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DEPARTMENT OF DEFENSE INVESTMENT IN TECHNOLOGY AND CAPABILITY TO MEET EMERGING SECURITY THREATS

HEARING

BEFORE THE

SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES

OF THE

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HOUSE OF REPRESENTATIVES

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DEPARTMENT OF DEFENSE INVESTMENT IN TECHNOLOGY AND CAPABILITY TO MEET EMERGING SECURITY THREATS

HOUSE OF REPRESENTATIVES,
COMMITTEE ON ARMED SERVICES,
SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES,
Washington, DC, Tuesday, July 26, 2011.

The subcommittee met, pursuant to call, at 2:05 p.m. in room 2212, Rayburn House Office Building, Hon. Mac Thornberry (chairman of the subcommittee) presiding.

OPENING STATEMENT OF HON. MAC THORNBERRY, A REPRESENTATIVE FROM TEXAS, CHAIRMAN, SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES

Mr. THORNBERRY. The hearing will come to order.

And let me first express our appreciation to the witnesses for your patience, as we have finished votes. The bad news is that we are late. The good news is, now we are not going to be interrupted for a while. So I appreciate, again, you all's patience.

This hearing should shed light on matters that are squarely within the center of this subcommittee's jurisdiction. Namely, what are the emerging threats to the national security of the United States? And what are the emerging capabilities in which we need to invest in order to meet those threats?

The one fact of which we can all be assured in national security is that there will be change and there will be uncertainty. We can't predict the future, but we can watch for trends and we can develop technologies that can help meet a variety of challenges in a rapidly changing world.

Of course, the Department of Defense is not the only place where those trends can be detected, or where those technologies can be identified. And we have certainly assembled a top-rate panel today to help us with that task of detecting those trends and identifying those technologies. And we appreciate each of you being here.

I understand that Mr. Langevin is on his way. We will give him the full opportunity to make his opening statement and whatever he would like to do when he—later when he arrives. But for now, I think we should proceed with the summary of the witness statements.

Without objection, your full statements will be made part of the record. But I would be delighted to hear your summary of your statements before we go to questions.

Before us today we have Mr. Jim Thomas, Vice President and Director of Studies for The Center of Strategic and Budgetary Assessments.

We have Dr. Hans Mark with The University of Texas at Austin.

We have Mr. Jean Reed, Distinguished Research Fellow at National Defense University, with some prior association with this committee.

And Mr. Alfred Berkeley, chairman of Pipeline Financial Group, who is a member of BENS, Business Associates—Business Executives for National Security.

Again, we appreciate all of you being here.

Mr. Thomas, if you would like to begin.

STATEMENT OF JIM THOMAS, VICE PRESIDENT AND DIRECTOR OF STUDIES, CENTER FOR STRATEGIC AND BUDGETARY ASSESSMENTS

Mr. THOMAS. Thank you, Mr. Chairman, for the opportunity to appear before the subcommittee today.

In my testimony this afternoon, I will describe some of the major security challenges we are likely to face over the next 2 decades, outline potential discontinuities in future warfare and their implications for defense planning. And finally, I will suggest some capability areas that may appear as growth opportunities for investment.

The United States, as you know, is facing a multitude of threats. But three principal securities challenges stand out: Dealing with the rise of China, defeating violence extremism, coping with radicalization and destabilization in key countries around the world.

And finally, preparing for a world in which there are more nuclear armed powers. The geographic nexus of these three challenges is the Indo-Pacific Region, stretching from the Persian Gulf around the Malay Peninsula to the Sea of Japan, where high economic growth rates are likely to fuel continued regional increases in armaments and intense resource competitions that could jump the track into the military domain.

Potential changes in warfare will also affect how we deal with these challenges.

First of all, American power projection in its familiar forms could become obsolete as countries like China and Iran acquire extended-range, precision-guided weapons, advanced sensors, and the means to attack opposing electronic systems, thereby creating anti-access or area denial zones.

The second is that proliferation of guided weaponry and nuclear weapons makes the prospect of large armies invading other countries less likely, while coercive missile campaigns and cyber warfare may become far more likely.

The third is that conflicts will extend into the global commons of the high seas, air, space and cyberspace. These are areas where the United States traditionally has dominated.

And the fourth is that the United States is in danger of losing its lead in critical military technology competitions, such as cyber, precision warfare and directed energy.

These continuities have several implications. Above all, future environments in which U.S. forces are likely to be—above all, future environments in which U.S. forces operate are likely to be far less permissive than in the recent past.

High signature forces that depend on theater air bases, large naval surface combatants, sizable ground formations, and large footprints of logistical supply through ports and airfields, as well as satellites and low earth orbit and geostationary orbits and computer networks, will all be far more vulnerable.

DOD [Department of Defense] should maximize investments and systems to perform under a range of nonpermissive conditions while minimizing investments and systems whose optimal performance depends on relatively benign operating conditions.

The United States and its allies must also improve their ability to counter coercion and more ambiguous forms of aggression, encouraging allies and friends around the world to field their own anti-access and area denial systems, including active and passive defenses, as well as precision weaponry, could enable them to withstand coercive efforts by local hegemonic aspirants.

Finally, U.S. research and development and intelligence efforts will need to be more closely intertwined to prevent technological surprise. Fostering creativity and experimentation within the U.S. military will maximize the odds of discovering the next big thing in military innovation before our adversaries do. In light of these implications, eight capability areas look particularly attractive: Countering or eliminating nuclear and biological weapons; operating from range and penetrating into denied areas to conduct surveillance and strike missions; defending against ballistic missile and shorter range guided rocket artillery, mortars, and missiles, otherwise known as G–RAMM systems; conducting special reconnaissance, direct action, and unconventional warfare in denied areas; conducting unwarned land attack, sea denial, and reconnaissance from undersea; channeling or controlling access and movement via non-lethal weapons; disrupting, deceiving, or negating the sensors and processing capabilities of hostile powers; and finally, building up the capacities of key allies in friendly states around the world, not only for internal defense, but for external defense increasingly as time goes on.

In closing, let me express my appreciation to the committee for its efforts to raise the level of discourse and awareness on these important issues. There is absolutely no question as we—looking at our current fiscal woes—that we are entering an age of austerity and that tough choices face DOD in the years ahead. But there still will be an imperative on protecting the seed corn of the Department, especially in R&D [Research & Development] and making sure that we are making prudent investments to maintain our military edge.

Thank you.

[The prepared statement of Mr. Thomas can be found in the Appendix on page 37.]

Mr. THORNBERRY. Thank you.

Dr. Mark.

STATEMENT OF DR. HANS MARK, PROFESSOR, AEROSPACE ENGINEERING AND ENGINEERING MECHANICS, JOHN J. MCKETTA CENTENNIAL ENERGY CHAIR IN ENGINEERING, UNIVERSITY OF TEXAS AT AUSTIN

Dr. MARK. Here we go.

Mr. Chairman, and members of the committee, I am very honored and humbled to be here. I don't have a broad view of this situation.

I am a professor at the University of Texas at Austin, Mr. Chairman. And I used to be chancellor; I think I may have signed your degree, if you are——

Mr. THORNBERRY. I think you may be right, Dr. Mark. So it makes it even more valuable.

Dr. MARK. Look it up, all right?

So what I am going to do is talk about some personal things and personal opinions. I don't have a background in organized things like this.

I do agree with my predecessor here that China and terrorism and the Persian Gulf are important issues. China, I think, is the most serious existential threat to the United States, because if they decided to do so, they would become another Soviet Union. Fortunately, they are very different from the Soviet Union. They don't have an ideology that had some purchase around the world for some years.

And I think that their strategy will rather be to become, first of all, the world's first economic power. And then what they are going to try to do, I think, limit our access to the western Pacific and maybe even more. In short, they are going to build a navy.

We have ways to respond to that and I think that the issue of sea power in terms of military capability has to be—has to have the highest priority in what we are going to have to do, and that is supported by air and space power.

The policy I think we should adopt toward China is what the principal Chinese military philosopher, Sun Tzu, once said, that the best way to defeat an adversary is to persuade him not to fight. And I think that we ought to take positions that reflect that view.

And finally, I think we need to make alliances. We have a strong alliance with Japan. I think we ought to make a very strategic strong alliance with India. Technology has a place in that, in India especially. We should share technology with them.

In the Persian Gulf, the case of course is very different. There is also an existential threat there, which is not now based on the possession of nuclear weapons, but based on the possession of an oil resource that we may lose. And what that would mean to the industrial world is serious.

The United States doesn't depend that much on Middle Eastern oil, but the rest of the world is more dependent, Europe and other regions.

I think in the case of the Persian Gulf, we need to go back to what President Carter said in his 1980 State of the Union message where he said, "The Persian Gulf is an area of vital interest to the United States. And we will see to it that the flow of oil will be maintained, even if it takes military force." That was in the record, said in so many words. And I think that is still true, two-thirds of the world's known easily recoverable oil resource is still there.

And you will remember that perhaps back in 1987 or 1988 we actually did put our ships at risk. And we kept the pipelines—the communication line—open. I think that the Persian Gulf eventually will solve itself as other energy sources become available.

And so it will decrease in importance, but we still need to keep the 5th fleet there, for example. And make sure that we are in a position to influence things in a military fashion if we have to.

Finally, there is terrorism, and I have been very uncomfortable with the formulation of the war on terror. But terrorism is a military tactic, it is not an enemy. And there are terrorist groups around the world that we deal with, have to deal with. We have the FARC [Revolutionary Armed Forces of Colombia] in Colombia. You have the Mexican drug cartels. You have got Al Qaeda, of course. But there are lots of terrorist groups.

And I think the civilized world has to say, "Look, terrorism is unacceptable." And we have to make that an international effort somehow. I think we have done pretty well at it, as a matter of fact.

I think if you look at the various terrorist movements that have come and gone, it is a record of some success. I notice there is a red light blinking here, which I think tells me that I am overrunning my time.

What I want to do in the question period, if I may, is to talk about some technologies that are on the horizon, that are relevant to the points that I have made and that you have also made.

So, thank you very much, and I will quit here.

[The prepared statement of Dr. Mark can be found in the Appendix on page 49.]

Mr. THORNBERRY. Thank you, Dr. Mark.

The time is to try to give you a guidance for how far you are. But I do want to get back in questions to the capabilities you talked about in your written statement, quantum computing and other things.

Mr. Reed.

STATEMENT OF JEAN REED, DISTINGUISHED RESEARCH FELLOW, CENTER FOR TECHNOLOGY AND NATIONAL SECURITY POLICY, NATIONAL DEFENSE UNIVERSITY

Mr. REED. Mr. Chairman and members of the subcommittee, it is an honor to be here today. And a personal pleasure to be back in this room to speak to you about some of the potential emerging and future security threats and challenges facing the United States and the Department of Defense.

My remarks today will focus on future technology threats that I see and general trends with regards to areas of emphasis. They reflect my own views, not necessarily those of the National Defense University, the Department of Defense, or any other organizations with which I am affiliated.

Throughout history, planners and strategists have had a tendency to consider future threats within the context of what they knew about the current threat. Thinking about science and technology has been similarly linear and compartmentalized, with projections within any scientific discipline being based on past progress.

As a result, planners and strategists have been repeatedly surprised by the application of new technology to warfare, whether actual or economic, by the advantages conferred, by the unique com-

binations of different technologies, and by the non-linear, often exponential, advances in science and technology.

Examples abound. In 1921, General Billy Mitchell demonstrated the vulnerability of battle ships to bombs, but our navies of the world ignored that. And then the combination of aircraft, highly mobile armor, and radio, known as Blitzkrieg, took the allied armies by surprise at the beginning of World War II.

More recently, the use of precision-guided munitions, armed drone aircraft, and satellite GPS [Global Positioning System] positioning has changed the complexion of today's battlefield.

Unfortunately, we have also experienced the advantages that can be gained by ingenious use of low technology as well, such as delivering biological agents via the postal service, flying passenger planes into buildings, or improvising roadside bombs.

Within the context of the Cold War, planners on both sides had a degree of confidence in the technological capabilities of their counterparts. Science for its part was highly disciplinary and progress was largely made in incremental fashion within a given discipline that allowed for reasonably accurate planning and the ability to integrate new advances into weapons platforms and defensive systems.

Times have changed and three things have changed with that. First, the demise of the Soviet Union and its replacement by new transnational adversaries. Secondly, science underwent a dramatic paradigm shift in which trans-disciplinary research with its ability to affect exponential advances within disciplines, and in fact create entirely new disciplines, became the norm.

And then third, information has become ubiquitous, allowing individuals access to technology on an unprecedented scale. The world, in short, is a much more unpredictable and chaotic place, and the emerging threats are equally problematic.

The spectrum of emerging threats has been enlarged by both the exponential advances in scientific knowledge and its availability to a broader range of potential bad actors that no longer need to have advanced scientific training. Deciphering this threat spectrum requires a robust investment in science and technology, particular in its evolving trans-disciplinary paradigm.

The concept of technological convergence is critical to understanding future threats, as there are some scientific disciplines which will be radically shaped by their convergence with other areas.

The disciplines of nanotechnology, biotechnology, information technology, and cognitive neuroscience are four areas which will be pivotal in this anticipating and countering future threats, and I have addressed them in my written statements.

In the interests of time, I will confine my oral remarks to biology, where convergence—where the classic example of technological convergence—is the convergence of genomics and information technology, which has led to the sequencing of the human genome, and which will be the basis for personalized medicine.

But the flip side is the ability to alter the genomes of pathogenic organisms to create entirely new biological threat agents not found in nature. The ability to predict and plan for such optimal techno-

logical convergences will largely determine the technological leaders of the 21st century.

How to predict and plan for such an outcome is the question, and some of my colleagues at the National Defense University have suggested navigating through this increasingly complex environment using foresight, a structured way to think about evolving trends and security challenges, a disciplined analysis of alternative futures that could provide decision makers with the understanding needed to better influence the future environment.

I believe that the DOD has recognized the changes in the threat landscape and understands the paradigm shifts, which have changed both the way science is conducted, and also its potential to generate new threats.

There is also a clear awareness that the DOD needs to continually invest in its laboratory infrastructure, both physical and human capital, in order to stay abreast of exponentially increasing scientific advances. And perhaps more important, to invest in training the next generations of scientists and engineers.

