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The E-Bomb

How America's New Directed-Energy Weapons Will Change the Way Future Wars Will Be Fought

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Introduction

JOANNE MYERS: Good morning. I'm Joanne Myers. On behalf of the Carnegie Council, I'd like to welcome you to our breakfast program.

Today, as we continue our inquiry into the structure of American military power, we will be focusing on the moral aspects of asymmetric warfare. With this in mind, we are very pleased to have as our guest speaker Doug Beason, who will be discussing his book, *The E-Bomb: How America's New Directed-Energy Weapons Will Change the Way Future Wars Will Be Fought.* His presentation will provide us with a window into the costs and benefits of an increasing reliance on ever-more-technologically-sophisticated "wonder weapons."

As we enter the twenty-first century, we find ourselves on the verge of a new breakthrough in warfare. Just as the victories of the past exploited technology and effected a revolution in military affairs, once again the military is using science and technology to deploy a new generation of weapons which are slated to become the centerpiece of twenty-first century arsenals. These directed-energy weapons—whether lasers, high-power microwaves, or particle beams—signal a major shift in the use of weaponry. In fact, these weapons are so dramatic, so disruptive, and so profound that they will change the way wars are fought.

In *The E-Bomb,* our guest this morning will introduce us to this new technology. Dr. Beason traces its development over the past three decades and talks about their likely deployment and impact on the battlefield. He tells us that as soon as these once-imagined weapons of the future begin to appear on today's battlefields, the sci-fi worlds of Flash Gordon and his ray gun or visions of Darth Vader wielding his light saber will become a reality.

Our speaker this morning is a man of science, learning, and imagination. For the past twenty-eight years, Dr. Beason has been one of the key architects in conducting basic research, directing national security programs, and formulating national policy in the field of directed energy. Among the many and varied positions he has held are researcher at the Lawrence Livermore National Laboratory, director of a plasma physics laboratory, and professor of physics at the Air Force Academy. He has also served on the White House staff, working for the president's science adviser under the Bush and Clinton administrations, where he was adjunct to the National Space Council.

In addition, our speaker is the author of over a hundred scholarly papers, fourteen books, including some popular fiction techno-thrillers that even captured the attention of Hollywood, where one was bought by Universal Studios and another optioned by ABC.

Currently, Dr. Beason holds the title of Associate Director of Threat Reduction at the Los Alamos National Laboratory, where he is responsible for over 1,400 professionals who conduct research in directed energy, intelligence, space science, remote sensing, nuclear nonproliferation, bioscience—and, if that is not enough, they are also charged with developing technologies to reduce threats from weapons of mass destruction and with solving and defeating new and emerging threats to our environment, infrastructure, health, and national security.

In our previous program on American military power, our discussion focused on the size of the army.

Although size does matter, this morning's lecture may very well convince you that in the end it's technology that wins wars.

Please join me in welcoming our guest speaker today, Dr. Doug Beason.

Remarks

DOUGLAS BEASON: Thank you for the introduction.

They say that the movie *Star Wars* was probably the greatest boon and the greatest bane for directed energy, because when the movie came out over twenty years ago, half the people thought that we had already done it—and half those people were in the Pentagon—and the other half thought that it would forever be science fiction. So that's what we have to struggle against.

Yes, the size of the army matters, but it's technology that wins wars. If you are unconvinced, then ask the Mongol invaders, who, in 1232, during the battle of Kai-Keng, were repelled by rudimentary, yet for the time, technically advanced Chinese rockets called "arrows of flying fire." Or ask the Japanese, who at the end of World War II surrendered after experiencing the horrific effects of the atomic bomb. Or, even more recently, ask the Iraqi army, which was overwhelmed by stealth and precision guided weapons.

In these and many other cases, from the introduction of the stirrup to the invention of the rifle, advanced technology gave war fighters the upper hand and determined who won the battle. More importantly, these advances were not merely evolutionary increases in science and technology, but true revolutionary gains and leaps in capability, leaps all made possible by advances in science and in technology.

