty Dr. Smith referred to is primarily due to the fact, of course, that we have had no large-scale EMP imposed on power systems. We have, however, had God's EMP, which is associated with very severe solar storms. The modulation of the Earth's magnetic field by interaction of the solar wind during those storms causes the low-frequency, or mimics the low-frequency components of EMP, and those are widely reported. For instance, the Federal Power Commission reports that those have resulted in widespread outages, and the magnitudes of upset that induced those outages are known.

And so there is a little bit of a handle from a little bit of data in the real world that indicates that time varying magnetic fields on scales of tens to hundreds or, for that matter, thousands of kilometers of very low amplitude are sufficient to cause the protective equipment in electric power systems to trip out.

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Whether or not that equipment reconnects the power system is dependent on circumstances. But there have been large-scale blackouts associated with especially severe solar storms in this country in the past couple of decades.

Mr. **BARTLETT.** And what is the magnitude—what is the equivalent energy level in these storms as compared to EMP from the weather?

Dr. **WOOD.** Very small compared to a megaton burst, sir. The time varying magnetic fields are tiny fractions of egals per second. And these are much, much smaller than are calculated to be associated with megaton bursts over the central United States. They are orders of magnitude less than are calculated to occur.

Mr. **BARTLETT.** So at very low intensity levels, we have had some meaningful disruption of our power systems from naturally occurring activities; and so one would suspect there would be very widespread impact on our power grid with the detonation of a one megaton weapon, for instance?

Dr. **WOOD.** Those are the formal documented projections, sir, yes.

Mr. **BARTLETT.** What about the effect on our communication system? Is it more or less vulnerable than a power grid?

Dr. **WOOD.** It has become exponentially more over the last decades, sir, as our communications systems have come to depend on integrated circuits of smaller and smaller physical dimensions.

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The integrated circuit density that we see at the present time is nearly a factor of 10,000 greater than it was just a quarter century ago, and that basically says that the vulnerability of the individual devices have increased correspondingly. There is reason to believe that the semiconductor-based portions of our communication system, which is to say essentially all of it, would be extremely EMP vulnerable. Measurements done on individual systems certainly support that projection.

Mr. **BARTLETT.** What date was the Johnston Island detonation?

Dr. **ULLRICH.** I think it was 1962, in July.

Mr. **BARTLETT.** To what extent were we using microelectronics then as compared to now?

Dr. **ULLRICH.** Well, the circuits at that time were substantially different than what we use today and that, in fact, is part of the difficulty in using old data and part of the difficulty in assessing infrastructure systems like power grids.

Power grids can use technologies dating back to the early 1900's, all the way up to the present. It is a question of how updated it is. It is very difficult to make an overall assessment and pin it to a specific number.

Mr. **BARTLETT.** Is it not true that a vacuum tube is one million or so times less susceptible to EMP effects?

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Dr. **ULLRICH.** Absolutely. Vacuum tubes are inherently hard to these kind of effects.

Mr. **BARTLETT.** If we had some meaningful disruption of communications in 1962 with the technology then in use in our communications systems, would we not expect today enormously more disruption from a burst of similar size?

Dr. **ULLRICH.** That is certainly possible. Again, one has to go back to the details of what actually was disrupted and what the circuit mechanism was.

I think there possibly is reason for optimism on the telecommunication grids, with a trend toward fiber-optic. But still, you know, you are dealing with repeater stations that involve power and involve electrical signals. So certainly there is still difficulty even if we took that path.

But I think there is reason for optimism. The power grids, however, are more difficult.

Mr. **BARTLETT.** I just want to reemphasize what you said, that the fiber-optic in and of themselves are immune to this effect. Wherever you have switching and control and so forth, you now have microelectronics and those are vulnerable. So the fact you are transmitting the signals through a nonsusceptible medium really doesn't do much.

Dr. **ULLRICH.** The point I was trying to make is there is the potential certainly for hardening these repeater

stations, along the lines of the protocols that we have developed for military systems. You can isolate them but if you have too many of them, it gets to be a big cost factor. The fiber itself is, in fact, immune to the effect.

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As you pointed out, you reconvert to an electrical signal at these repeater stations. But there is a potential for isolating those vulnerabilities and potentially fixing them. That is my point.

Mr. **BARTLETT.** Yes, sir.

Dr. **WOOD.** Dr. Ullrich's point is a very important one. Even back when we depended on copper landlines for our strategic war communications systems, those systems were made and tested under quite realistic circumstances. It would be very hard with EMP and other effects by well-known approaches and techniques.

The most obvious one is burying the switching stations and so on well underground and making sure the portals to the surface were well-designed and well-maintained.

So it is feasible, in principle, to make communications systems, even the national communications infrastructure, quite hard. But the processes and techniques are generally not employed. They add slightly to cost, so it is not represented much in current civilian infrastructure.

It would be relatively straightforward in a lot of cases to harden, however, as Dr. Ullrich has implied. It is technically feasible to do so, probably not at great cost.

Mr. **BARTLETT.** It is my understanding the rise time of this initial pulse travels at the speed of light, so it is essentially instantaneous over the country. The rise times are in nanoseconds, billionths of a second. Do we, in fact—two questions relative to that. One, do we have the ability to simulate those pulses so that we can, in fact, effectively test?

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Dr. **SMITH.** Yes.