While it is virtually impossible to predict *a priori* what the future threats will be, maintaining clearer scientific superiority with the strategic investment based on strategy—technology convergence—offers the best chance to drive and exploit scientific advances and to anticipate and respond to new threats.

Mr. Chairman, this completes my prepared remarks. And I will be happy to answer your questions.

[The prepared statement of Mr. Reed can be found in the Appendix on page 63.]

Mr. THORNBERRY. Thank you.

Mr. Berkeley, thanks for being with us.

STATEMENT OF ALFRED R. BERKELEY III, CHAIRMAN, PIPELINE FINANCIAL GROUP, INC., MEMBER, BUSINESS EXECUTIVES FOR NATIONAL SECURITY

Mr. BERKELEY. Thank you for having me, Mr. Chairman, Ranking Member Langevin——

Mr. THORNBERRY. If I could get you to hit your microphone, please?

Mr. BERKELEY. Sorry.

Thank you for having me.

My name is Alfred Berkeley. I am here as a private citizen. I have not read the Quadrennial Defense Review. I was asked to come and give the perspective of businesses, particularly businesses in the technology arena.

I have had the privilege in my life of being an investment banker and a research analyst following such companies for 24 years and working at the NASDAQ [National Association of Securities Dealers Automated Quotations] stock market for 7 years, essentially raising capital and providing a secondary market for some of the leading technology companies in the world.

I will tell you that I hope my comments will complement the remarks you have heard before. They are going to be a little bit different. The businessmen that I talk to see six threats.

They see one goal. They see six capabilities that ought to be developed. And they have a very specific "ask" of what the Government needs to do to make it all work for business.

The six threats, first, there is an enormous concern that as a country we are not providing enough economic opportunity to build a committed citizenship, a committed populace.

We had the wisdom 100 years ago of the Homestead Acts where our forefathers knew that wave after wave of immigration, particularly from class-stratified and disenfranchised people in Europe, was not a good basis for building a sound citizenship—citizenry here. We wanted to get into the hands of as many people as we could the ability to make a living and the ability to own some productive assets.

And in the agricultural age, 40 acres and a mule was a good way to do that. In the industrial age, stock options were a good way to get people a piece of the pie. In the information age, it is probably all about education.

I had dinner last night with yet another large company executive, who—and I was telling him why I was in Washington—and he said, well, you are going to talk about the education problem, aren't you?

And that is the recurring theme that I hear from business that we are losing our edge, not just in STEM [Science, Technology, Engineering, and Mathematics], but also in the basic desire to hold education as a revered, respected use of time for young people.

So I would encourage you, using the tremendous analytical capabilities and the enormous educational requirements that the military has, is to learn what the science is of how people actually learn.

Where is the science in our States' implementation? We have a federalism issue, obviously, with education. But we need to figure out how to get more people actually learning.

And that is the biggest single business concern that I bring. I realize it is not typically thought of as a DOD issue. But because DOD has such massive intellectual capability to do good science and get good analysis, I bring it to you.

The second thing that businessmen talk about repeatedly is in energy independence. I won't elaborate on that. The third problem is cyber espionage, particularly theft of our intellectual property.

In my industry, the financial services industry, the big topic is cyber theft of money and the trillion dollar drain that we have on our financial system just by rampant theft.

So the two cyber issues, cyber industrial espionage and cyber theft, are high on businesses' list.

The War on Drugs is next. We are not winning the War on Drugs. We are doing something wrong; we need to rethink that.

And the last point would be that we are in a long economic war. That the warfare is a continuum and it starts with economic war. It is a relentless—it is 24 hours a day—it doesn't stop, and we need to figure out what to do about it.

In terms of capabilities, in preparation for coming here I asked a number of businessmen what they thought the opportunities were for capabilities and one of them said to me, "Why don't we wipe out the language barrier?" Ever since the Tower of Babel and

the philosophy of the mythology of languages being developed, the strangeness of language has led to fear and uncertainty among peoples.

We are on the edge of computer science that will allow every language to be translated into every other language. We should think about language not as something that is just there, but as something that we can take and make a positive tool out of—a weapon for good, if you would—by making it clear to people.

The education issue I already talked about. We can, in the digital world, take education all over the planet. We can provide the best education that ever existed. We can do the same for medicine.

An enormous new battlefront is growing up in what is called near-field communications. It is the next generation of cell phones. All the current cell phones are now being built with the capability to hold the cell phone close to an RFID [Radio-Frequency Identification] tag and read from that RFID tag. And it is going to create billions, if not trillions, of new addressable locations and information associated with them.

We should think of that as a brand new opportunity where we have the opportunity to seize the hearts and minds of people by adding value to their lives by not letting someone else usurp our lead there.

So I am out of time, and I will take questions whenever you want.

[The prepared statement of Mr. Berkeley can be found in the Appendix on page 74.]

Mr. THORNBERRY. Thank you.

I appreciate it, all of you.

Mr. Berkeley, I can't help but reflect that in the mid to late 1990s, President Clinton and Speaker Gingrich put together a commission that worked over 3 years to look at national security challenges.

At the end of that time, the top two they came up with is proliferation of weapons of mass destruction, and recommended a Department of Homeland Security as a result.

But the other one of the top two was math and science education as a national security issue. So you are, you know, in good company, not that we have improved since in the last decade, but I think it is important to keep talking about that as a national security issue.

At this point I would yield to Mr. Langevin for any opening statement, as well as questions he would like to ask.

STATEMENT OF HON. JAMES R. LANGEVIN, A REPRESENTATIVE FROM RHODE ISLAND, RANKING MEMBER, SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES

Mr. LANGEVIN. Well, thank you, Mr. Chairman.

And I want thank our panel for being here and for your very thoughtful presentations here today. I certainly look forward to hearing more about your expert views on how the Department of Defense might shape the strategic planning efforts to maximize research and development investments to meet our future national security needs in a fiscally constrained environment.

This year, of course, our subcommittees has held a number of hearings to better understand the Department's near-term investments in technology capabilities that address current threats in Iraq, Afghanistan, and a number of other countries.

Now, a significant portion of those investments over the last decade have been focused on technologies to transform our military to prosecute the war on terrorism. Now, we have had some successes with fielding MRAPs [Mine Resistant Ambush Protected vehicles], UAVs [Unmanned Aerial Vehicles], ISR [Intelligence, Surveillance, and Reconnaissance] and medical capabilities.

However, we have stepped back from fully developing major transformational technologies, such as the future combat system, joint strike fighter, and the presidential helicopter, just to name a few.

And as you know, these programs and others are likely to have cost us billions, now with little to show for it. Considering the cuts in the defense budget are currently projected to be over $400 billion during the next decade, I believe it is absolutely vital to spend more wisely. Now these prudent and deep cuts, however, must not undermine our capability and our ability to maintain our current defense posture globally.

They must not jeopardize our ability to quickly adapt to future geopolitical environments that are stressed by rising powers, population changes, competition for resources such as food, water, energy, climate change, and other shaping factors that we hope to hear about from our experts today.

Again, from our earlier hearings, this subcommittee is familiar with the Department's current investments in technologies to combat violent extremists. We have heard a lot about investments and policy directions with regard to cyber security, as well as the Department of Defense's efforts addressing the threats of weapons of mass destruction and our challenges with global strategic communications.

These are all critically important problems and security challenges that are facing us today. However, given the factors I mentioned earlier and the potential impact on our future national security needs, we are investing—we have to make sure that we are investing in the right technologies and that is a significant question that we posed, to meet the future threats as well.

Are our national security and defense strategies are aligned appropriately to guide future investments? And should we develop an interim Quadrennial Defense Review now, or wait until the next full review? Your thoughts on how DOD might reform its current cumbersome program, budget decision process, to plan future technology development strategies and investments would be helpful. And I know the members of this subcommittee would benefit from your expert opinion.

I also would be interested in your thoughts on how the Department might improve the overall management of the defense research, engineering, test and evaluation program, both within the Pentagon and throughout the research engineering enterprise.

For example, what technologies should the DOD continue to lead investments in, and where might we better leverage industry and our foreign partners instead.

With that, I just want to thank you once again for being here, for your time today. And I look forward to the questions and answers.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Langevin can be found in the Appendix on page 35.]

Mr. LANGEVIN. Thank you, Chairman. Again, Chairman, I want to thank you for holding this very important hearing and it is a very timely topic.

My first question for the panel, what are some of the technology areas in which the U.S. no longer leads, or will lose the lead in the next 5 years?

Whoever would like to start.

Mr. BERKELEY. Well, I would start with one, which is ballistic missile lift capability for satellites in international laboratories.

Mr. REED. Almost all the U.S. semi-conductor production is offshore. The production within the United States of advanced semiconductors is sorely limited.

Mr. BERKELEY. Virtually no computer screens are manufactured in the United States.

Mr. LANGEVIN. Anyone else.

Mr. THOMAS. I would just touch on directed energy. And this is an area which has enormous potential as a military game changer as we look ahead.

But the scenario which the United States probably is underinvesting in relative to some of its competitors out there, countries like China and even Russia.

Mr. LANGEVIN. Do we no longer lead in these areas, or are we—would you assess that we are in danger of losing the lead within an area in the next 5 years?

Mr. THOMAS. I think in with respect narrowly to directed energy, I think our lead in there is questionable at best.

Mr. LANGEVIN. Thank you.

For which technologies does the DOD need to lead research and development? And for which technologies can the DOD rely on industry and the commercial sector to lead research and development?

Dr. MARK. May I try to answer that? I think that on the directed energy question, my colleague here is a little pessimistic. I think we have done things that are truly unique and I think have future potential.

I am talking here now about a program in which I was personally involved, and that is to put a big laser on an airplane and to shoot down some ballistic missiles. We have done that. And we have done it for ranges that are of military interest. They are classified. I can't tell you what they are.

But we have shut the program down and we did it to ourselves. We have a lead in that area and we stopped. So I think that you agreed? Yes.

Let me talk about some things that I personally have been involved in in the computer area. The computer is nothing but an assembly of switches and storage devices, information storage devices.

And the ability to make very capable computers depends on how many of these you can put in a volume that you can handle that is small enough. And the technology that is on the horizon today I think is, in my mind, anyway, the most interesting new step that we are taking, or we can take, where we have the clear lead. And I am talking about what has come to be called Quantum Computing.

I don't want to go into the technical details, but just to confirm that we are in the lead, our current Secretary of Energy, Steve Chu, won the Nobel Prize in Physics in 1997 for essentially inventing the—I shouldn't say invent—for discovering the phenomenon that makes these devices perhaps possible.

Now, what I am talking about? A current transistor on a chip is about a nanometer in dimensions, between 1 and 10 nanometers. That means it is between a 100,000 and 1 million atoms. You need that many atoms to control a current, an electric current.

What Steve Chu showed is that you can influence single atoms if you can capture them and keep them steady to store information. Our estimates are that you might be able to make computer elements, not out of a million atoms, but about of a few hundred. And so, you have orders of magnitude of computer capability that we may be able to get.

The interesting thing is that some tantalizing experiments have already been done. A fellow by the name of Shore built one of these devices that works with a very small number of atoms and discovered that you can factor large numbers very much more rapidly than you can with an existing computer. The National Security Agency is very interested in random number tables, because it is these tables that allow you to initialize a decoding procedure. Well, this guy has a computer that can generate these tables in a time that is much shorter than what we have now.

So I think there is something on the horizon here that we are pursuing and we will continue to pursue. But I think my guess right now is we are investing probably about $70 million a year in that.

It is not really necessary to put a lot more money into it, but there are some things that aren't being funded. And the point is that by increasing that by 50 percent, you might find the one person that has the good idea.

We are not at the place where money is terribly important yet. We are at a place where I think we—by doubling the investment that we have for something like that—we might make more rapid step-wise progress.

Mr. LANGEVIN. Any other member of the panel?

Mr. REED. In my statement, I talked about nanotechnology, biotechnology, information technology and cognitive neuroscience as being areas of emphasis, an increasing emphasis within our research and development program, our science and technology program.

But the fact that you can get things for good coming out of that, as well as things for bad, depending upon how the technologies are applied, it is important that we take means to ensure that the things for good are coming out and that we can detect when there are cases of the potential for things bad coming out. And the tech-

nology getting into the hands are being put to use by someone who can do us harm.

That is a both an intelligence problem, but it is also a problem within the teaching and the education process. We are still the focal point for education of sciences, scientists, and technology in the United States. We have that edge.

But if you look at the youngsters, if you will, who are participating in that, there are a number of Third World countries represented and they come, they go to school, they may stay. But they may very well go back to their own home.

What we want to do is to make it, I think, in one case, is to make it attractive for them to stay within the United States and work within the U.S. research and development infrastructure. Problem, look at the industrial research and development infrastructure in the United States, what was there and what is not there today.

The General Electric laboratory in Pittsburgh, the last time I was in there about 10 years ago when I was on the staff of this committee, there was an activity associated with, I believe, General Dynamics, that was doing chip-growing there. They were canceled out. But the only other thing in that massive research and development facility was a Siemens research activity.

All of that activity, gone. Bell Laboratories in Whippany, New Jersey. When I was commanding a laboratory at the Picatinny Arsenal back in the mid-1980s, that was a mecca. It was a mecca for research for years and years and years, and it is gone and in the hands of another activity.

Certainly industry has to build to the bottom line, but there is a—we are not doing something right in this area if we are letting our research and development—industrial research and development—and the departmental and interagency research and development lose the support that it must have if we are to maintain the cutting edge of technology in this globalized world.

Mr. LANGEVIN. Okay. I thank the panel.

Unless there is someone else who wants to add in, I will yield back.

Mr. THORNBERRY. I thank the gentlemen.

Mr. Franks.

Mr. FRANKS. Well, thank you, Mr. Chairman.

I am trying to figure out the order of procedure here with this new process. I guess I got here before anyone else does. So I will be glad to defer to Mr. West, if he is prepared for questions?

Mr. WEST. Thank you, Mr. Franks.

And thank you, Mr. Chairman.

And also our Ranking Member.

Thank the panel for being here today.

And I am glad, Dr. Mark, that you and I agree on something. I think war on terror is a terrible misnomer. We did not go into World War II to fight the Blitzkrieg nor the kamikaze. So we have to have a strategic level perspective.