So when today's military is offered a similar asymmetric advantage, you would think that they would acknowledge history and embrace any improvement possible, especially when lives are at stake. But it is not the war fighters who determine what S&T (science and technology) is funded; it is acquisition bureaucrats. Although they have the best intentions, they are not closely connected to war-fighting needs and generally pick the least risky option to conduct war. Most acquisition strategies are evolutionary. They raise the tide equally among proven technologies so that present-day systems gradually increase their capability. What is needed is a more aggressive acquisition strategy, one willing to exploit the new technology that is now on the horizon.

Revolutionary capabilities forever change the way that wars are fought and provide overwhelming, decisive victories, such as the Chinese rockets in 1232 or atomic bombs in 1945. For it is visionaries who win wars, and not bureaucrats.

So what type of new asymmetric advantage would today's military commander want against uncontrollable crowds and insurgents, in Iraq, for example? What would that same commander say if revolutionary science and technology was available today?

Further suppose that this science and technology was infinitely precise, so precise that it could discriminate between innocent civilians and combatants at ranges that are greater than small-arms fire. Or suppose that this science and technology was infinitely fast, so fast that it could encircle the earth more than seven times in a second. Best of all, what if this science and technology presented this commander with a spectrum of options, so that instead of yelling at somebody or shooting at him, suppose the commander had the ability to dial an effect—that is, from warning an adversary to denying them access, to destroying them.

The good news is that this science and technology exists today in the form of directed energy, or millimeter waves, high-power microwaves, and lasers— the so-called electromagnetic E-bombs, or the electromagnetic spectrum bomb. The bad news is that directed energy is inadequately funded because acquisition officials would rather use scarce research-and-development dollars to ensure gradual evolutionary gains rather than risk revolutionary capability. In fact, if funding had not been cut in the late 1990s, one type of directed-energy weapon, called millimeter waves, or Active Denial, might have been used to quell the urban fighting that exists today in Baghdad, Fallujah, and other cities in Iraq, perhaps even saving hundreds of lives.

This revolutionary directed-energy program has enabled researchers to develop non-lethal force fields that can keep enemy combatants at bay over 700 meters from high-value targets, such as embassies, airfields, command posts. In a way, it's a true modern demonstration of "phasers on stun."

So why hasn't Active Denial made the papers or caught the public's imagination? For one, people have been waiting for a Buck Rogers ray gun-type weapon ever since Dr. Maiman invented the first ruby laser back in 1960. In some ways, as I mentioned before, the worst thing to happen to directed energy was *Star Wars.* Half the people thought that it was science fiction, and the other half thought that it had already been done.

But the major reason why this technology has not been fielded is the unwillingness of acquisition officials to take risks. They will say that Active Denial and other directed-energy-type programs are funded. Yes, they are funded, but only at a very minimal level, with no sense of urgency and with insufficient contingency to anticipate unforeseen science and technology problems. They compete against evolutionary programs, and have little prioritization and little critical mass for funding.

In fact, a recent study concluded that Active Denial could have helped prevent the 2000 bombing of the USS Cole. Another study concluded that if this technology had been available earlier, perhaps scenarios such as "Black Hawk down" could have been prevented. But this could have only happened if Active Denial and other directed-energy concepts had been funded and not been cut.

These emerging directed energies are not just new, but they are world-changing, revolutionary applications of science and technology that have struggled up the so-called S-curve of development. Directed energy will be instrumental to win not just the last war, such as yesterday's faster airplane or more accurate rifles might have done, but this technology will help overwhelm the enemy in a way that they are unprepared to defend against today. Science and technology advances have even made it possible to install a high-power laser in a modified 747 that the U.S. Air Force is now planning to use in shooting down ballistic missiles.

So acquisition officials should focus on a few revolutionary breakthroughs, fully fund them, and accelerate these systems to the battlefield. Fully funding mostly evolutionary increases in capability is a real disservice to our war fighters. In actuality, it only supports incumbent defense contractors, by constantly upgrading old legacy systems that are fighting the last war. Some upgrading is needed, granted, but not at the expense of new capability. For it is revolutionary leaps, not evolutionary plodding, that will win future wars. That future is directed energy, so-called E-bombs, in the form of infinitely precise weapons that travel at the speed of light.