Dr. **ULLRICH.** There are several EMP simulators that are currently operational and are capable of meeting the frequencies and intensity levels (i.e., peak electric field in volt/meter) that are representative of those pulses.

Mr. **BARTLETT.** To what intensity level?

Dr. **ULLRICH.** I don't have the number with me right now. I could provide that for the record.

[The information referred to can be found in the appendix beginning on page 119.]

Mr. **BARTLETT.** It is my understanding we used to have more test facilities. A major test facility has been shut down?

Dr. **ULLRICH.** Yes, that is the case.

Dr. **SMITH.** I think we are getting into classified areas, Congressman.

Mr. **BARTLETT.** We will proceed with that in the classified area.

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I need to ask one more question in open session. I would presume that an airplane would function as a pretty effective antenna and in coupling with these forces. Conventionally manufactured airplanes, I would suspect, are inherently susceptible?

General **MARSH.** Yes, sir.

Mr. **BARTLETT.** One would expect if there was a 1 megaton burst producing 10 kilovolts per meter of energy U.S. wide, that would affect all planes which are in the air?

Dr. **WOOD.** Yes.

Mr. **BARTLETT.** Would you expect them to fall out of the air?

General **MARSH.** I wouldn't expect it to fall out of the air.

Mr. **BARTLETT.** If all of their control mechanisms were disabled, what would you expect them to do?

General **MARSH.** I can't answer precisely, Congressman. I would expect the avionics to be considerably disrupted, severely disrupted; and that would obviously influence the ability to land and—depending on what they had for navigation capability and so on, it would be very, very disruptive.

But you are right. As we tested our advanced airborne command posts, the 747's, to make them EMP hard, we found that we had to make very significant investments in order to do that. So that says to take a commercial airplane and make it EMP hard is a major undertaking. They are soft in that sense.

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

Dr. **WOOD.** Sir, for reasons of safety having to do with large-scale electrical system failures, most civilian passenger airliners can be flown by hard wire and control cable, physical control cable. So, for instance, landing gear can be lowered by a hand-cranked gear system; and the control surfaces, although they are extremely difficult to operate, can be operated by very strong and determined pilots. This has been demonstrated in emergency circumstances on a number of occasions.

It is probably clear that if this attack occurred at night that most of the planes, most of the civilian airliners in the air, would be lost for obvious reasons. They simply won't be able to land. They won't have landing aids, probably no lights on landing strips and so forth. Those would be lost.

Many that were aloft in a daytime attack could probably be landed with a great deal of determination and good fortune on the part of the crews.

But, as has been remarked, military aircraft that are considered to be EMP hard not only have to have a great deal of work done on them but they have to be tested on a regular basis. The Air Force operates DNA and the Air Force operates major test facilities that can, for instance, encompass even an entire B–52; and the qualification of those systems against EMP hardness is considered a very major one by Strategic Command.

Mr. **BONO.** Would you yield?

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Mr. **BARTLETT.** And then I have one more comment and will yield totally.

Mr. **BONO.** In that same context, would that knock out the computers in the—it would knock out all the computers, so wouldn't that affect more than just the landing capabilities?

Dr. **WOOD.** Yes, sir. It is a reasonable projection that most, if not all, modern computer systems exposed to referenced EMP field levels—which are 50 kilovolts per meter, not just 10—but the very high levels you might see in most of the United States—most modern computer systems ranging from laptops to mainframes would wilt. By wilting, they would at least cease to function. In many cases, they would be burned out. So it would require very major maintenance before they could be restored to operation.

Not just computers in aircraft but computers everywhere, other than in this type of very high integrity metallic enclosures that Dr. Ullrich sketched in his opening statement. Computers in any other enclosure than that type would be compromised, if not destroyed outright.

Mr. **BARTLETT.** Just one other comment, Mr. Chairman; and then I will yield.

In a large city like Washington, DC, hundreds of thousands of homes on any one day, there is a very, very small percentage of those that burn. Yet none of us would sleep well tonight if we had not paid up our fire insurance premium on our home.

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Using this analogy, we are not even close in this country to even considering whether or not we should buy insurance against this kind of potential disaster, let alone coming to the point that we are willing to make the necessary investment and insurance premium payment. I think that kind of analogy is a reasonable one.

General Marsh, there is not much probability your home will burn tonight, but I bet you have a fire insurance policy on your home. There is not a large probability that we are going to have an EMP laid down over our country, but the probability is certainly not zero. I would submit that, in terms of relative probabilities, we are more likely to have that as a Nation than the probability that your home will burn tonight.

We as a Nation need to have the same kind of security, confidence, that comes from you having a fire insurance policy on your home. We need to have the equivalent of that in our Nation, and we are not even talking yet about whether or not we should go out and search for an appropriate policy. I think that is where we are, and I am very pleased that we are having this hearing today.

Mr. **WELDON.** Thank you.

Ms. Sanchez.

Ms. **SANCHEZ.** Thank you, Mr. Chairman.

Having read quite a bit on this and having had some of you come in to talk to me about it, I have several questions, but probably best left to—of a sensitive nature that are best left to a closed session.

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I will at this point yield over my time and move on, hopefully.

Mr. **WELDON.** Thank you.

Mr. Pappas.

Mr. **PAPPAS.** No questions.

Mr. **WELDON.** Mr. Chambliss.

Mr. **CHAMBLISS.** Thank you, Mr. Chairman.