This past weekend I had the great opportunity to go visit the Special Operations Command and Admiral Olson, who as you know will be changing out command and retiring in about a couple of weeks.

And what we ruminated on was the incredible advance in technology. When you go back and you think about the failure of Desert One, to now today where we were able to execute a zero illumination cross-border attack into Pakistan and take out the world's number one terrorist. And also capture that completely on video and also the use of the new biometrics.

I recall going—I spent 22 years in the United States Army, just so everyone understands my background. But I remember, you know, sitting down, reading writings such as Francis Fukuyama about the end of history. And then also Samuel Huntington, who talked about the clash of civilizations remaking the world order.

And a lot of people didn't pay any attention to that. When the Soviet Union collapsed, everyone was cheering and talking about how that was going to be a new state and no one projected out what would happen as far as the world and how that order would change.

So, my question to you looking at where we are today and from a warrior's perspective on the ground, if I were to lock you four very astute gentlemen into a room, as we should/would do army planners, and tell you that you could not come out until you gave me the top two or three threats to this country and its national security as you move forward, what would be those top two or three threats that you would present?

Mr. THOMAS. Sir, if I might begin and I guess to answer your question, I would start by saying the United States is in a very different time than we were in 1950, as people like Paul Nitze were writing NSC–68 [National Security Council Report 68]. And you could focus on one overarching threat for your defense planning. We face a panoply of threats, and we are going to for the future.

So then I think you would start to think about, well, what threats are essentially overarching? And if you are able to deal with those challenges, it actually buys you fungible capabilities and forces that you can apply elsewhere.

And there, I guess I would really say there are three. I mean, if you have the capabilities to maintain a stable military balance vis-à-vis China, those capabilities are fungible for other source of anti-access, area denial challenges you would face around the world.

If you have the capabilities to locate, tag, and track dangerous individuals and to pursue groups like Al Qaeda and other non-state actors, those capabilities are fungible for a range of other problems that you might face as with radical elements around the world.

And finally, we once thought a lot about nuclear weapons and guys like Thomas Schelling, more than half a century ago, and Bernard Burney, thought about what our strategies would be in a nuclear world.

We are now entering a second nuclear era with new nuclear powers, such as North Korea and Iran, and we are going to have to think about regional nuclear balances. And this is an area where we are going to have to do it. And building those strategies for countries like North Korea or Iran, again, will be fungible in other areas.

Dr. MARK. Yes, let me continue the discussion of nuclear weapons, because I spent 14 years in that business between 1956 and

1960—1970, I am sorry. And you are absolutely right. That is, nuclear weapons are not going to wait. And our problem is to maintain, under very difficult technical circumstances, the stockpile that we have.

We have not tested a nuclear weapon since 1993, and we have not developed a new design in spite of the fact that there is a vast increase of knowledge in technologies that pertain to nuclear weapons in that same period.

I served as Director of Defense Research and Engineering in the second term of the Clinton Administration, and I, for various reasons, I also wore the nuclear hat, because the president decided to abolish the nuclear job in the Pentagon. And they came to me and they said, "You are the guy that knows something about nuclear weapons, so you do the job." So I had two jobs, actually.

The reason I make this point is that we started the program in that time which said our nuclear stockpile today is decaying. We never built a nuclear weapon with a shelf life in mind, how long we would keep them, because as soon as we deployed one set, we would start a new generation.

We managed to persuade the Clinton administration to put a fair amount of money into refurbishing the stockpile, and then we also initiated an idea of building a new weapon entirely without having to test it.

That is, the weapon would have to be compatible with our delivery systems, it would have to be safer than the current weapons that we have in the stockpile, it would have to work without being tested.

We started that program. We put some money into it and actually ran a competition between the two nuclear weapons laboratory, and we have a completed design, and then we stopped it.

I think that the nuclear issue has to do with the fact that we need to maintain technological leadership in that area, and that is the only way that we will be able to, I think, deal with people who try to threaten us.

Mr. WEST. Thank you.

Mr. Chairman, Ranking Member, I yield back.

Mr. THORNBERRY. Thank the gentlemen.

Mrs. Davis.

Mrs. DAVIS. Thank you, Mr. Chairman.

And thank you, gentlemen, all for being here.

I wonder if you could, Mr. Berkeley particularly, go a little further in terms of the education piece and, perhaps people would suggest that we are talking more about soft power, smart power? And how do you think that the Department of Defense could be or should be using that intellectual capability that you speak of to add greater value to our learning, to the schools and, perhaps, you are speaking more in the sciences?

But where do you see that piece? And where have we either felt that it is not appropriate perhaps for the Defense Department to be adding that value in some ways? Or what is it that kind of keeps us from looking at this particular issue in this way?

Mr. BERKELEY. I think you are on to one of the most interesting questions. I don't, for a second, want to give the impression that

I don't think we shouldn't have a steel fist, a nuclear capability, a directed energy capability, whatever it is.

I think we need steel fists, but I think that maybe a short story will illuminate the thinking. I ran into John Negroponte in the Zurich Airport last January, and I happened to have another fellow there with me that I didn't know well, but I had met. And I said, "John, I would like to introduce you to the most powerful man you have never met."

And he had looked at me sort of startled, and there was a young man there in is 30s. And I said, "I want to introduce you to the director of research at Facebook. He can talk to 500,000 million at once."

I actually think that the battle space is being dramatically expanded and the most powerful weapon that we have is something called the cell phone, and it is because so many hundreds of millions of people are going to be able to get information through it.

And I think that the idea of having an "All Education, All the Time"—remember "All News, All the Time" at KYW in Philadelphia? "All Education, All the Time," where no matter where you are in the world, you could get yourself educated. Or "All Medicine, All the Time," where no matter where you are in the world, you can get yourself some knowledge about diagnosing symptoms.

Those kinds of soft power issues may be able to preclude the fear and uncertainty, the doubt, mistrust and jealousies that lead to simple ideological conflict.

So the question about where the military fits in is that the military has—it is a nation-state unto itself, in that it has schools, it has to train its people, it has to be sure its people's children are trained and it can do the science. It can lead the way. I am not saying replace what the States are doing, or replace what the Department of Education is doing.

I am saying give a shining example that is so visibly powerful because it is intellectually rigorous and proven, that it becomes a standard if it deserves to be the standard. So I want the science done. I want the research done, and it doesn't take marshalling all the States to do that.

I happen to have been on this issue of the 18- to 24-year-old cohort. I happen to have been responsive to General George Casey's call for a number of business people to come to West Point and spend 36 hours talking about this issue. And you should take a look at what Lieutenant General Ben Freakley is doing in South Carolina and several other states, Oklahoma also I think, to bring some Army resources into the elementary and secondary school system for the purpose of keeping people in school.

It is not necessarily a STEM effort, but it is of the 25 or 30 programs that the Army does offer school systems, ranging from ROTC [Reserve Officers' Training Corps] to send you some pamphlets. They are trying to push the limits and say, "Okay, can we affect the staying-in-school issue?"

I want to go a lot farther than that. I want to understand the neuroscience of how people learn. How many repetitions does it take to get something into long-term memory? It is a physical thing——

Mrs. DAVIS. In politics, seven, the rule of thumb, so that is——

[Laughter.]

Mr. BERKELEY. But the Army—okay, you understand.

Mrs. DAVIS. Right. Yes.

Mr. BERKELEY. It takes a lot of repetitions to get things into long-term memory. My understanding is that most American curricula give about half the repetitions it takes to get something into long-term memory. Therefore, 3 weeks later, the child doesn't remember.

Dr. MARK. I wonder if I could follow up your comments, because I teach the freshman course in our Aerospace Department. I have 140 students every year, every semester. Their question is, "What is the DOD doing about education?" And the answer is a lot.

For example, we have defined—I was on a committee a couple of years ago or more, 4 years ago—that defined the area of systems engineering to be something that is in trouble within the Department of Defense, because we have spent much too much time on the process, rather than on the technology.

And so, if you look at the schools that are looking at systems engineering, I think they are probably part of the problem by making complicated rules.

This same Defense Department, then, when we pointed this out to them, gave us a grant of half a million dollars to get started on a systems engineering course in our department that we are just starting to teach, that will be the other end of this freshman course that I teach, where we will do hands-on problems, where the students must learn how to do engineering tradeoffs, where they must learn how to work in engineering teams, where they must learn how to influence a customer. That is, how you sell your product?

And I think that the Defense Department is aware of the importance of education and if you do the right things, they will provide the money.

Mrs. DAVIS. Thank you.

Thank you, Mr. Chair.

Mr. THORNBERRY. Thank you.

Mr. Franks.

Mr. FRANKS. Well, thank you, Mr. Chairman.

Thank all of you, gentlemen, for being here. You are sort of that invisible frontline of freedom, and we appreciate your intellect and your commitment very much.

I was intrigued, Mr. Thomas, when you mentioned earlier about the threat from technological surprise, and I guess the line of questions I would like to begin with is just to suggest that perhaps the surprise may be from an old technology that is applied in a new way.

And as you know, there has been some recent reports, or recent information declassified, related to China's EMP [Electromagnetic Pulse] capability, not only to create IEMI [Intentional Electromagnetic Interference], but also their preparations for hardening their own grid and other facilities in case there is some type of disagreement over the Taiwan territory. So with that in mind, I guess, I would ask a couple of questions.

First of all, in light of the last few reports on EMP and its potential danger to our electric grid from FERC [Federal Energy Regulatory Commission], from National Academy of Sciences, from the

Department of Defense, and there is just six or seven of them that all seem to have come to a very common conclusion that this represents a pretty profound threat to us.

Now I would like to, first of all, find out if there are anyone on the Committee that either agrees significantly with that or disagrees with it. What do you think the potential threat to our grid? What does EMP represent in terms of potential threat to our grid if it was—say we will start off from a geomagnetic storm and then progress to a high-altitude nuclear burst?

Mr. THOMAS. I think it would be very difficult to overestimate the severity of the threat that could be posed by electromagnetic pulse devices. What is particularly interesting is research that is going on around the world looking at non-nuclear electromagnetic pulse and, particularly, microwave devices.

Given our dependence not only as a society, but as a military on advanced telecommunications and networking capabilities, we, of course, are particularly vulnerable both in the civil regard as well as in a military regard.

And this is something on the military side I know is really an animated point right now in terms of how we think about conducting operations in the future, potentially in denied communications environments.

This is not only a technical challenge in terms of how we think about going back to old-fashioned modes of communication, like line of sight, but also for our precision navigation and timing, how we will operate, but also how we will adopt mission-type orders, as we did in the past, so that our forces can self-form networks and continue with commander's intent long after their communications back to higher headquarters had been eliminated.

Mr. FRANKS. Well it seems to me that if Iran gained a nuclear weapons capability today, that our—we would be fairly intent on trying to harden our grid immediately. It seems like that will be something that we would want to do right away.

Given some of the technology discussed in some of the released information related to China, that is much smaller warheads can be enhanced and have a much greater capability in terms of its EMP application.

I am going to run out of time here. By the time I ask this question, you guys will—what I would like to do is let me ask one question and hope that each of you, as you feel led, will address the question.

What do you believe that we should be doing about either defending against or preparing for the Iranian nation or others that could potentially gain this capability? I am going to stop there.

In other words, I know that even with China's growing capability, that perhaps the indications are that we might not have as much to worry about their intent, as we may have to worry about Iran.

If Iran gained a nuclear capability today, knowing that they have done some exercises that seem to be EMP related, what would be the best thing that we could do to defend ourselves against that, and how serious do you take this threat? And I will start over here with Mr. Berkeley and go left, even though it is hard for me to do that.

Mr. BERKELEY. Well, I think the structure of that answer it gets at the question of what is the right role of Government and what is the right role of business? And if you look back to the example of Civil Reserve Air Fleet, where the jet fleet was introduced with a lot of Federal help to build capacity and those planes where then available, for example, during Vietnam for troop transport, are available during national emergencies. That was a pretty good tradeoff between the public and the private.

So if you want a hardened grid over and above what the economics dictate from the business community, I think it is sensible for the Government to pay for that hardening and then have a call on that capacity when they need it.

Mr. REED. I would branch on the threat as you have portrayed it by saying that one of the things you also need to be very concerned about is the potential threat to the electronic grid, and to almost every place that we are using electronics, from cyber warfare.

And that that, in my personal view, is probably a more likely threat that we ought to be—or let me say equally as frightening in terms of the overall effect that we could—that would occur, and it could be done a lot more surreptitiously than in an overt nuclear strike.

Dr. MARK. Yes, I would agree with that, and I have spent a fair amount of time thinking about EMP. And it is not as easy as it sounds. The problem is that an electromagnetic pulse is hard to control. It is not clear whether you can do what you want to do. I was present at the Starfish event in 1962, where we first discovered electromagnetic pulses. And let me tell you what happened, because it was very interesting.

The explosion was at 400 kilometers altitude and we could see it. I was sitting on the beach in Kauai at Barking Sands at the range there. And you could see it above the horizon. And we got word that the streetlights in Honolulu had been taken out. But nothing happened to the power system. The reason for this is that the particular pulse that this device emitted was tuned to the streetlights, and so it deposited a lot of energy there, but didn't do anything else.

So I am not sure that it is a weapon that you could rely on to do what you think it will do, what you want it to do. So it is there. We know how to harden things against it. The problem has always been how much do we spend on that?

Mr. THOMAS. I will just say, picking up on that, I mean at a minimum, you certainly want to harden your nuclear command and control——

Mr. FRANKS. They are already hardened.

Mr. THOMAS. And a lot of your strategic capabilities so that you have a retaliatory capability. And then when I think it comes to infrastructure, I think that, as Dr. Mark suggests, you are going to have to think about some of the tradeoffs in terms of how much is enough relative to other threats that you have to prepare against, such as cyber attacks, to take down your critical infrastructure.

Mr. FRANKS. Well, thank you, Mr. Chairman.

I think this is a subject that should be discussed a lot more. Of course if we have a nuclear burst, Mr. Chairman, you know the cyber, it's ubiquitous. We don't computer capability at all without electricity. And I hope that in the ways you all deem fit that you will look at some of the new vulnerabilities of our new grid.