From here, what I would like to do is deviate from my prepared remarks (because I have quite a few more) and, instead, jump into what directed energy is.

Over the past week, I have been speaking in Washington, D.C. Most people think directed energy is things like light sabers, phasers, and so on—things that shoot out through space and make zapping noises. Actually, directed energy is all around us. We have been experiencing directed energy over the past hundred years in one form or another. All that directed energy means is a way to take the energy from the electromagnetic spectrum—that is, the same energy that is emitted by light-bulbs, by the sun, by flashlights—and direct it in some way.

But the difference is that this directed energy, instead of being randomly produced by a source such as a light-bulb, is what we call coherent. In physicists' terms—I'm a physicist—what that means is that all the wavelengths are lined up; they are not only going in the same direction, but they are in the same phase. Imagine the Chinese army, millions and millions of soldiers, all marching to the same beat in the same direction in perfect unity. If you can multiply that by a factor of billions, that is what you have with lasers and microwaves.

The electromagnetic spectrum—that is what is emitted from light-bulbs, from the sun—covers the gamut from radio waves to very long waves of the electromagnetic spectrum, to microwaves, which are shorter wavelengths, to millimeter waves—the waves are called millimeter waves because they are actually measured in terms of millimeters—to heat, which is infrared. As you get shorter and shorter wavelengths, you get to visible light and then x-rays and gamma rays.

So all this is really the same thing. It is electromagnetic radiation. It is things that we are exposed to every day, in this room, right here. But again, the difference with directed energy is that all this radiation is in lockstep.

The first laser was created in July 1960. It was actually theorized much sooner than that. The first microwave was created earlier in the last century. In fact, the Japanese were so impressed by microwaves that they tried to invent a high-power microwave weapon back in 1943 to shoot down American planes. It was a dream that they had. It was a very low-power magnetron that they developed. Of course, it failed, because it didn't have the power to do that.

So all these weapons—microwaves, lasers—have been around for a while. The public has always had a dream of using these things—H.G. Wells, for example, back with *The War of the Worlds.*

But what are the attributes of directed energy? Why does it capture the public's imagination? The first attribute is that it is near infinitely fast. I mentioned before that it travels seven times around the world in less than a second. That's about 186,000 miles a second—pretty quick. The equivalent in metric units is about 3 x 1010 centimeters a second, much faster than you can blink, which means that if you can see a target, you own that target; you can kill that target; you can lay energy on that target.

Another attribute of it is that it's infinitely precise. That is, these wavelengths don't spread out very much at all. You can shoot them hundreds of thousands of kilometers away. We have hit the moon. We have hit reflectors on the moon with them.

Because they are infinitely precise, what that means is that they are inherently defensive weapons and not offensive weapons. These are not weapons of mass destruction. But they are so precise that what that enables you to do is to pick out individual targets—in fact, individual places on a target. The airborne laser that I was mentioning earlier that the Air Force is developing has the capability for shooting laser beams over hundreds of kilometers at quickly rising rockets— not just at any part of the rocket, but to determine an exact spot on that rocket within centimeters, and to be able to find that spot and hold that laser on that spot. This has been demonstrated out in the deserts of New Mexico.

So we have infinitely fast and near infinitely precise as two attributes of this. Plus they don't follow the laws of gravity. That is, you don't have to worry about ballistics. You don't have to lead a target. Unlike bullets or rockets, which may take many minutes to get to a target, you can not only deposit the energy near-instantly, but you don't have to lead the target. Again, if you can see it, you own the target.

Why haven't directed-energy weapons, then, been a great success? Forty-five years ago, when they were first invented, back in 1960, the first energy of a laser was measured in milliwatts. A milliwatt laser is about the same as the pocket laser for use in PowerPoint presentations. But what you need are what we call megawatts, the megawatt class, to kill things like ballistic missiles. So over the past forty-five years, science and technology developments have been made which have enabled researchers to increase the power levels of these lasers by a factor of a billion. That is 10^9, a billion times, which is incredible. So we are now just getting to the point where the power levels are high enough to do this.