Not being a physicist and not knowing much about this, I am here to listen and learn. I appreciate the opportunity to ask questions, but I have none at this time.

Mr. **WELDON.** Thank you.

We have a distinguished guest with us, the physicist from the Science Committee, Mr. Ehlers. Do you have any questions?

Mr. **EHLERS.** Thank you, Mr. Chairman. I appreciate the opportunity to ask a few.

I am not a member of this committee, as you know, so if I ask any improper questions, you can—that is what I am asking. I have another meeting I am supposed to be at, so I will not be able to stay for the closed hearing.

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I haven't looked at EMP for a long time, and I hope you will forgive me for being behind the times on this, but am I to understand that you are saying that the pulse could be generated by a high altitude explosion of any nuclear weapon? Or would it have to be a specially designed weapon to provide the magnitude of pulse you are talking about?

Dr. **WOOD.** Sir, any nuclear weapon of the type that is stockpiled anywhere at the present time will generate high altitude EMP simply because some finite fraction of the order of percent of its output will be in the gamma rays that drive the pulse, as Dr. Smith and Dr. Ullrich extremely ably described it in their opening statements.

Specially designed types of nuclear weaponry might put out large fractions of their total yield in the form of gamma rays and thus would be correspondingly more threatening as sources of EMP. Equivalently, very low-yield nuclear weaponry that was specially designed could have the same EMP implications as megaton class ordinary weaponry.

Mr. **EHLERS.** To get the magnitude you are talking about, 10 kilovolt per meter at the fringes of the country, what size convention weapon would you need for that?

Dr. **WOOD.** Convention nuclear weapon, one megaton class would impose field strengths of at least 10 kilovolts all over the continental United States. The actual field strengths would be more in the neighborhood of 20,000 to 50,000 volts per meter, not 10. And as the fringing fields.

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Mr. **EHLERS.** As you mentioned earlier, God's impact on EMP was the solar effect. What about lightning? How does that compare in magnitude to something like this?

Dr. **WOOD.** At very close ranges, sir, at 10-meter distances, you can see electric field strengths on the ground which are comparable to or larger than EMP. But, of course, very few pieces of either military or civilian equipment operate within 10 meters at ground level of a lightning stroke.

Also, the frequency characteristics—we are talking about just magnitude. The characteristics of lightning, it is a much lower frequency than EMP; and the threats that it poses to equipment operation have a rather different character.

Mr. **EHLERS.** Now, the 10 kilovolt per meter figure, has that been verified experimentally? Or is that based on your calculations?

Dr. **WOOD.** No, sir. Those field strengths were measured in the Pacific tests. The measurements were sporadic. They weren't nearly of as detailed a nature as people would certainly have liked to have had even a few years afterwards, but the advent of comprehensive test ban precluded future measurements.

The calculations of models have been built up by special weapons. The Defense Special Weapons Agency and its predecessors over the last three decades have reproduced the Pacific high altitude test phenomena very well; and these modeling capabilities have also been well exercised and validated in underground nuclear tests, some of a very realistic nature, which have been conducted since then.

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Mr. **EHLERS.** At what altitude were those tests conducted?

Dr. **WOOD.** The Pacific tests, sir, were altitudes of 100 to several hundred kilometers. The simulated altitudes and underground nuclear experiment circumstances varied from levels of a few dozen kilometers all the way out to very high altitude equivalents, well in excess of 1,000 kilometers.

Mr. **EHLERS.** Is there something unique about the higher altitudes that enhances the effect or is it simply you are high enough to have a line of sight to a larger region?

Dr. **WOOD.** The latter.

Mr. **EHLERS.** Which countries would be capable of doing something of this sort?

Dr. **WOOD.** Any country that potentially owns a single World War II level nuclear explosive, sir.

As Dr. Ullrich pointed out in his opening statement, the EMP effects are not strongly dependent on the yield of a nuclear explosive. While megaton class definitely delivers larger output than kiloton class, any country that owns fission nuclear explosive weaponry potentially has these capabilities. It is necessary, of course, to get the explosive device to altitudes of 100 to a few hundred kilometers in order to get really widespread effects in order to be able to cover large regions.

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But if you are concerned, for instance, with a military theater of operations somewhere in the Third World, you don't need to go to 5,500 kilometers or 300 kilometers. You can get the effects you are interested in very satisfactorily by detonating your device at a 100 kilometer altitude. Because you are interested in, for instance, attacking American forces without doing a lot of EMP damage to your own territory.

Mr. **KLINGER.** I need to emphasis at this point, from a space perspective, acquisition of the capability to detonate a nuclear device is one thing. Getting it to the altitudes, even 100 kilometers we are talking about here, much less higher, is a different matter altogether.

We are reminded every time NASA or the Department of Defense launches a satellite that, to a great extent, this is an art as much or more than it is a science. It has taken us 30-some-odd years to get to the point where we are the preeminent space-bearing country in the world. Yet, as we saw earlier this year when we tried to launch GPS satellites using the Delta rocket, which has an unparalleled record of success, we had a detonation—we had a malfunction detonation and the loss of the satellites and nearly had significant damage to the launch pad.

Launching rockets into space is not a trivial matter technologically and goes directly to the issues that some of us were discussing earlier with regard to how we judge the threat associated with a high altitude EMP burst and the threat that that poses, independent of the downside consequences.