The old grid during Starfish Prime was pretty much impervious to EMP, whereas the one that we have today, we have engineered ourselves into just profound vulnerability, I think.

Anyway, thank you, Mr. Chairman.

Mr. THORNBERRY. Thank you, sir.

Let me go back and pick up on several things that each of you said.

Mr. Thomas, in the beginning of your comments, you talked about, perhaps, power projection becoming obsolete and a variety of things, and then I am listening to Mr. Langevin's statement about the severe budget situation we are in and the necessity to make tough tradeoffs.

And while, obviously, the purpose of today's hearing is to think ahead, part of our brain is in the here and now and the challenges we face with spending. But my impression from your comments is that we are spending money in the wrong places now.

That a big percentage of our defense budget is going to things that are or are becoming obsolete. Is that what I should conclude? Do we need a fairly drastic overhaul of our spending priorities and to meet the emerging threats in national security and to develop the capabilities we need?

Mr. THOMAS. Thank you, Mr. Chairman. I think it is a terrific question.

Around Washington, especially in defense circles, you hear a lot of talk about tradeoffs between high-end and low-end threats. How much should we be spending and preparing for irregular warfare? How much should we be thinking about China? I really think this is the wrong way to frame a very important debate.

As we look to the future, what we see and what has come out of a lot of war gaming that we have done is that environments across the board, whether it is in thinking about advanced military states and the kinds of challenges they will pose, or it is thinking about non-state actors and what they will do, all of those environments become increasingly nonpermissive. And that is going to be true both at the high end and the low end.

And what we see is that our feeder bases are going to be more vulnerable in the future. Our long-haul communications are going to be more vulnerable. Our global logistics systems are going to be more vulnerable.

A navy that operates very close to the shores of an adversary may be more vulnerable to threats like anti-ship cruise missiles and submarines, and our ability to not only operate at range, but to penetrate into denied airspaces, remains quite limited.

So across the board, we look and see that we face these challenges. And even in the realm of a irregular warfare, as we think about groups like Hezbollah, and what they were able to do in 2006 with unguided rockets, the potential escalation in terms of the severity of their attack should they have guided systems in the future is pretty profound.

And I think if there is one theme that I really could hit on in terms of how we think about a big strategic review, it will be we really want to think about how we optimize ourselves for nastier environments in the future. And we really take a hard look at what capabilities are we acquiring or are we developing, which really depend on some very benign assumptions?

Mr. THORNBERRY. Okay, thank you.

Mr. Berkeley, I am not sure you got to fully develop your point that you made in your written statement that what business is looking for from the Government seems—is predictability. And I take it that is your primary—you mentioned one thing, business is looking to for us for. Would you elaborate on that, I mean particularly in this environment?

Mr. BERKELEY. Yes. I would be delighted to, Mr. Chairman.

The certainties that business needs come because so much about competition is uncertain. And if Government wants funding for commercially risky technology, it needs to provide some certainty that that funding will be there. And we have funded an awful lot of research on earmarks and we have done it through the grant process with relatively small, relatively short-term grants that are then have to be reapplied for. And an awful lot of the university-based science leverage that is available to the Government.

Business always looks at things as where is the leverage? Where can I get at low marginal cost get high marginal value? The single thing that the Government could do, in my opinion, would be to provide longer term predictability for funding for things that the businesses are not going to invest their own funds in, but are needed by the country.

Mr. THORNBERRY. Well, and Mr. Reed, let me ask you to pick up on that, because you talk about the need to invest in labs. From your vantage point, what grade would you give us on investing in the right things for the long term? Or has more and more of our investment been focused on short-term immediate payoff, which is an impression I have in recent years?

Mr. REED. Clearly, a lot of our current investment has been focused on the war at hand, if you look at the amount of money going in to both development of technology, for instance in terms of mine-proof or mine-protected vehicles and in the procurement associated with that. I look at the overall science and technology account and, of course, I worked that in this committee for a number of years.

I have been focused rather narrowly for about the past 5 years on the biological side of that and the medical countermeasures, and I think for the most part that, that area we have got just about right, right now. Because there is a very strong funding stream going into the biomedical arena, both within the Department and within the Department of Health and Human Services, with respect to the medical counter-measures technology development effort. And with some very smashing success. And of course, Andrew Weber appeared before this committee and talked about that earlier this year.

It is important that be sustained, because right after the nuclear threat is, in many ways, a more probable biological threat that we have got to be ready to deal with.

And that implies both the defense at the personal level in terms of therapeutics and vaccines, but also in the surveillance area and the establishment of surveillance networks worldwide, aimed not only at a potential bad actor, but also at the threat of naturally occurring diseases, and of course, that is the focus of that program, as you know.

The laboratory sustainment area, I think, is absolutely critical, and we need to ensure that we are putting enough money into the Government side of the Government laboratories, the Department of Defense laboratories, to ensure the ability to attain and retain some really world-class youngsters that are coming out of the academic environment now. And are, in fact, going to work for some of the Government laboratories.

It is almost eye-watering to see the sort of work they are going to do, but that is a fragile resource. And it is not in a time of the force coming back and having to rebuild and recock from the two wars. It is an area that will not be high priority for the military departments, for the Services, in terms of what they feel they have to spend their money on. You need to look very seriously at that, and I feel that very, very strongly. And of course, I commanded an RD&E [Research, Development & Engineering] center myself, back in the 1980s.

I know the kind of work that we were doing then. The work that is being done in the various laboratories, not only in the Department of Defense, but also in Health and Human Services and then Homeland Security and the rest of the Federal establishment, and in the universities from the standpoint of multidisciplinary research universities and in the smaller schools, as well, that needs to be sustained.

That is where the seed corn is grown, and that is where—and we need to mature or nurture and then mature that seed corn and have places for them to go to work in support of the Nation.

Mr. THORNBERRY. Okay, thank you.

Mr. REED. I will get off my soapbox now——

Mr. THORNBERRY. You are making a point strongly, and I appreciate that.

Dr. MARK. Mr. Chairman, may I add something——

Mr. THORNBERRY. Sure.

Dr. MARK [continuing]. To what my old friend, really old friend Jean, has said?

And from the point of view now of the university, where do our students go to work today? Now engineering happens to be a profession where jobs are available, not only available, they are actually looking for people to take them.

About 15 years ago, the then-new dot.com business was where the brightest kids went. Today, when my students leave and where do they want recommendations to? I can tell you the two largest, most popular places are the MIT [Massachusetts Institute of Technology] Lincoln Laboratory and the California Institute of Technology's Jet Propulsion Laboratory.

The best students now want to go into Government-supported laboratories, some of them related to national defense. For example, Lincoln is an Air Force laboratory, or mostly Air Force. So I

think that we are in a position now to take advantage of a renewed interest in service to the Nation in one way or another.

Mr. THORNBERRY. Dr. Mark, let me ask you to can you just touch on the potential national security implications of quantum computing? And then, give us, for laymen who are technologically challenged, touch on your other key capability, hypersonics?

Dr. MARK. Well, certainly, I would be glad to. I am also technologically challenged by these things. The question of size in the elements out of which a computer is made is the critical one. The number of computers—the number of switches, the number of elements that you can put in a small volume is key.

The human brain has something like 10 to the ninth, or is that 100? A trillion. A trillion what we would call transistors. And that is because the switching elements in our neurons have approximately between 300 and 1,000 atoms, instead of the million or more that you now have in the computers that we build.

What you can do with that is to essentially make a redundant computer and teach it to find its own paths to come to conclusions. That is what the human brain does, and it does it because it is highly redundant. A very small number of the neurons that we actually have are used at any one time. And we would be able to program that into our computers.

See, I was involved in the beginning of the advent of parallel computing. You know we ran into a limit in the 1970s of the speed of light. If a computer has one central processor, then what determines its speed is how fast the signals can go from one element to another.

And what we said—or Dan Slotnick was the one who really had this idea was, "Why don't we have several of these run in parallel on the same program?"

And we actually were able to put together a computer that had 64 of these things running in parallel. And we were able to show, after a lot of mistakes, that by God, yes! You could increase the speed simply by having more CPUs [Central Processing Units] work on the same problem.

Today, thousands of CPUs work in the large computers on the same problem. And that was a real breakthrough. I think this breakthrough I see coming anyway in size of the processing elements are—they are going to be equally important. And I think that we have talked about robots, the capability of robots, I think that is where the first big application is going to be.

But the one thing I am sure of is that we sure didn't predict what we could do with computers when we put that first 64 processor machine together. So it is hard to say much more.

With respect to hypersonic propulsion, that is a practical engineering problem. We have not been able to really do it, because we do not have—we have computers that can calculate hypersonic flow in the machines that we have built. What we don't have are ground-based test facilities to verify the computer codes.

In all of the other aeronautical advances, we have been able to build wind tunnels where today we design our airplanes on the computer, but every once in a while you want to go make a test and make sure that your computer program actually reflects what happens.

In the case of hypersonics, that is a very heavy investment. In my prepared statement, I have put a picture of a facility that was built in 1962, or started in 1962, and it was used only once, really, to test a ram jet run by a nuclear reactor.

We ran that reactor for 5 minutes, and it had a total energy capacity of 500 megawatts, and we had a hypersonic wind tunnel there. I think some of it is actually still at the Nevada test site. I am not sure of that now, but——

We would need to build something like that and make a commitment to develop hypersonic propulsion. Hypersonic means beyond five times the speed of sound.

People have talked about it now for decades. We have never made one work, because we didn't have the knowledge. We have now made two hypersonic tests in the last 2 or 3 years that were partially successful, and they were partially successful because we are beginning to learn how to do this.

The people that do these things, when I go talk to them, they tell me that if we could have a ground-based facility, where we could vary parameters. You see, these flights are pretty expensive. These are things that are dropped by that B–52 [Boeing Stratofortress strategic bomber] we have down at Edwards Air Force Base.

We had the X–51 [Boeing unmanned scramjet demonstration aircraft] on and we had the X–43 [NASA unmanned experimental hypersonic aircraft] in the last two or three—and I guess the 51 has the record of a couple of hundred seconds of hypersonic flight above Mach 5. And I think that I would seriously recommend that we consider putting a facility together and establish a leadership in this area.

Now, what do you get for that? If we could have hypersonic cruise missiles, rather than the subsonic once we have, the hypersonic cruise missile would travel at about a mile a second. So 60 miles would be a minute, you would have—and nobody could shoot that down, by the way. There aren't any missiles that maneuver fast enough to do that.

The other important application is space launch. You know, there is a company now that launches space vehicles starting with an airplane, it is an old Lockheed 1011 [TriStar airliner] that flies at 40,000 feet, and the Pegasus rockets are dropped from that airplane and then go into space. If that airplane, instead of running at Mach 0.8, which is 3 or 4 percent of what it takes to go into orbit, ran at Mach 5 or Mach 7, say, then you are a third of the way there in space.

We have a good rocket industry. That rocket industry has nothing to do now, because we have done away with the shuttle, they don't have to maintain those engines, and we are using Russian engines on our big rockets.

I think if we made a concerted effort to build an air-breathing rocket, which is what a hypersonic engine really is, and get sustained flight—and remember if you have a hypersonic vehicle and it flies for an hour, you have gone around the world pretty much, or close to it. Well, you have done what, 3,600 miles in 1 hour.

So that is something we ought to do. That ought to be a national program.

Mr. LANGEVIN. Could I ask a question? I will be very brief. Just for clarification.

Mr. THORNBERRY. Sure, sure.

Mr. LANGEVIN [continuing]. When you are talking about—when you are talking about hypersonic kind of—are you talking about Scramjet technology, or is that something——

Dr. MARK. Scramjets, yes. Scramjet means supersonic cruise ram jet, scramjet.

Mr. LANGEVIN. Because I know we had a successful test of that, then we had to table it.

Dr. MARK. Yes, we did. We had two initially. Well, we had two vehicles, but several flights.

Mr. LANGEVIN. All right, thank you.

Mr. THORNBERRY. Great.

Mr. Ryan.

Mr. RYAN. Thank you, Mr. Chairman.

I just had one question that maybe all of you can kind of touch upon. I am sorry for being late.

And as we are talking about the issue of hypersonic or we were talking about the labs that you were talking about and some of the technologies that you have brought forth in this hearing, one of the issues in a lot of areas around the country now is that this technology as it evolves doesn't necessarily get transferred into American jobs like it used to.

And where the Defense bill was always seen many, many years ago as a jobs bill throughout the country and almost every congressional district could identify very easily how those jobs were happening from the investment that the Pentagon was making.

And I find it very interesting that young people now are going into these labs, because some of the most cutting-edge research is being done there. And so, if you could just throw out some suggestions to us of some things that we can do from our end to invest in things like you were just mentioning, that I think capture the imagination of young people to want to be a part of something like that, which I was fascinated just listening you talk about it and I can imagine if I was an engineer how much I would want to be a part of that.

So what are those things that we need to invest in that have the practical appeal to achieve some of the goals that we need to achieve in the military? But also, will draw in the best and brightest back into the Government? And then how, when we develop that technology, what can we do from our end to help transfer the manufacturing and commercialization of those products to happen here in the United States?

And I know there is a lot of people who now want to manufacture near the research in order to continue to try improve the products. So I am just going to throw that out there? And if all of you can just kind of comment on it, I would appreciate it.

Thank you, Mr. Chairman.

Dr. MARK. May I follow about what Mr. Reed said about the labs? I think that the algorithm that we used to have was that we tried to lead in those technical fields that are on the cutting edge of something that lead to some new capabilities. And then, we do the—we build the first airplanes or the first military vehicles,

ships, whatever, but you cannot after that prevent other folks from building these things, and so we actually invest also in foreign countries to get them built elsewhere.

But the key is to have the laboratories and to have the universities that can maintain that lead. I mentioned that our current Secretary of Energy performed the experiments when he was a professor at Stanford that led to this concept of quantum computing. Now, you hear somebody who is now in the position to do something about it and to make sure that the initial production, the initial big investments are made in the United States.

I was at a meeting the other day when we talked about this. When we built the first parallel computer, we didn't know how to program it.

But Burroughs company took the risk to build it. It was funded by the Government, but they put their best people on it, and so they actually had these people off the projects on which they were making their current profits, you see. And the Federal money allowed them to put this 64 CPU computer together.