The same with high-power microwaves. High-power microwaves are now being generated in what they call the gigawatt—or billions of watts—type of power level. Research has been going on in the various military services and the different national laboratories, such as Los Alamos, where I am from, for the past thirty to forty years on this. This is a tough problem. It's not very easy to get these types of power generations. In fact, up until a few years ago, the main drawback of directed energy was the power supply. You had to have something as big as an aircraft carrier in order to generate the power necessary to generate these beams. In fact, some of the weapon concepts that I worked on twenty years ago were housed in buildings that were as big as hangars. That's where our power generators were kept.

So the technology to shrink this power generation, the technology to aim, to point, to keep stable these beams, is what has really enabled us to come to a point where we are just now on the verge of being able to field these weapons.

The two that I will talk about very quickly today are, first, Active Denial, which I referred to at the beginning of my talk, and second, the airborne laser—both very controversial types of weapons systems, but both types, I think, that can give the asymmetric advantage that can provide the war fighter with the capability to win the next war, and not fight the last war.

Active Denial was a concept that used what we call millimeter waves—again, this is in between microwaves and visible light—to produce what is known as the "flee effect." It was unveiled by the military back in 2001. Up until that time, it had been a classified program. People have known for years—in fact, decades—that millimeter waves (about 100 gigahertz is the equivalent frequency) have generated what is known as the "flee effect."

The "flee effect" is when the millimeter waves are absorbed within about the first third of a millimeter of your skin, and that energy, when it is absorbed by your skin, is picked up by your nerve endings. The nerves are not actually affected. What the nerve endings feel is the energy that is absorbed by your skin as intense heat. It's not intense heat; it is actually just millimeter waves that are depositing their energy. In fact, the amount of energy that is actually deposited by a weapons system such as this is less than one-tenth the amount of energy that you get by standing out in the sun. It is just at a certain frequency. When you are standing out in the sun, you get millimeter waves. You get what we call a black-body spectrum of radiation. You just don't get as much as what is being broadcast by the Active Denial.

Your body, as you know, absorbs radiation from all sources—radio waves passing through us right now (in case you didn't know), gamma rays, even some x-rays that are being generated from cosmic rays. So we are already in this environment. What this millimeter-wave technology does is concentrate the energy at this certain spectrum.

The nice thing about this is that not only is this "flee effect" created, but also it's very noncarcinogenic. What do I mean by that? Studies over the past two decades have shown that this type of radiation, since the millimeter waves don't penetrate into the body and are only absorbed by the first third of a millimeter, is not of high enough energy to knock the electrons out of the atoms that are in your cells, which is typically the cause of carcinogenic effects.

So down at Brooks Air Force Base, the military, over a series of two decades, has produced studies which have shown that these effects are not only noncarcinogenic, but also that they dissipate extremely rapidly. What that means is that when you are exposed to the Active Denial effect, it is as though a huge oven has opened up in front of you: You feel intense heat—again, it's not actual heat; it's the millimeter wave that is being absorbed by your skin—and what you want to do is get away from that effect. Your psychological response to this is to turn around and flee.

I was lucky enough to be exposed to this about four years ago, when they first started human testing, known as the human protocol. Since then they have had several thousand people undergo these tests. This is something that I still remember today. If there was a place that was being defended by this, I wouldn't want to get close to it.

Did it harm me? When I was exposed to this, I fled, and when they wanted me to go back and do the test again, I was kind of hesitant, saying I didn't know if I really wanted to do it. But I completed the protocol. I got some good stories there, I suppose.

They had doctors and psychologists there that were measuring our responses during the testing phase; and the body showed no physiological change. But you were experiencing this intense heat that you didn't want to experience.

What the military is planning to do with this—and they are conducting tests on it—is to be able to project this over a distance of greater than 700 meters. Why that distance? Because it's greater than what we call small-arms fire—pistols, that type of thing—and to use it to what they call "assess intent."