Dr. **WOOD.** With respect—the ability to launch rockets into space was one which was extremely massively demonstrated by the Nazis in World War II. The V–2 rocket, which they launched, flew into space over 2,000 times in the process of targeting allied forces in England.

The Soviets took the V–2 engineering crew to the Soviet Union, and they started cranking out in the early 1950's several generations of rockets which are now known to the world as Scuds. Those rockets have been sold very extensively throughout the Third World to the point that even, if you will, a rinky-dink power like North Korea is capable of indigenously producing rockets which are imminently satisfactory for launching not only conventional payloads but nuclear trajectories that go into space.

The Scud rockets used by the Iraqis very effectively, as terror weapons in Operation Desert Storm, flew to altitudes of 150 kilometers, which is imminently satisfactory for the type of regional EMP laydowns I have been referring to.

The Iraqis succeeded in launching not only 80 rockets—79 rockets that landed on or near targets, but they succeeded in launching them at extremely high rates with a very high rate of success. Over 90 percent of all the launches they attempted were successful.

They succeeded, in one particularly striking set of launches, in launching seven of them nearly simultaneously within a time window of 10 minutes. Each of these rockets flew into space. They achieved apogee altitudes of about 150 kilometers. One of these rockets could have carried a nuclear explosive of a kiloton class yield into space and, in particular, detonated it over our forces.

So while I can agree with Secretary Klinger that the very high-tech time of launches that we attempt to do in the United States, particularly launches of spacecraft that survive for long periods of time in deep space and so forth, are still fraught with peril, unfortunately, the Soviet-developed and proliferated capability for Scud-type launches is extremely widely proliferated through the Third World at the present time. Scud-type rockets exist in copy to the extent of over 15,000 Scud class rockets owned by over 30 nations in the world at the present time. So getting to the threshold of space and carrying a nuclear explosive there is something that, unfortunately, is a regrettably potentially widespread—maybe actually widespread capability.

I remind you that, in August of 1995, the director of the Iraqi special weapons projects defected to Jordan and stated—he happened to be Saddam Hussein's senior son-in-law, since deceased—but he stated in a press conference in Amman, Jordan, in August 1995, that his nation had been on track to have Scud-deliverable nuclear weapons by April 1991.

We went to war with Iraq in January, 1991, and finished our business with them in February as far as hostilities were concerned. His program was on track, he said, to produce more than one Scud-deliverable nuclear warhead 2 months after Desert Storm was completed.

That was, I respectfully suggest, a very close call. They went to war too early, in other words. But he stated that his nation was on track to have the ability to deliver nuclear warheads by Scuds in the spring of that year.

So these are things that we have to keep in mind, not just as very remote possibilities but as things that, in the distinctly foreseeable future, we may have to actually face.

Mr. **KLINGER.** In fact, to add, I would keep a number of other things in mind then.

A number of those Scuds broke up in midair. It is one thing to launch a terror weapon, one that has a nuclear front end on it. Presumably, the party launching it has a vested interest in not only launching it but making sure it detonates not over their own territory but reliably over their intended target.

The point being, this is not nearly as simple a matter as some would imply. Further—I fall back to my previous statement—it is one thing to have a delivery capability; it is another thing to be able to demonstrate the capability, a real, life-threatening capability to detonate a high-altitude nuclear burst over the United States. There is no question that this is a threat over which we are concerned, but the essence of the importance of part of this issue is perspective.

Mr. **BONO.** If the gentleman will yield.

Dr. Wood, I guess what you are saying is it—there is a little contradiction here in that——

Dr. **WOOD.** There is a difference of an opinion.

Mr. **BONO** [continuing]. A difference of opinion that we really don't have to—it really doesn't require as much sophistication, as I understand was being said—as what Mr. Klinger is stating.

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Compounding that, wasn't a Scud fired from a truck that just traveled wherever it wanted to go? When it wanted to hide, then it just fired and did a considerable amount of damage. Would that be the case in this situation with EMP?

Dr. **WOOD.** Scuds are almost invariably fired from mobile launchers, sir. That, of course, is the thing that made it so difficult for us to eliminate the Iraqi Scud-launching capability, is because they tended to pop out of hiding, erect, launch, and pop back into hiding before our strike fighters could localize them and kill them. We didn't have any confirmed kills of Scud-launching capability during Operation Desert Storm, in spite of having flown 8,000 sorties that were specific against Scud launchers.

The launching capability, however, is perhaps not the one that Secretary Klinger was keen on. I don't mean to put words in his mouth, but he was pointing out the obvious concern that—do you want to take your first nuclear weapon you have ever got, stack it on top of a Scud and launch it and hope your firing circuitry and everything else and so forth works and works the very first time out and works without a lot of prior testing? So do you want to really do that?

Hey, that is certainly not something I would ever recommend to my Government, but my Government doesn't own Scuds, and it fired its first nuclear weapon more than a half century ago and so forth.

The Iraqis, obviously, were much less risk averse than we were. They took a lot of chances. If they had understood clearly they had an opportunity to deal a very severe blow to our forces if this particular endeavor succeeded and they had not lost very much if it did not succeed, I would not want to advise my Government that such a step would seem unlikely. It just seems rash to suggest other than be worried about it.

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Mr. **BONO.** In conclusion, in your view then, the potential to launch EMP from a Scud mobile unit is very possible, correct?

Dr. **WOOD.** Of course. It is certainly possible. The only difference of opinion I think that Secretary Klinger and I would have is the likelihood of success. He would see the glass as half empty; I would see it as half full.