Then they gave it to us at our research center, a federal research center, the NASA [National Aeronautics and Space Administration] Ames Research Center, and we made it work. And we made it work, because we had the time and we had the Federal employees who could do that. They didn't have to go somewhere else into a profit-making activity.

So that system works, and what has happened recently is, as I mentioned a couple of things, where we have deliberately stopped. And I think that, you know, when I was in the Pentagon in the 1970s, when we had relatively more freedom and more money than we have now, we used to fund some high-risk projects by simply taking some airplanes off the production line.

You know, remember, we stopped the 141 [Lockheed C–141 Starlifter strategic airlifter] program for a while to get something started that we wanted to. And I think that, that we don't have as many airplanes anymore to do that now. But somehow we need to get back to the point where we can establish and maintain leadership in the critical technologies, and I have mentioned two of them. There are more.

Mr. BERKELEY. I would think that your question might lead to geography by geography, starting out with what are the strategic advantages that State or that region has? And then, offering some predictability for the businesses that are there, and there are two aspects to this.

I am less interested, I think, in grants than I am in revenues. You want to have a customer, and so the steps to being a customer is having access to having your product evaluated.

Atlanta's business community about 15 years ago got together and the large companies agreed to allow the small entrepreneurial companies that by any normal procurement officer's approach would never have qualified to be a customer of that large company.

But they agreed to put those small companies through the procurement process and to give them honest evaluations as to where their technology stood and why they were going to get the business, or why they were not going to get the business.

So that they had a feedback loop that shortened the period of uncertainty as to whether they had a viable product or not. That was very popular with entrepreneurial and venture-backed companies in the Atlanta region in that period of time. This is when I was working at NASDAQ and I heard about this, because the venture capital community brought it into us as a very interesting idea.

The Government could help with that, not only by asking Government contractors to entertain the look at this product process, the procurement process, but also to look at how the Government itself has barriers to new companies getting started, because of the concept of size, concept of viability. I don't have—I am just thinking this out in response to your question.

But I think there is a lot here that doesn't cost a lot of money, it just costs a commitment to giving people a chance to have access and then after they have access, if they have got something, some acceptance process that may not be in the normal Federal procurement model, but could get a good technology, a customer that might ultimately be——

Mr. RYAN. And would you say most of those folks in the supply chain, or if they are not on the supply chain, then trying to get into the supply chain with some of the bigger companies, with a little bit of help from the large company, could quickly meet the standards that they would expect a supplier to meet?

Because I have seen this with other company where a G.E. comes in and says, "We want to buy something from you. You are not quite doing it right. Here is how we need you to do it." And within a few weeks, they have it retooled. And is that something that could be fairly easy to do?

Mr. BERKELEY. Yes, yes. It is important in the learning cycle by having—your shortening the time at risk. Looking at it from an investor's point of view, you are helping figure out whether there is a "there" there to that product. Is there ultimately a chance to be somebody's supplier?

And I think there is something to this. I mean, your comments sparked my mind, that you can reduce risk and reduce time and, therefore, reduce capital costs by getting somebody's product evaluated honestly, quickly. And then if there is something there, help them get through this complicated federal procurement process, or even the complicated commercial procurement process for large companies.

Mr. RYAN. Thank you, Mr. Chairman.

If I could just make one comment, too? I mean a lot of these, the labs and the investments, I think I get worried sometimes that the national discussion is that there isn't anything, any investments, that the Government makes are good.

And I think that is the backdrop of the national discussion right now. And I think when we are looking at competing with China and some of these other countries that are putting a lot of money behind a lot of different initiatives, we are playing the short game here. We are not playing the long game. And I just get worried.

So if you can help us say, "Hey, well, here is some Government investment that really had this ripple effect through the economy," I think that could be helpful for those of us who were trying to at least bring that to the discussion that we are having, nationally.

Mr. THORNBERRY. Thank you.

Mrs. Davis, did you have other——

Mrs. DAVIS. Yes, just briefly, Mr. Chairman.

I think that we have really touched on a lot of very important issues, and I think just that the title of this hearing—you know, looking at the Department of Defense's investment in technology and the capability to meet emerging security threats. Can you correct me if I, you know, I have a sense from this that you would not necessarily give us terribly high marks, or the Department of Defense, I guess, terribly high marks, for aligning the technology investments with real threats today.

Is that correct? Or it is somewhere in the middle there of how those investments that we are making today really align with the security threats?

Mr. BERKELEY. Well, I think it is important to not to ask basic research to find a home too early. I do think we have spent a lot of time gearing to applied research, because of the conflicts we are in, and because of the need to solve a particular new set of problems, IEDs [Improvised Explosive Devices] for example.

But I would protect that basic research and fight like that like a fierce cornered dog to protect that basic research. And it will not have an obvious answer, but you need to task well-meaning, well-educated responsible judgment to make those decisions. It cannot be put in a formula.

Mrs. DAVIS. Yes. And I guess I don't want to ask you what kind of a grade you would give us doing that and protecting that basic R&D, because I think over the last few years, I have certainly seen where we actually did have to work hard to protect it. And I am not sure that in the end we did a fabulous job at it. So——

Mr. THOMAS. If I could just pick up on that last comment. I think that is absolutely right that you want to cast a very wide net in terms of basic science and technology research that you are doing. One of the challenges we face, though, is that the program of record is so entrenched that programs get stuck in a development vortex, and it is wasting taxpayer dollars.

And it is a lot of these programs that are in development that really would very directly address some of the specific sorts of security challenges and emerging threats that we have been talking about.

But the problem is just that it is a zero sum game, and that they are going to displace some program which is far more mature, it has jobs across a number of congressional districts, and is very close to—or is in procurement. And so, how we strike that balance in the future will be tricky.

Mrs. DAVIS. Yes. No, I appreciate that. We know that is difficult on a host of different levels. And I think in the past, I know I have been interested and I think my colleagues, too, is at what point do you necessarily pull the plug on some things that really aren't developing in the way that they should? And how are those decisions made?

But I think the other issue was really around human capital, and the extent to which we are—number one, I think keeping people in the military who have phenomenal skills who are going into in-

dustry and we lose them. We may keep them because they are in those fields. That is a dilemma at times.

And the other one is how we use the resources and particularly coming out of the Iraq and Afghani wars today are service members who are quite capable of developing further in some of these areas. And yet, sometimes I am not sure we capture them and help them to do that as best we should. I don't know if you have any other thoughts on that?

And the other issue that you have talked about certainly is the SBIR [Small Business Innovation Research] grants, the role that they play in terms of helping people to move, you know, through a so-called "Valley of Death" to really develop in a way that is important. And we can't get too far along in that, but I appreciate it because you have talked a lot about of those different issues.

Do you want to comment on——

Mr. REED. I was just going comment that the Department in its 2012 budget request, I think as you are aware, has significantly increased its funding for—or its request for basic research. Now, the advanced 6.2, the next stage up, that is down a little bit. And there may be reasons for that intrinsically as far as the programs are concerned, that they are targeted towards.

But it is imperative, in my view, and I think the view that this committee has had in the past and I think maintains today, to ensure the funding in the basic research programs and in the S&T [science and technology] in general. Because you have got to move that-through that in order to get what is ultimately going to go into development. And you have to make the—provide the wherewithal so that there is a bridge across that "Valley of Death" for something to get into development. And we could go on all day about that, and I won't bore you with that.

But I think the Department has made, at least, as I read the budget and both getting ready for this and previously. It is on the right track as far as the 6.1 program. And it needs to—we need to continue that and taking all of them to the next stage.

Mr. BERKELEY. Just on the human capital side, I would say that I would encourage you to look at a differential incentive. For example, servicemen to go into advanced degrees in the G.I. bill, and other approaches.

I am not so much steering it to STEM necessarily, but I would steer it to advanced degrees in an engineering model.

The other thing that, as an outsider to this process and never having read the Quadrennial Defense Review, I am glad you are asking the question about basic research. So don't fail to—just asking the question is important, getting it on the table.

Mr. THORNBERRY. Well I think this committee, on a bipartisan basis, will continue to, as Mr. Reed said, argue for basic research. But I don't think any of us ought to underestimate the challenges of the fiscal environment we are in either. And it will be relatively easy to cut and it would be a great mistake, I think, to do so.

You all have been very helpful, as Mrs. Davis said, lots to think about here, and we have just touched the surface. But it is very helpful in our deliberations.

Thank you all for being here.
And with that, the hearing stands adjourned.
[Whereupon, at 3:49 p.m., the subcommittee was adjourned.]

A P P E N D I X

JULY 26, 2011

PREPARED STATEMENTS SUBMITTED FOR THE RECORD

JULY 26, 2011

Statement for the Record
Submitted by Congressman James R. Langevin (RI-02)
Hearing on Department of Defense Investment in Technology and Capability to Meet Emerging Security Threats

July 26, 2011

Thank you, Mr. Chairman. I, too, thank each of our witnesses for being here today and look forward to hearing their expert views on how the Department of Defense might shape its strategic planning efforts to maximize research and development investments that meet our future national security needs in a fiscally constrained environment.

This year our subcommittee has held a number of hearings to better understand the Department's near-term investments in technology capabilities that address current threats in Iraq, Afghanistan, and a number of other countries. A significant portion of those investments over the last decade have been focused on technologies to transform our military to prosecute the war on terrorism. We have had some successes with fielding MRAPS, UAVs, ISR and medical capabilities. However, we have stepped back from fully developing major transformational technologies such as Future Combat System, the Joint Strike Fighter, and the presidential helicopter, just to name a few.

And as you know, these programs and others like them have cost us billions with little to show for it. Considering that cuts to the defense budget are currently projected to be over $400 billion during the next decade, it is vital to spend more wisely.

These prudent and deep cuts, however, must not undermine our ability to maintain a strong defense posture globally. They must not jeopardize our ability to quickly adapt to future threats stemming from geopolitical environments that are stressed by rising powers, population changes, competition for resources such as food, water and energy, climate change, and other shaping factors we hope to hear about from our experts today.

Again, from our earlier hearings, this subcommittee is familiar with the Department's current investments in technologies to combat violent extremists. We've heard a lot about investments and policy directions with regard to cybersecurity, as well as the Department of Defense's effort addressing the threat of Weapons of Mass Destruction, and of our challenges with global strategic communications. These are all critically important problems and security challenges facing us today. However, given the factors I mentioned earlier and their potential impact on our future national security needs, are we investing in the right technologies to meet the future threats as well? Are our national security and defense strategies aligned appropriately to guide future investments? Should we develop an interim Quadrennial Defense Review now or wait until the next full review?

Your thoughts on how the DOD might reform its cumbersome budget decision process would be helpful. I know the Members of this subcommittee would benefit from your expert opinion.

I would also be interested in your thoughts on how the Department might improve the overall management of the defense research, engineering, test and evaluation enterprise both within the Pentagon and throughout the research and engineering community. For example, what technologies should the DoD continue to lead investments in, and where might we better leverage industry and our foreign partners instead?

Thank you once again for your time here today and I look forward to your testimony.

CSBA Testimony

July 26, 2011

DEPARTMENT OF DEFENSE INVESTMENT IN TECHNOLOGY AND CAPABILITY TO MEET EMERGING THREATS

By Jim Thomas
Vice President for Studies, Center for Strategic and Budgetary Assessments

Testimony Before the U.S. House of Representatives, Committee on Armed Services, Subcommittee on Emerging Threats and Capabilities.

Thank you, Mr. Chairman, for the opportunity to appear before you today, and to share my views on emerging threats facing the United States, and capability areas that may require greater investment to meet them. My testimony is intended to provide context within which one might assess the Department of Defense's research and development priorities.

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In my testimony today, I will describe some of major security challenges the United States is likely to face in the two decades. I will then outline potential discontinuities in future warfare that should be considered when making future investment decisions. Building on those discontinuities, I will discuss their broad implications for U.S. defense planning. Finally, I will suggest capability areas that appear to be potential growth opportunities for investment given these discontinuities and their implications.

I. Major Security Challenges Facing the United States

The United States faces a multitude of threats, but three principal security challenges stand out:

- Hedging against the rise of a hostile and more openly confrontational China and potential challenges posed by authoritarian capitalist states;
- Defeating violent extremism and countering radicalization and destabilization in key countries throughout the world; and
- Preparing for a world in which there are more nuclear-armed powers.

The Rise of China. Although China is not an enemy, it has the greatest military potential to challenge the interests of the United States, its allies and friends in the coming decades. China's growing economic wealth, thirst for commodities from overseas, and unsettled territorial claims – coupled with its sustained military modernization and more confrontational approach on regional issues – are raising concerns throughout East Asia. China appears to be attempting to create a sphere of influence in East Asia and to displace the traditional role of the U.S. military as a security provider in the region. Its military has developed a sophisticated anti-access/area denial (A2/AD) battle network to hold U.S. military bases and naval ships forward-deployed in the Western Pacific at risk. This A2/AD network includes growing inventories of medium- and intermediate-range missiles; state-of-the-art integrated air defenses; submarine forces; anti-satellite systems; and computer network attack capabilities. The United States is developing new concepts like AirSea Battle to ensure military forces will continue to be able to gain and maintain sufficient freedom of action and preserve the stable regional military balance that has benefitted all countries in the region in the face of these A2/AD challenges.

Violent Extremism and Destabilization of Strategically Important States. Despite the killing of Osama bin Laden earlier this year, violent extremists, whether al Qaida or associated radical Islamist movements, are continuing their attempts to destabilize fragile strategic states such as Afghanistan, nuclear-armed Pakistan or oil-rich states such as Saudi Arabia. Some of these groups are sponsored or aided by states hostile to the United States, to include Iran and Venezuela. The lethality of violent extremists, moreover, would increase dramatically should they acquire nuclear or biological weapons. Radicalization and destabilization, however, are not limited to the greater Middle East. Within our own hemisphere, narco-cartels continue to threaten the stability of key partners such as Mexico and Colombia. The United States' preferred strategic approach is to work indirectly with local governments and regional players to counter terrorism, insurgencies and narco-cartels. Such preventive efforts, while not necessarily involving the use of force, represent an important and enduring mission for the U.S. military.