Up to now, commanders on the battlefield have had only had two options: shouting at somebody to stop them or using lethal force, trying to stop them with that. There are other non-lethal methods to try to stop people, but these methods are really dependent upon the person's weight, his makeup, how big he is—things like TASERs, things like sonic weapons, things like beanbags that you throw at people. For example, if you take a beanbag, and you have two people that are coming towards you and one may be a little girl, that could kill the little girl because of kinetic energy exchange with the beanbag. If the other target is a football player, that just might tick off the football player, make him madder, and he will come and rip your head off. So you don't know what the response would be with these other non-lethal weapons, even TASERs.

But with Active Denial, everybody tested so far has demonstrated the same "flee effect."

So let's imagine a scenario: Suppose you have a crowd that's coming towards an embassy. First the crowd is warned to stay away from the embassy. If they keep coming, especially if they're using hostages, for example, up to now we didn't have any other option but to shoot at them or to use some other type of non-lethal force where you don't know what the effect was going to be. With Active Denial, because you are using directed energy, which is very precise, you can actually pick out the individual aggressors, those that you want to key in on. This has been demonstrated in tests, person after person.

If those people, after experiencing the Active Denial effect, continue to come towards you, then you can continuously assess their intent. The normal person who is caught up in a mob mentality would not still be rushing you, unless they had some kind of hostile intent. At the time that they cross the line into hostile intent, there is the option of using lethal force. It allows the commander a spectrum of response.

Right now the system is being tested at Kirtland Air Force Base down in New Mexico. It may or may not be funded after the tests are through. But because it operates through things like clothing and buildings, many believe that you could use this type of technology to quell insurgents.

So this is one option.

The other option that I would like to briefly talk about is the airborne laser. This is the laser that is being put inside a modified 747. It's what they call a COIL-based laser, a Chemical Oxygen Iodine Laser. This laser was actually invented about the same year I graduated, as an undergraduate, back in the late seventies. From then, this laser has experienced power growths just like the original laser, from milliwatts up to what we call the megawatt class—that is, near millions of watts of power.

This laser is currently undergoing testing at Edwards Air Force Base in California. It has a mission now of shooting down tactical ballistic missiles in what we call the boost phase—that is, when the tactical missiles are still boosting. As of yet, we don't have any way to go against these missiles. If you go back and look over the Gulf War survey, for example, it was originally thought that the Patriot missiles had contributed to taking out the warheads of the Scuds, which are tactical missiles. This was false. In fact, no warheads were taken out by the Patriot missile.

What we have, then, is a threat that we have no technical response for. This is why the Air Force chose to look into the airborne laser, to go after these missiles while they are still in the boost phase.

As you know, there is a lot of politics wrapped up in this, since this is now a Missile Defense Agency program. But the point is that the different technologies of this weapons system have all been tested and all been proven.

The largest difficulty that this weapons system has to go through now is during the integration phase— shaping the laser pulse so that it can travel through the atmosphere in a way that it can assemble itself to make it very accurate. What do I mean by that? Right now, when a laser punches through the atmosphere, it diffracts, like all lasers do. There are abnormalities in the atmosphere, brought about by changes in density, changes in dust, through particulate matter, through water vapor, that cause the beam to break up. This is the reason why stars twinkle when you look at stars at night. (At least we have stars in Los Alamos; I don't know about here in New York.)

This technology was developed back in the late 1980s and early 1990s, in a classified program for SDI (Strategic Defense Initiative, commonly known as Star Wars) at the time, when the astronomical community wanted to take the twinkle out of stars. They were about ready to embark on a multibillion-dollar program to build what we call adaptive optics. Adaptive optics is where you have a mirror and you change the shape of this mirror many hundreds of times per second. Why do you do that? Because the atmosphere changes many hundreds of times per second. The idea is, if you have a perfect beam of light coming from a star that goes through the atmosphere, it changes in some way, depending upon the perturbations in the atmosphere. Suppose you can put the reverse of the perturbations in the atmosphere on the back of this mirror. There are ways to do this, by shooting laser beams up and back down from the sky, calculating what a perfect beam looks like and then deconvoluting the beam when it comes back.