The point made at the outset by the Chairman, however, I think is one that also has to be kept in mind. Very

advanced Scud capability, the type the North Koreans have evolved and have reasonably close to deployment at the present time, the Taepo Dong 2, is generally given credit for capability of reaching only into the mid-Pacific. If the assumed warhead was not in the thousand pound class but substantially smaller, that system could potentially loft packets into orbit; and, in particular, it could throw a small nuclear warhead over the United States.

Such small nuclear warheads exist; there can be no denying. Whether or not the North Koreans have access, by purchase or whatever other means, to the technology that tells them how to make those warheads is any person's guess. But the Chairman's suggested scenario is certainly not conjectural. It has a very substantial character in capability that might exist at the present time.

Mr. **EHLERS.** Reclaiming my time, just one final question, certainly no scientific component to this one.

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But the question is, why would any nation choose to launch a strike of this sort as a single shot? It seems to me that one might do it as a first shot out of a multiple barrage where you are trying to disable the enemy beforehand, but it seems most of the concern we have currently is about rogue nations launching a few nuclear missiles at our country or perhaps at our troops elsewhere.

The question is, why would they launch EMP attacks rather than launching a direct attack against some of our defense installations or our cities?

Dr. **WOOD.** As I said in my opening statement——

Mr. **EHLERS.** That question goes to anyone.

Dr. **WOOD.** As I said in my opening statement, the Soviets planned a very extensive EMP laydown over the United States and elsewhere; and they had a substantial amount of their ICBM force devoted to doing that. So, yes, indeed, they would do just as you anticipated. The rationale thing is punch and punch again and keep on punching so there is a very high likelihood of nothing escaping.

The only reason that you would not do that if you were a Third World power is you lacked both the warheads and the delivery systems that the Soviet Union enjoyed. If you had a few or perhaps only one or two nuclear weapons, you probably would want to use them in the fashion which imposes the largest damage expectancy on the United States and its military forces.

If you are going to go after the military forces and you only have a few, by far and away the most effective way that you could potentially use it is an EMP laydown. If you were going against the American civilization itself, again, the largest damage you could expect to see by far is that associated with EMP laydown.

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As I said earlier, a large laydown over the lower 48 States has a damage expectancy which can be reckoned in trillions of dollars. Not 10 trillion, but well above a trillion dollars. So what you get the most bang for your nuclear buck out of, you get it out of most heavily damaging your adversary in either the military sense or the sense of civilian infrastructure. EMP is the attack mode of choice.

Mr. **EHLERS.** The question still remains. Why would someone do this against the strongest nation in the world with the most missiles available to respond? We used the philosophy of mutually shared deterrence for a number of years. Why would any nation want to tackle us, knowing they would likely be obliterated as a nation?

Dr. **WOOD.** The Soviet Union, of course, was led by cautious folks. But they didn't do such a thing.

We worry nowadays about what the former chairman of the parent committee, Les Aspin, referred to as the undeterables in the world, the folks who, like Muammar Qadhafi of Libya said, "if I had ICBM's, they would be unleashed against New York and Washington"; against the Kim Chong-ils of North Korea, whose grip on reality is not considered to be an extremely strong one and who apparently continues to contemplate what would have the character of a suicide attack against South Korean and American forces. We worry about people who don't calculate or look at the world in anything like the fashion that we could and simply might not be deterable.

Mr. **EHLERS.** Thank you very much, Mr. Chairman.

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Mr. **WELDON.** Thank you, Mr. Ehlers, for being with us.

We are going to get to the classified portion; but before I do, I will ask Mr. Pickett if he wants to make any comments.

I would like to make two statements. One is a result of, as the members know, I try to avoid extremes on the issues we deal with, which is very easy, because we have people on both sides, one side that wants to recreate the cold war and the other side that wants to deny there is any threat. I try to find the center in each of the areas we focus on as a subcommittee and full committee.

A couple of comments came to me. One is the status about the control of nuclear weapons. I forget who made the comment in their statement, but I would just mention this.

Doing a lot of work in Russia—I was in Moscow 6 weeks ago with five other Members of Congress in a meeting with General Lebed. General Lebed was asked about the status of nuclear forces in Russia. He told us—using his exact quote, "Mr. Congressman, when I chaired the Defense Council for Boris Yeltsin, one of my responsibilities was to account for all of the suitcase-sized nuclear devices that we built inside of Russia."

He went on to say that during the tenure of building these devices, they had, in fact, manufactured 132; and he told us they had only been able to account for 48.

The status of the others? Who knows. But the point is that Russia certainly doesn't have total control over its nuclear weapons or its fissile material. We have seen evidence of that from time to time. It doesn't mean we should abandon them, but we have to understand and deal with that potential threat to our security and our troops.

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The second point is a specific response to the testimony of General Marsh again on page 6 and 7 where you talk about the fact that this likelihood of an event with EMP is unlikely and difficult to achieve, so it doesn't warrant serious discussion. You go on to say the administration's policy is to prevent proliferation and unauthorized access.

My problem with that is—and I am going to ask unanimous consent to enter this as part of the record.

[The information referred to can be found in the appendix on page 109.]