Regional Nuclear Dangers. The probability that we will see the use of nuclear weapons within our lifetime increases with the number of new nuclear powers. North Korea's acquisition of nuclear weapons has already changed the security calculus in Northeast Asia, while its eagerness to proliferate nuclear weapons technology to countries such as Iran and Syria destabilizes regions further afield. The number of nuclear powers may further expand in the coming decades, especially if Iran acquires nuclear weapons and prompts others in the region to follow suit. The United States will have to develop regionally-tailored doctrines for nuclear deterrence, WMD elimination, limited nuclear use, and war termination in a more proliferated world.

The geographic nexus of these three challenges is the Indo-Pacific region, stretching from the Persian Gulf around the Malay Peninsula and up to the Sea of Japan. Although the U.S. military does not have the luxury of focusing on a single theater, the greatest tests our armed forces will face in the coming decades are likely to emanate from this region. East Asia is likely to be the engine of the global economy. High economic growth rates are likely to fuel continued regional increases in armaments. The danger of a nuclear confrontation

between India and Pakistan remains high. Terrorist attacks similar to those perpetrated in Mumbai in 2008 and again on July 13th could destabilize governments in the region or trigger a major war between nuclear powers. And finally, intense resource competitions driven by emerging powers in the region may cause economic competitions to jump the track into the military domain.

As America faces these challenges we must also confront another national security threat, but one that has its roots within our country. As the Chairman of the Joint Chiefs of Staff and others have indicated, America's current fiscal predicament is a national security threat. I wholeheartedly agree with that assessment. America's fiscal woes, and our success or failure in addressing them, will greatly influence our options for dealing with external challenges to our security and how we prioritize capability investments.

II. Potential Discontinuities in Warfare

As we look ahead, we not only face a range of security challenges, but also see emerging patterns and potential changes in the character of warfare. Four major discontinuities, in particular, may influence how we think about future warfare, forces and capabilities:

First, American power projection in its familiar forms could become prohibitively costly in the future as A2/AD battle networks proliferate. The U.S. military has longed enjoyed the luxury of being able to dispatch its forces at intercontinental distances to theater bases around the world that afforded a high degree of sanctuary, and to conduct naval patrols very close off the coasts of potential aggressors with impunity. But as countries such as China and Iran acquire extended-range precision-guided weapons, advanced sensors, and the means to attack opposing electronic systems, they are creating contested zones in which the risks associated with current patterns of U.S. power-projection and forward-presence operations could become prohibitively high. With such capabilities, they can hold at risk theater air bases from which many of our strike aircraft traditionally operate. They can attack large surface combatants within range of their anti-ship systems. High-signature ground and amphibious forces can be targeted as they land on foreign shores. And U.S. logistical systems and satellite communications – critical elements of America's global military network – could be corrupted or destroyed. The continued proliferation of weapons of mass destruction only compounds the challenges of gaining access and operating in distant theaters.

Second, the proliferation of guided weaponry and nuclear weapons makes the prospect of large armies invading other countries far less likely. For much of the past several decades, the U.S. military has honed its warfighting skills based on a narrow set of scenarios that envisaged them either repelling or conducting large-scale land invasions. The epitome of this was the Cold War battle that never occurred at the Fulda Gap, where NATO forces were deployed to repel a Warsaw Pact invasion of West Germany. Even after the Cold War, the U.S. military continued to focus on two canonical warfighting scenarios that both involved repelling large ground invasions of allies or friendly countries. Over-optimizing forces for repelling invasions and conducting counter-offensive, large-scale land invasions in kind, however, has left forces less prepared for irregular warfare; coercive wars waged with missiles, submarines, and cyber attacks; nuclear exchanges between regional nuclear powers; and more ambiguous forms of limited, creeping aggression to assert sovereignty

over contested offshore oil and gas fields. Such contingencies may represent more realistic and more taxing scenarios than the canonical invasion/counter-invasion/regime change scenarios of the past.

Third, in an era of globalization, conflicts are unlikely to be geographically limited in scope but will instead extend into the global commons of the high seas, air, space, and cyberspace. Wars are likely to be preceded by massive cyber attacks to disrupt opposing sensors, command and control, logistics, communications or air defenses. Such attacks could be used to "jump over" opposing forces to attack the civilian society of the enemy directly, non-kinetically performing functions that were previously accomplished by strategic bombardments. Attacks against space assets could affect global civilian communications, banking, and other non-military functions. Military conflict will also expand below the waves as more countries develop the means to wage undersea war and covet the unguarded wealth that lies upon the seabed – submarine communications cables, oil and gas reserves, and concentrated fields of precious metals.

Fourth, the United States is in danger of losing its lead in critical military-technology competitions. While the United States remains the premiere cyber power given enormous investments over many decades in its cryptologic complex, its ability to sustain that lead is in jeopardy as a number of states, terrorist groups, and criminal organizations develop sophisticated means of conducting cyber attacks. Similarly, the United States is losing its near-monopoly on precision-guided weaponry as those capabilities proliferate rapidly around the world. In space, decades of investment in orbiting systems for reconnaissance, communicationsk, and navigation can now be held at risk with relatively less expensive anti-satellite systems. And in research and development, the United States appears to be at risk of falling behind other powers such as China and even Russia in critical areas such as directed energy technologies.

Together, these four potential discontinuities could negate many of the precepts of defense planning since the end of the Cold War. Accounting for them may require a better understanding their implications and the adoption of new force and capability designs.

III. Implications for the Design of U.S. Forces and Capabilities

The potential discontinuities described above suggest several implications for U.S. military planning and future capability investments:

Future environments in which U.S. forces must deploy, and conditions under which they must operate and sustain themselves are likely to be far less permissive than in the recent past. We may be entering a post-power projection era in which many traditional modes of projecting power may no longer be viable making it harder to deploy, operate and sustain U.S. forces in the face of robust A2/AD battle networks. Over the past several years, it has become fashionable to talk about trade-offs between preparing for so-called "low-end" irregular conflicts and "high-end" conventional threats. But this is a false dichotomy. The reality is that although we will continue to face irregular threats long into the future, irregular opponents will likely adopt high-tech weaponry including guided rockets, artillery, mortars and missiles (G-RAMM) to create their own anti-access/area denial challenges, albeit on a smaller scale. This is not too far a leap from what we already see occurring in Iraq and Afghanistan, where Iran has supplied its proxies with explosively

formed projectile IEDs and other sophisticated anti-personnel weapons. At the same time, advanced military powers will continue building up their capabilities to deny the United States the ability to access and operate with impunity in their respective theaters. High signature forces that depend on theater air bases, large naval surface combatants, large ground formations, logistical supply through large ports and airfields, satellites in low-earth or geostationary orbits, and U.S. military computer networks will all be more vulnerable in the future, not less. Consequently, military systems designed with assumptions of relatively benign operating conditions may be ill-suited for the types of operations we might actually undertake in the future. Continuing to adhere to these legacy assumptions will jeopardize lives and the prospect of deterring future conflicts, or of winning them should deterrence fail. A prudent pattern of future investments might be one that maximizes investments in systems that perform under a range of non-permissive conditions, while minimizing investments in systems whose optimal performance depends on relatively benign operating conditions.

The United States, its allies and partners must improve their capabilities to counter coercion and more ambiguous forms of aggression. Around the periphery of Eurasia, the greatest military dangers may stem more from the coercive use of force by potential adversaries than the threat of large-scale land invasion: waging missile campaigns; conducting cyber attacks; imposing maritime exclusion zones; and brandishing nuclear threats intended to break the will of adversaries rather than physically subjugate them. Countries like China and Iran are building up sizable missile forces that would enable them to conduct coercive missile campaigns against their neighbors. Encouraging allies and friends around the world to field their own A2/AD systems, including active and passive defenses, as well as precision weaponry could enable them to withstand coercion by local hegemonic aspirants.

The U.S. military will need to adopt more globally integrated approaches to deterrence and the conduct of warfare. To address conflicts that will cross-cut the Regional Combatant Commands, we will need to reconsider the ways in which we have organized and partitioned the Earth into regional military theaters. Similarly, the roles and missions of the U.S. Armed Services may need to be reconsidered to address the risk of conflicts that can spread across the areas of responsibility of the Regional Combatant Commands. Command and control decisions may need to become more centralized to ensure global coordination, even while the execution of those decisions may become even more de-centralized.

U.S. research and development and intelligence efforts will need to be more closely integrated to prevent technological surprise. The United States may no longer be able to lead in all technological categories. In some, we must anticipate or identify technological breakthroughs that may occur abroad and more quickly adapt ourselves to exploit or counter them. As with Nazi Germany's development of Blitzkrieg in the 1930s, the next big military innovation may be less the result of a single technological breakthrough than the harnessing of multiple technologies that might already be available for a new military purpose. Fostering creativity and experimentation within the U.S. military will maximize the odds of discovering the "next big thing" in military innovation before our adversaries do.

IV. Needed Capabilities

In light of these implications, new criteria emerge for evaluating potential U.S. military investments: How capable are systems in non-permissive operating environments-- e.g., in the face of cyber attacks, denied communications, advanced air defenses, missile attacks on theater airbases or large naval combatants? How relevant are they to countering coercion? And how fungible are they globally and across a range of scenarios? I would suggest that eight capability areas look particularly attractive in light of these criteria:

Countering or eliminating nuclear and biological weapons. Perhaps no technical challenge is as great as improving the ability to locate, secure or neutralize uncontrolled nuclear weapons. Ground forces will need equipment and training to sustain long-duration operations in WMD-contaminated environments to find, secure or eliminate WMD. Research is also needed to develop medical countermeasures to defeat a broad range of bacteriological and viral pathogens.

Operating from range, penetrating into denied areas, and persisting in conducting surveillance and strike missions. Long-range strike and surveillance capabilities would ideally be provided by a mixture of land- and carrier-based aircraft. They should improve the ability of the future force to deny sanctuary to adversaries, while reducing some of the vulnerabilities associated with theater basing. Future long-range airborne systems, manned or unmanned, should be capable of operating in situations where satellite communications are denied.

Defending population centers, military bases, and forces from ballistic missile and G-RAMM attacks. Ballistic missile defense systems will need deeper magazines of interceptors if they are to withstand larger missile salvos. Small, highly distributed landing parties will be needed to designate anti-ship missile batteries and air defense facilities for attacks and create counter-GRAMM perimeters so that larger forces can attain lodgments ashore. Solid-state directed energy systems look particularly attractive in countering G-RAMM threats given their virtually unlimited "shot magazines." With appropriate funding, it may be possible to field, within the next decade, the first high-power solid state laser weapons system capable of providing ship-borne defenses against anti-ship cruise missiles, UAVs, and fast attack craft.

Conducting special reconnaissance, direct action and unconventional warfare in denied areas. Special operations forces may require new long-range airborne and undersea systems to insert and extract teams undetected. Future gunships should be suited for operations in non-permissive environments and be day/night/all-weather-capable.

Conducting unwarned land attack, sea denial and reconnaissance from undersea. Undersea warfare is a longstanding U.S. military advantage, but there is a need to increase the precision-guided conventional weapons payloads of U.S. submarines and increase the endurance of Large Diameter Unmanned Underwater Vehicles. U.S. submarine forces, as well as surface combatants, could also be enhanced by developing the means and methods for them to re-arm at sea rather than returning to port.

Channeling or controlling access and movement via non-lethals. Non-lethal technologies can improve force protection while reducing U.S. manpower requirements. For example, non-lethal technologies could be used to create "virtual fences" around captured weapons

caches, or to protect forward operating bases from attacks employing far fewer soldiers than might otherwise be required. Non-lethal weapons also offer the promise of increased security to our deployed forces without the risk of causing unwanted and potentially costly collateral damage to civilians and civilian infrastructure.

Disrupting, degrading, deceiving, manipulating or negating the sensors and processing capabilities of hostile powers. In countering the growing threat of precision-guided weaponry, the ability to deny an adversary effective means of targeting – especially against mobile or redeployable forces – will confer a significant military advantage. While many elements of U.S. forces are involved in countering ISR systems, there is no integrated mission area that addresses the emerging importance of "blinding campaigns." Technologies that help to disrupt, degrade or spoof enemy sensor networks will play critically important roles in new concepts such as AirSea Battle.

Building up the capacities of key allies and friendly states for internal and external defense. In recent years, the Department of Defense has been focused on building the capacities of partner military forces to combat internal security threats. These efforts should be continued. But they should also be expanded to assist allies and other key partners in building greater capacity for themselves to withstand external military threats with less reliance on U.S. forces for their self-defense. U.S. allies and partners, especially in the Indo-Pacific region should be encouraged to build up their own A2/AD battle networks to constrain the power projection options of shared adversaries.

V. Conclusion

In closing, let me express my appreciation to the Committee for its efforts to raise the level of discourse and awareness on these important issues. Given our country's fiscal situation, there is little margin for error in the investment choices we make for the U.S. military in the years ahead. By emphasizing capabilities that perform well in non-permissive condition, counter emerging coercive threats, and apply across a range of global scenarios, I believe we can best meet the challenges ahead. Thank you.

About the Center for Strategic and Budgetary Assessments

The Center for Strategic and Budgetary Assessments (CSBA) is an independent, nonpartisan policy research institute established to promote innovative thinking and debate about national security strategy and investment options. CSBA's goal is to enable policymakers to make informed decisions on matters of strategy, security policy and resource allocation.

CSBA provides timely, impartial and insightful analyses to senior decision makers in the executive and legislative branches, as well as to the media and the broader national security community. CSBA encourages thoughtful participation in the development of national security strategy and policy, and in the allocation of scarce human and capital resources. CSBA's analysis and outreach focus on key questions related to existing and emerging threats to US national security. Meeting these challenges will require transforming the national security establishment, and we are devoted to helping achieve this end.

Jim Thomas is Vice President and Director of Studies at the Center for Strategic and Budgetary Assessments. He oversees CSBA's research programs and directs the Strategic and Budgetary Studies staff.

Prior to joining CSBA, he was Vice President of Applied Minds, Inc., a private research and development company specializing in rapid, interdisciplinary technology prototyping. Before that, Jim served for thirteen years in a variety of policy, planning and resource analysis posts in the Department of Defense, culminating in his dual appointment as Deputy Assistant Secretary of Defense for Resources and Plans and Acting Deputy Assistant Secretary of Defense for Strategy. In these capacities, he was responsible for the development of the Defense Strategy, conventional force planning, resource assessment, and the oversight of war plans. He spearheaded the 2005-2006 Quadrennial Defense Review (QDR), and was the principal author of the QDR Report to Congress.