Astronomers knew that in theory this could happen, and so when they went out to embark on this multibillion-dollar program— I happened to be at the White House at the time and was cognizant of it— it was felt that instead of having them invest all this money, it would be better for us to declassify this technology called adaptive optics and let the astronomical community use it. Now every major telescope in the world uses this type of technology called adaptive optics.

The Air Force is using the same type of technology to preform the beam in its laser beam, to put abnormalities into the beam before it propagates to the target, so that by the time the beam gets to the target, since you are putting, in a sense, the reverse of these abnormalities on the beam, it forms itself to this near-perfect beam when it gets to the target. This has been demonstrated, and not just in New Mexico, but there is a valid concern that sometimes the variations of the atmosphere may be such that in different parts of the world you may not be able to do this.

So with these different types of technologies— the power level and the beam steering, the beam shaping —these have all been proven, in the laboratory and in the field. The big difficulty now is integrating this all together to show that a successful weapons system could be made. As a physicist, I'm very optimistic that this can happen. My engineering colleagues are not so optimistic. To me, it's just what I call an engineering problem.

A quick example. One of my good friends, the late Robert Forward, talked about how it's possible to create zero gravity here on earth. That's because gravity is what we call a vector field, and all you need in order to create a volume of zero gravity is a shape the size of the moon. You press it down to about the size of a football field, support it with diamond columns ten feet thick, and inside this volume you have zero gravity. It's just an engineering problem— theoretically possible.

As a result, what we have, then, are two radically different weapons systems that are about to be given to war fighters. One has been proven and shown to produce effects in the field. That's Active Denial. The problem here is the funding, as well as the other problems of building ethical constraints in there as engineering controls, to make sure this weapon is not misused.

What do I mean by that? Right now there are engineering controls to make sure that the operators of these types of systems cannot keep the beam on for more than a specified amount of time. The "flee effect," occurs near-instantaneously. It a very long time later that you start to get other types of effects, such as a mild sunburn. So the time between the effect and any type of physical effect is very large. The operator has engineering controls built onto the device that prohibit the use of this. That is, they physically cannot keep the beam on for that amount of time.

The airborne laser also has issues that need to be considered. For example, the light that is being emitted by the airborne laser is one which is not friendly to your eyes. It could create eye damage. So if somebody happens to look up at the time that one of these missiles has been lased by this laser, then it is conceivable that there could be eye damage. Of course, if they are in the way of the beam, then it's something else. But, remember, it's the near-infinite precision of this beam that allows it to be used as a weapons system in the first place.

Do I have time for questions?

JOANNE MYERS: Absolutely. Thank you very much.

DOUGLAS BEASON: I'm sorry for deviating from my prepared remarks, but I thought it would be better that I explain a little bit of the background of directed energy.

Questions and Answers

QUESTION: Thank you for enlightening us on something that we don't often have so much information about—physics and engineering. My question is, what other country is doing research on the E-capabilities—for example, China? What does this mean about future warfare? Are we preparing defenses against these lasers? It's quite probable, if there is so much open information, and there are many spies, that other countries will be able to have this information as well.

DOUGLAS BEASON: Yes, other countries are pursuing this type of research. Because it is such a technically tough problem— the United States has been conducting this for decades, and we're still meeting significant technical challenges—the status of these research programs in other countries is behind us. Yet we're aware of what they're doing.

It is conceivable that as these weapons evolve, they could be used against us as well. So there are studies being done to look at our vulnerabilities to these weapons and how to decrease them.

Two points I would like to make. The first is that because these weapons are so technically advanced, we really think it will be decades before we have to worry about adversaries. But we are making plans just in case. In fact, my main worry is not with the military being vulnerable, but with the United States or the U.K. or Canada being vulnerable. What I mean by that is that most of these weapons don't go against people, except for the non-lethal one that I just talked about. Most go against infrastructure, be it rockets or electronics. If we ever get to the point where these weapons can be used against our infrastructure, I think that we and our allies, the most technically advanced nations in the world, that rely so much on electronics and e-commerce, are going to be hit at home first, and not on the battlefield.