Mr. **WELDON.** A statement before a congressional committee by retired Lt. Gen. Robert Schwitzer, U.S. Army retired, who as I understand has now been commissioned by Secretary Cohen to do the first white paper on EMP—so I would assume he has some credibility. Secretary Cohen has asked this individual to do a white paper on EMP.

In your statement, General, you make the point that proliferation is, in fact, the way we deal with this.

But if I read, as I am going to do, and enter in the record, as I have already done, the statement by General

Schwitzer, it doesn't coincide with that. In fact, General Schwitzer goes into a statement saying, from unclassified sources—quoting him now—"we know that Russia, Ukraine, United Kingdom, China, Australia, France are all ahead in the field of radio frequency weapons, while Germany, Sweden, South Korea, Taiwan, Israel are emerging and have details of the Russian work and proceedings of more than 20 years of international conferences."

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He goes on in his statement, which is going to be in the record, to document conferences that have been held where this technology has been distributed and goes on to point out, at some conferences, both Iran and Iraq have been participants and, in fact, have had this technology made available to them.

But here is the rub: Now here you have a supposed expert on this issue developing a white paper for Secretary Cohen who makes two points that our technology control is nonexistent. Yet your point is that is the way the administration deals with this issue, through technology control and control of proliferation.

In fact, let me quote again from General Schwitzer: "Although RF weapon components are on the critical technologies weapons list, there are no up-to-date DOD guidelines or directives on this subject."

This is not me saying this. This is not Lowell Wood. This is the person that the Secretary of Defense has gone to to advise him on this issue. He is saying, there are no up-to-date DOD guidelines—quoting him here—on directives on this subject. An attempt to do so was made 2 years ago when little was known on the subject. As a consequence, decisions within the U.S. scientific community are becoming harder and dicier to make. There is a lack of clear policy guidance and direction.

That is my concern. Any response?

General **MARSH.** Mr. Chairman, I have reviewed General Schwitzer's testimony carefully; and I think we are talking two different subjects. His entire concern has to do with RF—conventionally generated RF weapons—that is, conventionally explosive generated RF weapons; and he discusses that at great lengths. I don't believe—I don't think nuclear EMP and that are two different subjects.

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Mr. **WELDON.** Thank you.

I would say, on page 5, you say, we have also looked at localized RF weapons and discussed them with RF weapons experts. It is theoretically possible to develop such weapons; but, to my knowledge, the practicality has not been demonstrated. We will get into that in the classified session.

Maybe I am misreading this, but the general thrust of your statement is the administration's policy is to prevent proliferation and unauthorized access, which I assume you meant to include both RF weapons which you did discuss in the preceding paragraph as well as EMP, is that correct?

General **MARSH.** That is not correct. I did not intend that to cover RF weapon technology.

Mr. **WELDON.** Do you agree with General Schwitzer we do not at this time have clear policy directives within DOD on RF weapons technology?

General **MARSH.** Sir, I don't know. I did not address whether there is a DOD policy on RF weapon technology or not. I just can't answer that.

Mr. **WELDON.** Does anyone know, in terms of technology transfer?

Mr. **KLINGER.** Sir, the only thing I can address is, as General Schwitzer correctly pointed out, those things are controlled. It is a critical technology.

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We have the policy guidance that exists with regard to space systems which is not explicit with regard to RF weapons. It is generalized with regard to the classes of threats against which we need to protect ourselves which encompass RF weapons.

Those are the only two data points I have.

Mr. **WELDON.** He goes on to give a very specific example that I am not going to get into about Weltron microwave tubes and an example of that not being properly controlled by DOD, and that is my concern.

Again, not to scare anyone, but from a practical standpoint, I agree we should be controlling proliferation. But if we have someone, also an expert, saying we are not doing that, OK, if it is only RF weapons, then we need to discuss that.

That problem exists with EMP technology—in his case, he is talking about RF and, to some extent, the impact of a laydown. That is the point of what we are trying to get at. From a policy standpoint, are we doing enough? Do we need to do more? Is there adequate testing in place? Perhaps most importantly, which will be the subject of the next part of this hearing, is the intelligence community adequately updating us with an assessment that we can make an intelligent decision upon where to base our dollars?

Our initial—my initial feeling on that is when we contacted them and got a 10-year-old report that perhaps maybe that is not the case. Maybe we will hear differently when they come in in the next session. But that is going to be the subject of the third part of this hearing, which will take place as soon as I conclude this.

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Mr. Pickett, any closing comments?

Mr. **PICKETT.** One issue, Mr. Chairman, that is not clear to me; and that is whether, in assessing the issue of the nuclear threat, that this notion of using a nuclear device to create EMP is classified the same as using a nuclear device for any other purpose against our Nation.

I don't know if anyone is prepared to answer that this morning. But it seems to be, inferentially anyway, if you start messing around with nuclear devices, whether it is an EMP generator or whether it is actually something that is intended to destroy physically property on the face of the continental United States, that the response is going to be the same.

Does anyone have any information they can give us on this issue?

Dr. **WOOD.** Yes, sir, but I would respectfully suggest it is appropriate for closed session.

General **MARSH.** I would only add one comment, and that is I think the uncertainty of the results of a deliberate EMP attack, especially by a terrorist or some rogue nation, the uncertainty of what they would achieve I would think would mitigate strongly against using that one or few weapons for its EMP effect versus known effects of very serious damage by way of blast and thermal. That is a personal opinion.