Jim began his career in national security at Los Alamos National Laboratory, analyzing foreign technological lessons learned from the first Gulf War. After serving as research assistant to Ambassador Paul H. Nitze, Jim joined the Department of Defense as a Presidential Management Intern in 1993 and undertook developmental management assignments across the Department of Defense over the next two years. From 1995 to 1998, he managed a NATO counter-proliferation initiative and wrote three reports endorsed by Allied Foreign and Defense Ministers to integrate countering-WMD as a mission area into NATO post-Cold War force planning. From 1998 to 1999, he was seconded to the International Institute of Strategic Studies (IISS) in London, where he wrote Adelphi Paper 333, The Military Challenges of Transatlantic Coalitions (Oxford: Oxford University Press, 2000). From 1999 to 2001, Jim worked in the Secretary's Strategy Office, playing a lead role developing the Department's Defense Strategy and force planning construct for the 2001 QDR. From 2001 to 2003, he served as Special Assistant to the Deputy Secretary of Defense. He was promoted to the Senior Executive Service in 2003.

Jim received the Department of Defense Medal for Exceptional Civilian Service in 1997 for his work at NATO, and the Department of Defense Medal for Distinguished Public Service, the Department's highest civilian award, in 2006 for his strategy work.

Jim is a member of the Council on Foreign Relations and the International Institute for Strategic Studies. He holds a B.A. degree with high honors from the College of William and Mary, an M.A. degree from the University of Virginia, and an M.A. degree from the Johns Hopkins University School of Advanced International Studies.

A former Reserve Naval officer, Jim attained the rank of Lieutenant Commander.

DISCLOSURE FORM FOR WITNESSES
CONCERNING FEDERAL CONTRACT AND GRANT INFORMATION

INSTRUCTION TO WITNESSES: Rule 11, clause 2(g)(4), of the Rules of the U.S. House of Representatives for the 111th Congress requires nongovernmental witnesses appearing before House committees to include in their written statements a curriculum vitae and a disclosure of the amount and source of any federal contracts or grants (including subcontracts and subgrants) received during the current and two previous fiscal years either by the witness or by an entity represented by the witness. This form is intended to assist witnesses appearing before the House Armed Services Committee in complying with the House rule.

Witness name: James P. Thomas, Vice President, Center for Strategic and Budgetary Assessments

Capacity in which appearing: Representative

If appearing in a representative capacity, name of the company, association or other entity being represented: Center for Strategic and Budgetary Assessments (CSBA)

FISCAL YEAR 2011

federal grant(s) / contracts	federal agency	dollar value	subject(s) of contract or grant
WHS	DOD/ONA	$1,360,000	Assessments/analysis, wargames, and briefings on international security environment, strategic challenges, future warfare, and portfolio rebalancing.
DARPA/Strategic Assessments	DARPA	$95,000	Crisis simulation exercise in national security decision making environment
DLA Acquisition Directorate	National Defense University	$75,000	Secretary of Defense Corporate Fellows Program Orientation

FISCAL YEAR 2010

federal grant(s) / contracts	federal agency	dollar value	subject(s) of contract or grant
WHS	DOD/ONA	$3,000,000	Assessments/analysis, wargames, and briefings on international security environment, strategic challenges, future warfare, and portfolio rebalancing.
Department of the Interior	DARPA	$815,000	Real Time Sensor Simulation: IR Sensor Modeling in Real Time Simulations Study
DLA Acquisition Directorate	National Defense University	$75,000	Secretary of Defense Corporate Fellows Program Orientation

FISCAL YEAR 2009

federal grant(s) / contracts	federal agency	dollar value	subject(s) of contract or grant
WHS	DoD/ONA	$3,000,000	Assessments/analysis, wargames, and briefings on international security environment, strategic challenges, future warfare, and portfolio rebalancing, QDR 10
USAF	DoD	$250,000	Red Teaming, Analytical and Facilitation support to AF/A8X
CCE	D0D/Office of Force Transformation	$245,000	Transformation Roadmap Irregular Warfare
US Marine Corps	DoD	$65,000	External review of Vision and Strategy and other strategy documents

Federal Contract Information: If you or the entity you represent before the Committee on Armed Services has contracts (including subcontracts) with the federal government, please provide the following information:

Number of contracts (including subcontracts) with the federal government:

Current fiscal year (2011): 3;
Fiscal year 2010: 3;
Fiscal year 2009: 4.

Federal agencies with which federal contracts are held:

Current fiscal year (2011): 3;
Fiscal year 2010: 3;
Fiscal year 2009: 1.

List of subjects of federal contract(s) (for example, ship construction, aircraft parts manufacturing, software design, force structure consultant, architecture & engineering services, etc.):

Current fiscal year (2011): Research and Analysis
Fiscal year 2010: Research and Analysis
Fiscal year 2009: Research and Analysis.

Aggregate dollar value of federal contracts held:

Current fiscal year (2011): $1,530,000
Fiscal year 2010: $3,900,000
Fiscal year 2009: $3,560,000

Federal Grant Information:

CSBA has no grants with the federal Government in 2011, 2010, 2009

Testimony on "Department of Defense Investment in Technology and Capability to meet Emerging Threats" before the Subcommittee on Emerging Threats and Capabilities of the Committee on Armed Services of the U.S. House of Representatives

Hans Mark
The University of Texas at Austin
July 26, 2011

This paper is intended to provide a short outline of current and emerging threats facing the Department of Defense. The objective is to try and match these with new scientific and engineering developments. I will begin with defining the "far term" and "near term" threats and possible counter moves. Then, I will describe two emerging scientific and engineering developments that are, or might be, relevant to the threats I have defined.

I. Near Term and Far Term Threats and Responses

1.) China and the Importance of Sea Power

The only far term competitive nation we need to be concerned about is China. China poses an existential threat because it has, or will have, enough nuclear weapons with their delivery vehicles that can strike the United States with a crippling blow. However, having lived through the Cold War, my first assessment is that China is not nearly as dangerous as was the old USSR. The Communist ideology promoted by the Soviet Union had temporary (circa 1917 to 1970) appeal that transcended national boundaries. This was dangerous because the Soviets could and did use internal subversion to take over sovereign nations. In addition, the Soviets were willing to use military force, their own (Afghanistan) or their surrogates (North Vietnam, North Korea, Angola, Nicaragua, etc. etc.) to intimidate people and to expand that ideology. The Chinese strategy is very different. It is based on two principles: First, dominate the world's economy by successful competition using capitalist methods and second, develop sea and aerospace power to limit American access to the Western Pacific. China's first target would be in and around the East Asian littoral regions and expanding later to a wider area of dominance. To counter this, we need to make continuing investments in sea and aerospace power as a first priority. We must make certain that we stay ahead of the Chinese in these military capabilities. We need not fight a hot war with the Chinese but we need to keep Sun Tzu's maxim in mind: "The best way to defeat an opponent is to persuade him that he cannot win". We also need to grow our strategic alliances in the region. Japan has been a trusted and reliable ally for half a century and we need to maintain this relationship. In addition to Japan, we should develop a strategic alliance with India. India has reason to fear China and we have good reasons for helping them to

reduce that fear. We have much in common in that both nations are democracies and that many millions of Indians speak English. My sense is that it might be best to initiate a move to such an alliance by sharing technology. India has a scientific tradition and also an excellent system of technological universities. Such an approach could grow into a strong alliance that would contain any Chinese move to dominate the region.

2.) The Persian Gulf

The major near term threat is that the oil flow from the Persian Gulf is interrupted or completely curtailed. In the 1980 "State of the Union" message by President Carter he said: "Let our position be absolutely clear: An attempt by any outside force to gain control of the Persian Gulf region will be regarded as an assault on the vital interests of the United States of America, and such an assault will be repelled by any means necessary, including military force". The Persian Gulf is still a most important area because in this small region almost two thirds of the world's easily recoverable known oil reserves are concentrated. This is why President Carter defined its loss as an existential threat. The Gulf is about the same size as Lake Michigan and the oil fields are mostly within 100 miles or so of the shore. Iran is on the northeastern shore, Saudi Arabia and the Emirates are on the southwestern side. Diplomacy is most important with all who live there. However, we should be prepared to keep the oil tankers moving in the Persian Gulf as we did in 1987 and 1988. The U.S. Fifth Fleet has a major base on Bahrain, an island between the coast and Qatar. The presence of the U.S. Navy in the Gulf now stretches back more than thirty years to President Carter's speech. For the near term this is an important position, but the region is politically unstable so that things can change suddenly. Given the military functions of this fleet, short term innovations in communications, transportation and small craft used in littoral warfare are probably the most important. We are building the Littoral Combat Ships (LCS) and a new group of more powerful "Arleigh Burke" class destroyers for such inshore missions. My hope is that these ships will be armed with advanced weapons such as the electromagnetic railguns being developed at this time. These will contribute to enhancing the capability of the new ships and therefore the probability that they will successfully accomplish their missions. Eventually, as new oil and gas resources become available around the world, we can withdraw from the area.

In the case of air power, the most important objective has to be to preserve the extremely valuable "Global Reach" that we now have. In Libya, (to provide a recent example), both B-1B "Lancer" and B-2A "Spirit" aircraft participated in the campaign flying from bases in the continental United States. To do this, the aircraft must be refueled in flight. This requires a small number of strategically located bases around the world. In the Pacific, we have Guam, Midway and Hawaii, all of which are U.S. territories. In the Atlantic we have bases in the Azores Archipelago, which is a Portuguese territory and Ascension Island which is British. Both nations are staunch allies which, hopefully, will continue to be the case. In the Indian Ocean we have Diego Garcia in the Chagos Archipelago which is also British. I would feel more comfortable if

we had two or more bases of this kind around the world, especially in the Mediterranean Sea. We should develop diplomatic initiatives to acquire access to air bases on small islands that are likely to be easier to defend and hold than those on large land masses.

3.) Terrorism

The other near term threat is terrorism. I have always been uncomfortable with the term "war on terrorism". Terrorism is a military tactic, not an enemy against which you can fight a "war", be they Irish nationalists, Sudanese militias, the Arab Al-Qaida, FARC in Colombia or the Mexican drug cartels. In a civilized world, all terrorist movements are unacceptable and must eventually be eliminated. What is most important in controlling terrorism is intelligence because the most effective strategy to defeat a terrorist group is to find and kill the leaders. This means knowledge of their activities and also what drives them to commit terrorist acts. Technology plays an important role in the containment of terrorism, especially in the gathering of facts. But we must do more to nurture the "soft" skills of judgment, anticipation and the ability to act when necessary. Having said all of this, it is very critical to recognize that terrorism does not pose an existential threat to the United States: Al Qaida, or any other terrorist organization, cannot destroy the nation. We should ratchet down the talk but, as I have already indicated, we should spend more time and effort to penetrate terrorist organizations, kill their leaders and isolate their allies and clients to pre-empt future attacks. My judgment is that we have been successful in this effort and we will eventually see a reduction in terrorist activities.

3.) Summary

The existential far term threat is China. This must be met by superiority at sea as a first priority. Sea power must be supported by aerospace power equipped with weapons that the Chinese cannot match.

In the near term, we have to secure the oil supply from the Middle East upon which the industrial world now depends. Thus, this is also an existential problem today. As more oil and gas is discovered around the world and alternative fuel sources are developed, it will cease to be in that category. As the resource in the Middle East becomes less important, the United States and the rest of the industrial world can begin to withdraw from the region. My guess on the time scale for the decline of the Persian Gulf region is ten to fifteen years.

Finally, there is the matter of terrorism. Let me repeat that this is not an existential threat. It will arise around the world periodically and the most important capability that we need to deal with it as a nation is good intelligence.

II. Strategic Basic Research Areas and Engineering Developments

Technological forecasting is a risky business. I will not make a list of things that I believe will happen because my opinion is no better than that of anyone else. What I will do is to talk about two developments that are on the technological horizon with which I am personally familiar. That is to say, I can make judgments about them based on personal experiences that I have had with other, similar systems. It is because of this experience that I place the two I have mentioned at the highest level of priority.

1.) Quantum Computing

On May 15, 2010, the Chief Scientist of the Air Force issued a new "Report on Technology Horizons". This is something that the Air Force does periodically and I think that it provides a good guide for the development of a set of priorities for basic research. The central theme of the Air Force document is to exploit our strength in electronics, in solid state devices and in computer architecture, to create a new class of weapons that could operate without having people in the neighborhood to operate them. In order to accomplish this objective we need to have much better sensors and much more capable computers.

In the past fifteen years there have been some remarkable experiments that have been able to explore in great detail the behavior of single atoms in an ultra-high vacuum enclosure suspended and standing still. An appropriate combination of laser light beams or other possible combinations of electric and magnetic fields are used to achieve this condition. Experiments performed with single atoms under such conditions have revealed that they can interact with each other at very long macroscopic distances, meaning many centimeters. These interactions are not caused by forces such as the electromagnetic one which operates by the exchange of "virtual" photons. Rather, they are caused by the wave functions that characterize the atoms when they become "entangled". Therefore, they can cause the atoms to "feel" each other's presence. The ability to manipulate atoms in this way is purely a consequence of quantum mechanics. (It is of interest that the current U.S. Energy Secretary, Steven Chu, was awarded the Nobel Prize in Physics in 1997 for conducting the first experiments related to the one I have described.)

The ability to manipulate single atoms in this manner has raised the question of practical applications. The most interesting one is whether it might be possible to store information and also to develop switching elements that could be assembled into a computing device. Conventional computers are assembled with transistors as switches and various information storage devices that depend for their operation on the same properties of the solid state as do the transistors. These transistors and the storage devices depend on the cooperative behavior of a million or so atoms in semiconductors that also depend on the laws of quantum mechanics. They control the electrical currents that move the information in a way that is consistent with both quantum mechanics and

electromagnetic theory. In the case of single atoms that interact with "tangled" wave functions, could a much smaller number of atoms be arrayed in such a way that they could store information and to act as switches through "entangled" and "superimposed" wave functions? If this were possible, then we might be able to assemble computers with switches and storage elements that consist of a much smaller number, say hundreds, rather than the millions necessary for the conventional computer.