The second point I would like to make is that these weapons would be used not as a panacea to solve all problems, but only for certain classes of problems. I have a brother who is an F-15 pilot, F-15E, which is a fighter/bomber. Before he goes out on a mission, he selects A, B, C, or D, whatever weapons he needs, not just one weapon. It changes from mission to mission.

In the same way as a war fighter goes up against a certain class of threats, directed energy may fulfill one type, but not another type. That is, you don't want to use it against a tank, but you may want to use it against a rocket.

QUESTION: Directed energy seems so developed and so sophisticated in your description. I'm just wondering why solar energy has not been equally harnessed, and perhaps would be used in a different manner, but certainly in a constructive way that perhaps would avoid wars.

DOUGLAS BEASON: Thank you. Solar energy is great. I love it. There are two problems with it. The first is that there's not enough of it. Right now the efficiencies of solar cells are on the order of 25 percent, maybe 30 percent. That is, it converts 25-to-30 percent of the sunlight that impinges on it into electricity, which is nice. But on the other hand, it is so low in energy density that even if we were to cover all the earth with solar cells, it would still not be enough to live up to our demands, because we use so much energy. I could go through the math with you. It's just staggering.

Until we can get the solar cells up in high enough efficiencies to convert it to near that 100 percent— and we don't have too much further to go— it's going to have a place with other types of renewable energies, but it's not going to be a panacea.

Right now the Renewable Energy Laboratory in Boulder, Colorado, along with other laboratories, is making strides on that. There is an effort. But again, the main reason is because of the energy density problem.

QUESTION: We all go through our lives with an assumption that the future is going to be sort of like the past. In terms of energy, people are starting to reassess that assumption. I'm just wondering, as a military strategist who thinks broadly, what do you think is going to happen to the largest energy hog in the history of the world, the U.S. military, when oil is maybe $100 or $200 or $300 a barrel? Does a democracy get to a point where it says that it cannot afford to have a military that covers the earth and uses what must be an ungodly amount of energy every second?

DOUGLAS BEASON: I think, rather than that scenario, which is more of a linear one—that is, that we keep using the energy in the same way and the price of oil goes up—that we will have a bifurcation, in the sense that we will get to a point where we do reach a level of energy need where we will be forced to use alternate paths. I would say the most likely path is nuclear energy. When the demand gets so high for energy, I think we're going to be forced to go along a separate path, especially with the advances that we've made in safety, In France, 80 percent of the energy being used is nuclear power.

So I think it's really going to be a different type rather than just a linear scenario like that. Personal opinion.

QUESTION: You maybe were alluding to this earlier. I was wondering if you could say anything about electromagnetic-pulse weapons. You talked about concern about the U.K., France, and the United States. Is there anything you can say, unclassified, about that?

DOUGLAS BEASON: Yes. The original title of the book was *At the Speed of Light: The People, the Programs, and the Science Behind Directed-Energy Weapons.* My publisher didn't think it was sexy enough, so they called it *The E-Bomb.* Good choice.

The electromagnetic-spectrum bomb came about because of a electromagnetic burst, which was first identified back in the early 1960s during Starfish Nuclear Test, which was an aboveground—in fact, an outer space—nuclear explosion, when electronics for miles and miles around just ceased to work. The reason is that they were burnt out by this burst of electromagnetic radiation.

I could go through the physics explanation of this. It's really fascinating, about the absorption and re-emitting of the radiation.

But the fact is that this is seen now as a way to take down the infrastructure of the United States and our allies by emitting a nuclear burst, and instead of taking out a city, putting it high enough in the atmosphere that it kills not only most of the electronics in a certain area, but possibly many states—some people think it could affect an area as big as the entire United States—as well as, perhaps, taking out some of our communication satellites.

This is a real concern. It's one that the military is thinking about. But in a risk-based system, there are ways that they are dealing with this. One of the ways, for example, is making sure that the electronics are what we call hardened, so that they are not as vulnerable to it.