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

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Mr. **WELDON.** Let me thank all of our witnesses for outstanding testimony and helping us better understand what is arguably a very complicated subject. With the exception of our very technical people that you have seen today, most of us really are not adequately capable of assessing the technical aspects but rather, from a policy standpoint, want to make sure we are taking every step we can to deal with this emerging threat. We appreciate your help in accomplishing that.

You are all invited to stay because you have the appropriate clearances, I am sure, as we adjourn this session of the R&D subcommittee.

The subcommittee stands adjourned.

Staff will clear the room so we can have a classified briefing with the individuals that I have outlined: Dave Osias, the National Intelligence Officer for Strategic Systems and Nuclear Proliferation; Dr. Jose Pina from the Central Intelligence Agency; and Dr. Nelson DeGangi from the Defense Intelligence Agency. That classified session will be in room 2212.

[Whereupon, at 12:47 p.m., the subcommittee proceeded in Executive Session.]

"The Official Committee record contains additional material here."

QUESTIONS SUBMITTED BY MR. WELDON

Mr. **WELDON.** What policies and standards guide those responsible for the acquisition of space systems with respect to protection of those systems from system generated EMP (SGEMP) and other nuclear effects?

Mr. **KLINGER.** System generated EMP (SGEMP) results from the interaction of X-rays with the body and electronics of a satellite. These effects depend upon the amount of X-rays, the energy spectrum of the X-rays and most especially, the satellite design. There are several sets of handbooks and computer codes developed by the Air Force and the Defense Special Weapons Agency that provide the initial, physics-based starting point for SGEMP analysis.

The Joint Chiefs of Staff (JCS) have established criteria that define the hardening requirements for all space systems based on their mission, their validated threat, and the natural space environment in which the satellite will operate. These requirements are articulated in a system's Operational Requirements Document (ORD), translated into its Technical Requirements Document (TRD), and tracked by the Defense Acquisition Board (DAB) throughout the system acquisition per the DoD series 5000 acquisition regulations.

The DoD Space Architect has recommended hardening approaches for all space systems. These guidelines will be used as the basis for requirements and capabilities tradeoffs during system acquisition.

Mr. **WELDON.** How costly is the protection of space systems from SGEMP? How high a priority is this protection for space systems?

Mr. **KLINGER.** Protecting satellites from system generated EMP (SGEMP) effects is primarily accomplished through designs that consider the entire electrical interconnectivity of the system. This cost is typically low if the requirement is included as part of the original design of the satellite and usually grouped with the cost of radiation hardened microelectronics parts. The Defense Special Weapons Agency has studied this issue and found that, typically, SGEMP and radiation hardened parts add 1 to 8% to the cost of a satellite, if incorporated in the original design. If appropriate protection measures are not included as part of the original design, then the cost to add protection measures can increase significantly. The increased cost would vary from satellite to satellite, depending on the satellite's complexity. Several factors determine the requirement for hardening a satellite; its natural operating environment and, most importantly, the validated threat to the satellite. Each system will have a different requirement for nuclear hardness.

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Mr. **WELDON.** In establishing a space architecture, was the potential vulnerability to EMP effects of commercial satellites on which DoD now depends a serious consideration?

Mr. **KLINGER.** Yes. Assuming that the "EMP" above refers to High Altitude EMP (HEMP). Also, that the commercial satellites that DoD depends upon are primarily communications satellites at geosynchronous orbits. The potential vulnerability of these satellites is extremely low. However, that vulnerability was considered in establishing a space architecture.

Mr. **WELDON.** How vulnerable to EMP are the ground facilities needed to operate our space systems?

Mr. **KLINGER.** Vulnerability to EMP is a consideration in the overall design, construction and operation of satellite system ground stations. Detailed analysis and status is best addressed in a closed session.

Mr. **WELDON.** A recent "Army After Next" war game started with a concerted attack by "Red" forces that knocked out our satellites with EMP and other nuclear effects. Maj. Gen. Robert Scales from the Training and Doctrine Command, who runs the Army After Next program, now argues that all our satellites—even commercial ones—must have self protection capabilities. What is your assessment of the realism of the exercise? Do you agree with the conclusion drawn by General Scales?

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Mr. **KLINGER.** The Army After Next (AAN) Program provides the Army leadership strategic insights based on operational analysis of war in 2020. It is premature to draw any final conclusions from AAN war game results. The Winter War Game (WWG) in February 1997 was notable for a space campaign preceding the engagement of opposing ground forces. That space campaign included many hypothetical weapons systems and culminated in a nuclear attack on satellites. This direct nuclear attack did not utilize EMP as a kill mechanism.

Providing all satellites with self-protection is neither affordable nor necessary. System-level (architectural) trades have also shown that it is more important to protect the function, rather than protecting the individual assets that provide the function. The degree of protection for a space system is determined by the system's planned use, consequence of loss, potential threat to the system and cost.

Mr. **WELDON.** How routinely do we test for EMP vulnerability?

Dr. **ULLRICH.** Not as often as we used to test. In fact, very few systems are now tested because there are fewer new systems and requirements for EMP survivability have been reduced in recent years. Generally, extensive EMP testing is restricted to new systems and those with major retrofits. Periodic hardness maintenance and hardness surveillance tests should take place to preserve the hardness of fielded systems, but the amount of this testing varies from system to system.

Mr. **WELDON.** How good is the fidelity of the testing?