Does this mean all the systems are? Does it mean that commercial systems are? Probably not commercial systems.

So this is a concern. It's one that has a high impact value if it were to happen. On the other hand, it is, I think, of a lower probability. If you look at the threats that we are up against nowadays, that is more of a high-tech threat against us, where it would take a vast infrastructure to not only have a weapon, but to loft it up and get it in the right place above the United States to do that. It's easier just to let off a weapon like that, say, in New York, or even easier to buy more box cutters and take another plane into a big building.

So it's part of a risk-based assessment, I think, that the military has gone through, where it has decided that it is high-consequence, but low-probability.

QUESTION: Terrorism is another form of guerilla warfare, and traditionally guerilla forces have supplied themselves with equipment from the people they are fighting. What happens if the bad guys get hold of some of our weapons of this sort on the battlefield?

DOUGLAS BEASON: That's always a worry. But these new weapons are not like rifles or bayonets, where there are a lot of them out there. They are what we call high-value platforms, where there may be only a few of them. Right now there is only one airborne laser. There is a plan to build as many as seven. Right now there is only one Active Denial system. This system costs, as it turns out, about as much as an F-16 fighter jet does.

So not only would the security surrounding envelope for protecting these be large, but as it turns out, these weapons are also large—and this is one of the reasons why they're not fielded today. I may give the impression that, since we are testing them in the field, they are ready to drive out and be used in Baghdad. We are still lacking Ph.D.s to operate these. They have supercooled magnets. They have superconducting fluids that you have to worry about. They have very intricate electronics.

Down the road, this could conceivably happen, if we have a technological breakthrough and we are able to mass-produce these in some way, and especially if we are able to shrink them. Then I think we would have a proliferation problem. This is something that I think we need to be thinking about now, how we would not only produce the necessary defenses against something like this, but what we can do to proliferate something like this in the future.

But I don't see that happening for a decade or so.

QUESTION: A lot of folks get a little queasy when you talk about weaponry of any kind, let alone A-bombs, H-bombs, or E-bombs. My question really is this: What has been the real impact, in your opinion, on the disconnect between the political opposition to weapons development and research in the aftermath of the Cold War and the demand by some of those same opponents for more effective weaponry to prevent what is called collateral damage?

DOUGLAS BEASON: I think the biggest disconnect is what I mentioned at the beginning of the talk, an unwillingness to pursue a more aggressive strategy for the revolutionary type of weapon. In a way, I don't blame the policymakers for this, because these current weapons, the legacy systems, are proven. We know that even things like an F-16 can be used to take out targets on the ground. It is not built for that; it is not designed for that. It is very hard to divorce yourself from proven systems.

But I think we have gone too far in trying to raise the tide equally, by trying to increase the capability in an evolutionary way for all these legacy systems, rather than taking the next revolutionary leap for these truly asymmetric types of weapons. We have people who come out of the woodwork whenever they see their favorite weapons systems about to go away because, "We can't live without it."

There is even a Harvard case study, for example, on when the B-1 weapons system was killed, how that was resurrected by a cabal of people in the Pentagon at the time, who laid low and, working with the industrial partners, waited until the next administration came up.

So I think the general reason is this unwillingness to try and put all of our eggs in one basket. That's what it seems like we're doing with revolutionary advances. Instead, we are forced to the norm of just allowing evolutionary types of increases, if that makes sense.

QUESTION: You mentioned, on every level, that one of the problems is lack of financing. I think we spend $400 billion on defense, which is more than anybody else. What is that used for, if it isn't used for research as well?

DOUGLAS BEASON: I can't speak for the Defense Department, but personnel, infrastructure is a large part of it. I am sure we could get a breakdown of that. There is a chunk of it that goes to the research and development community. But again, it's just not a simple system of having a priority list of one through ten and starting to cut things off at the bottom, because what is one person's lowest priority is the highest priority for somebody else. It's that whole social dynamic in trying to fund that.

JOANNE MYERS: I would like to thank you very much.