Dr. **ULLRICH.** The test fidelity for smaller, self-contained systems, such as missiles, small aircraft, tanks, and mobile vans, can be quite good. High level EMP test facilities, or "simulators," are currently available in a number of locations around the country. A simulator of this type can illuminate a modest exposure area with a "threat level" electromagnetic field that very closely approximates a nuclear EMP pulse.

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Distributed systems (such as the national power grid, or the commercial communications network), and systems that

are attached to long conductors (such as a ground facility connected to power and telephone lines, or a train on a track), cannot be moved to a threat level simulator. The test fidelity is not as good for these systems because the testing has to be done on-site with transportable EMP simulators. Such simulators generally have lower simulation fidelity than threat level simulators. Additionally, the entire system cannot be illuminated simultaneously, so the system is tested a section at a time. Since it is usually not practical to test the entire system, analysis must be used to determine the overall system response.

Mr. **WELDON.** How predictable are the consequences of EMP on large systems?

Dr. **ULLRICH.** Predictions of the consequences of EMP that are based only on analytical methods are less accurate. This applies to both small and large systems. Recent DSWA research demonstrated that the complexity of modern electronic and electrical systems resulted in large errors in analytic predictions of the EMP effects on systems. The conclusion of the research was that high level testing of the full system is required to arrive at more accurate assessments of system response.

Mr. **WELDON.** Once tested and deemed secure from EMP effects, how often are facilities retested?

Dr. **ULLRICH.** Recommendations for revalidation testing have been from five to seven years or whenever there is a major modification of the system. Our experience has shown that hardness maintenance and hardness surveillance programs are not consistently implemented.

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Mr. **WELDON.** How are large systems tested for EMP resistance—for example, how is an ICBM launch facility or B–2 bomber tested to assure that it can withstand EMP effects?

Dr. **ULLRICH.** ICBM launch facilities can be tested by using a combination of field illumination simulators that apply EMP-like fields over the facility and current injection simulators to induce large currents on the external electrical cables and penetrations.

Large aircraft, such as the B–52 and the B–1 bombers, have been tested using the TRESTLE, HPD and VPD simulators located at Kirtland AFB, NM. The aircraft is placed within the exposure area and the entire aircraft is illuminated with EMP-like fields with their engines running and mission equipment operating. Such tests can also be combined with current injection tests to drive cables and the skin of the aircraft.

Mr. **WELDON.** Is component level testing capable of providing high levels of confidence that our strategic systems are not vulnerable to EMP?

Dr. **ULLRICH.** Component level testing alone is not capable of providing high levels of confidence that our strategic systems are not vulnerable to EMP. Successful EMP test programs have relied on a series of tests to achieve high confidence. These tests include component burnout tests, functioning subsystem current injection tests and high level, EMP-like field illumination of an entire functioning system. The final confidence is gained by the combined results of all the tests, not just a single type of test.

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Mr. **WELDON.** How robust are our EMP testing facilities? What EMP testing facilities are currently operational? Are they in good condition? Which have recently closed and why?

Dr. **ULLRICH.** Existing EMP facilities are generally physically robust. The most important component is the pulse power source. The pulsers require periodic maintenance to avoid serious degradation.

With the end of the Cold War and the accompanying budget constraints, many of the large, system-level EMP

simulators have been mothballed or decommissioned. The table provides a brief status of the major DoD facilities. A brief description of the simulators follows:

Table 1

In addition, DSWA has a Continuous Wave (CW) Measurement System that consists of low level CW field illumination and high level current injection. This system is transportable and allows testing of ground facilities (fixed and mobile) such as satellite communication terminals.

Mr. **WELDON.** Have tests been conducted that indicate that US ICBM launch facilities are vulnerable to EMP effects?

Dr. **ULLRICH.** Any comment on actual test results of specific U.S. systems would be classified; this question should be referred to the Air Force.

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Mr. **WELDON.** Are there significant differences between Russian doctrine and Soviet doctrine on the use of EMP to disrupt or disable U.S. strategic and other military systems?

INTELLIGENCE COMMUNITY WITNESSES. The information referred to is classified and is retained in the committee files.

Mr. **WELDON.** Are there any other nations with nuclear forces now capable, or potentially capable, of generating an EMP threat to U.S. strategic forces or U.S. strategic command and control?

INTELLIGENCE COMMUNITY WITNESSES. The information referred to is classified and is retained in the committee files.

Mr. **WELDON.** Do we have any indication that these other nations plan to use nuclear weapons specifically to generate high altitude EMP?

INTELLIGENCE COMMUNITY WITNESSES. The information referred to is classified and is retained in the committee files.

Mr. **WELDON.** How mature is RF weapons technology? What nations are developing this technology? Does the intelligence community have any projections about what nations might acquire such weapons?

INTELLIGENCE COMMUNITY WITNESSES. The information referred to is classified and is retained in the committee files.

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Mr. **WELDON.** Is the intelligence community aware of any potential terrorist threats to use RF weapons against key commercial targets?

INTELLIGENCE COMMUNITY WITNESSES. The information referred to is classified and is retained in the committee files.

QUESTIONS SUBMITTED BY MR. BARTLETT

Mr. **BARTLETT.** To what intensity level?

Mr. **ULLRICH**. The actual maximum intensity (peak electric field) level varies from simulator to simulator and within each simulator it varies based on the test object's location and extent. A nominal unclassified intensity that most threat-level simulators can generate is 50,000 Volts/meter.