For some years now, many people have been trying to develop computers based on the principles that I have tried to describe. For a conventional computer, the term used for a unit of information is the "bit" which is a binary unit that can have either the value of 0 or 1. In a quantum computer the equivalent term is the "qubit". This term does not have the same simple description as a "bit" but it does describe the ability of a quantum computer to process information. What the "qubit" does is to provide a measure of the "size" of the "quantum computer".

There have been some tantalizing experiments with various kinds of "quantum computers" that can perform simple but very large arithmetic operations. One example is generating random number tables which are of great interest to cryptologists. Other arithmetic operations include the factorization of large numbers. What I have just described is a basic research project that clearly deserves strong support. It is equally important to support work to find the practical applications of the new knowledge.

For more than three decades, we have been able to "predict" advances in computer technology using something called "Moore's Law". Gordon Moore, one of the co-founders of Intel, noticed in the early 1980's that that the capability of computers had doubled roughly every two years. The "law" was an extrapolation of Moore's observations. The ultimate size of a transistor is determined by known rules of the quantum mechanics of the solid state. People realized in the late 1970's that we were nowhere near the quantum size limit. Thus, the massive effort to reduce the size of transistors and information storage devices was justified and what we now call "Silicon Valley" resulted. Gordon Moore's quantitative statement produced a true revolution in the field because until we reached the size limit of transistor devices, investments made in Silicon Valley usually paid off.

In the past decade, people began to realize that the smallest reliable transistors or storage devices would have to consist of ordered arrays of about a million atoms, that is, devices in the size range of tens of nanometers. If transistors get smaller than that the band gap structures that make them work become blurred, so Moore's Law is no longer valid.

I believe that quantum computing is, therefore, very probably the next step. There are now groups working on the assembly of "qubits" in such a way that these can be used to perform mathematical operations in certain limited cases. We were in a similar situation in the late 1960's when we ran up against another limit in computing

machines which was the speed of light. At the time the speed at which a central processing unit (CPU) could calculate was determined by the speed of light with which signals move from one transistor to the next. Doing this required very elegant designs for the geometry of the circuits. Eventually, people recognized that the speed of light limit might be circumvented the by having more than one CPU working in parallel with others on the same problem. The Illiac IV was the first massively parallel computer with 64 CPUs running on the same clock. The machine was built before we knew how to program it but we were convinced that the parallel architecture would eventually work. The Illiac IV was installed at the NASA-Ames Research Center in the spring of 1972 and we began essentially by "hardwiring" the CPUs and by November 1975, we had several algorithms working with a crude operating system. Eventually, higher level languages were developed so that machines having a parallel architecture could be programmed for a great many different problems. The Illiac IV was decommissioned in 1982, having proved the concept that parallel processing works. Today all the really large computers have the parallel architecture with thousands of CPUs working together at the same time.

I have a feeling that the same approach might work to bring quantum computers into existence. We ought to fund people to build different kinds of quantum computers and then experiment with them the way we did with the Illiac IV and see what works.

This research should have the very highest priority. If we really can make quantum computers they would have the capability to run much more "intelligent" machines and weapons than those that now exist. Equally important is that the concept of "entangled" wave functions could also lead to the development of exquisitely sensitive detectors and extremely accurate timing devices. There is no question in my mind that the impact of this would have the same kind of impact that the introduction of aircraft made to warfare a century ago.

2.) Hypersonic Propulsion.

The two great "revolutions" in aviation were preceded by the development of new means of propulsion. The era of flight itself, began with the introduction of an internal combustion engine on an aircraft in 1903. Sustained supersonic flight began with the introduction of the turbine engine circa 1945. There is good reason to believe that we are ready now for a third era and that is sustained hypersonic flight.

The term supersonic means flight above the speed of sound which is about 1224 km/h (761 m/h) at sea level and normal temperature. The dividing line between supersonic and hypersonic speed is normally defined as five times the speed of sound or 6120 km/h (3805 m/h). Rockets routinely fly at or above hypersonic speed as they carry payloads into Earth orbit. However, a rocket must carry along its own oxidizer for its fuel because it is ultimately designed to fly in space. The objective is to develop an engine which can propel an aircraft to hypersonic speed using the oxygen in the atmosphere to burn the fuel. During the 1970's and the 1990's, there was considerable

interest in hypersonic flight. The propulsion would be provided by a scramjet (supersonic cruise ramjet) engine. This is a derivative of the ramjet engine which was developed during the Second World War by the Germans for their V-1 unmanned flying bomb. It consists of a tube which has three sections. There is a constriction of the air flow in the front end of the engine to compress the air. It then passes to the combustion region where fuel is injected and lit off to burn. Finally, the heated combustion gases are passed through an exit nozzle and this then provides the propulsion. A major drawback of the ramjet is that it cannot start without some other way of moving the aircraft as it begins its flight. The air must be "rammed" into the inlet of the engine in order to start working. In the case of the German V-1, the thrust to accomplish this was to catapult the aircraft from a long starting ramp riding on a rail propelled by a small rocket. Once it had enough speed to get air going through the engine, the fuel was injected, lit off and from then on, the aircraft could fly. To launch a ramjet or a scramjet without a catapult and a launching ramp, a two stage propulsion system is required. The first stage can be a rocket or a turbojet engine. These must accelerate the aircraft to a high enough speed to start the ramjet engine, which in the case of the ramjet, is relatively easy. For a hypersonic scramjet, which must fly at speeds above five times the speed of sound (Mach 5), the first stage must reach at least Mach 2 or 3 in order for the hypersonic inlet of the scramjet engine to pass the air to the combustion region so that the oxygen can burn the fuel.

During the 1980's, there was great interest in new kinds of aerospace vehicles. The "Orient Express" was supposed to be a Mach 20 civilian aircraft that would make the trip across the Pacific Ocean in less than an hour by achieving suborbital flight. There was also the dream of a "single stage to orbit" space launch vehicle which would replace all conventional multistage launch vehicles as well as the space shuttle. None of these ever went beyond the preliminary test stage. The principal problem was that supersonic and hypersonic flows are devilishly complex. There are many shock waves in the inlet, complicated by ionization and chemical reactions in the case of hypersonic speed air. These phenomena are very hard to program into a computer. Twenty five years ago, we simply did not have the computer capability to calculate the behavior of such high speed flows nor the ground test facilities to verify the calculations.

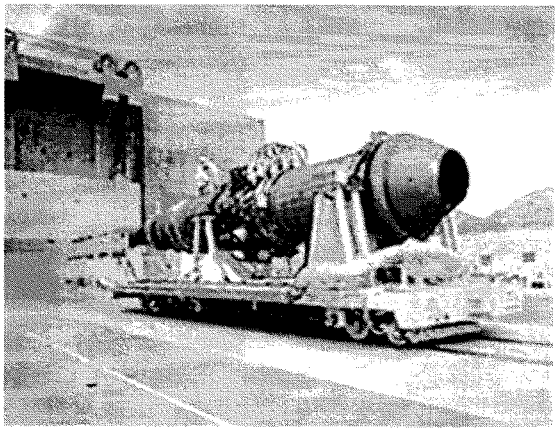
During the 1990's both NASA and the Air Force began to look at the problem again. The principal reason was that a hypersonic cruise missile was deemed to have important new military capabilities. In addition, a larger hypersonic vehicle might be a good first stage for a reusable space launch vehicle to replace the space shuttle. Experiments in available ground based facilities were performed and better computers were also available. By the early 2000's, several designs for small hypersonic vehicles were developed by NASA, DARPA and the Air Force. Toward the middle of the decade, two of these, the X-43 and the X-51, were ready for testing. Each of the test programs has been partly successful and more tests are scheduled.

The principal problem that hinders rapid progress is that there is no ground based test facility that can accurately reproduce the flight conditions above five times the speed of sound (Mach 5). The nation has had to face this problem in the past. During the 1930's, there were many high performance fighter aircraft on the drawing boards, but no one knew which was the best. In 1938, with war looming on the horizon, the National Advisory Committee on Aeronautics (NACA) authorized the construction of the largest wind tunnel in the world at the newly established Ames Aeronautical Laboratory, which had a test section with dimensions of 40 x 80 feet. This tunnel was operational in 1940. The performance of every American fighter aircraft was established using this facility. It is not an exaggeration to say that our air superiority in World War II was in large part due to this facility. When the Cold War with the Soviets was ramping up in the 1950's, we needed to have test facilities that could reach supersonic speeds. The Congress passed the "Unitary Plan Wind Tunnel Act" in 1949, and by 1960, each of the NACA aeronautical laboratories, now run by NASA, had brand new wind tunnels which had supersonic test sections. All of the aircraft and space launch vehicles that were used during the Cold War were tested in these facilities. Again, one of the few technologies where we still have leadership and a positive balance of trade is aeronautics and astronautics. The Unitary Plan Wind Tunnel Act passed by a far sighted Congress sixty years ago can take the credit for this state of affairs.

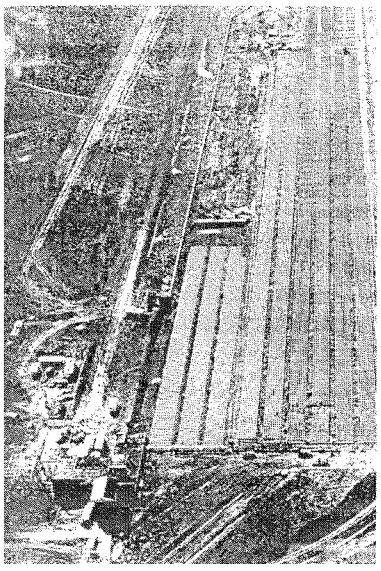
Is there an analogy with what I have described in the case of hypersonic flight? The people working on hypersonic flight tell me that a ground based test facility would make all the difference. Conventional wind tunnels can reach hypersonic speeds only by heating the flow using chemical reactions or electrical power which distorts the results. The air entering the inlet of the scramjet engine in real flight is not hot. It is possible to reach hypersonic speeds equivalent to what a flight vehicle would experience in "blow down" facilities. These have an air supply under high pressure which is "blown" through a small orifice which causes the air to reach hypersonic speeds. Existing "blow down" facilities with large enough orifices to make full scale tests can sustain flows of this kind for short periods of time - perhaps tens of seconds. This is not good enough for accuracy.

In 1964, we did have a very large "blow down" facility to test a ramjet powered by a nuclear reactor. It was part of a project at what was then the University of California's Lawrence Livermore Radiation Laboratory and located at the Nevada Test Site. A picture of this facility is on the next page. The facility stored 450,000 kg. of compressed air which was blown into the inlet of a 500 megawatt nuclear reactor at high speed for five minutes. Although I have not looked at the details, I believe that this facility could have been modified to do tests on the on the hypersonic vehicles that I have mentioned. The question is whether we should make the investment now to build a similar facility. I believe that the existence of such a facility would substantially hasten the advent of hypersonic aircraft.

PROJECT PLUTO



This picture shows the "Tory II C" reactor system. The air intake for the reactor is on the left side of the system pointing toward the concrete blockhouse. The air exhaust is the large circular aperture on the right. The reactor core itself is inside the cylindrical structure and it is about 2.0 meters long and 1.5 meters in diameter. The reactor was an air cooled beryllium ceramic moderated system with a beryllium reflector control system. It operated at a temperature of 1600 degrees centigrade. The reactor ran at a power level of 513 megawatts for five minutes at the Nevada test site on May 16th, 1964. The thrust developed by the reactor was 35,000 pounds. The test proved that the reactor could be made to work, but it was not operated under flight conditions. The Pluto program was canceled on July 1st, 1964.



The high pressure air supply for the Pluto reactor was built using oil well drilling casings as the "pressure vessel". About 25 miles of 10 inch diameter casings were laid out on the desert and huge pumps were borrowed from the Navy to bring the air supply to pressures of several thousand pounds per square inch. The picture on the left shows the facility as seen from a low flying aircraft. The reactor facility with the track on which the car carrying the reactor runs is shown at the extreme lower left.

3.) Summary

Probably the most promising approach to achieve an increase of several orders of magnitude in computer power is quantum computing. We are now investing about $70 million per year in this enterprise from various sources. My feeling is that there are enough good ideas around that a fifty percent increase to about $100 million is not out of bounds. This is a high risk investment but I believe that the risk is worth it.

The achievement of sustained hypersonic flight is a very different proposition. This is an engineering enterprise, not scientific research. The current tests are interesting enough to warrant further investments. Our computers are still not quite good enough to rely on them alone as can be done in the lower speed flight regimes. Therefore a ground test facility that would probably be an investment in the billion dollar range today is necessary.

III. Concluding Comments

There are too many people in our country who have lost confidence in our ability to achieve important ends. I have described two enterprises that carry inherent risks which I believe need to be taken. The effects on our military and on our society of having a working quantum computer would be huge; almost beyond the imagination. The cost today of research is small because throwing money at it will not help speed up the progress. What is needed is the "breakthrough" idea which, I believe will come in due course.

In the case of hypersonic flight is different. Building a vehicle to achieve this objective would be expensive – in the billion dollar range at least. The application to cruise missiles would also be expensive but it would be a weapon that could travel at a speed of 1.06 miles/second. Thus, it would essentially be impossible to shoot down. No one else in the world could produce such a weapon on the same time scale that we can. I would make a comparison of this technology with "stealth" technology which was also costly. A good argument can be that the rapid victory that the United States achieved in "Desert Storm" was in no small part due to the new "Lockheed F-117 "Nighthawk" aircraft that demolished the Iraqi command and control facilities on the first day of the war. We had "stealth" aircraft fifteen years ago but now other nations are building them so that this was a temporary advantage. The same can be said about hypersonic cruise missiles. They will also be expensive, but what price can be placed on victory?

Hans Mark

Professor
Aerospace Engineering and Engineering Mechanics
John J. McKetta Centennial Energy Chair in Engineering

Education: Ph.D., Massachusetts Institute of Technology

Office Location: W.R. Woolrich Laboratories (WRW)
Room 401B, Mail Code: C0600

Phone: (512) 471-9493

Email: hmark@mail.utexas.edu

Research Interests:

- Tilt-rotor Aircraft Applications
- Electromagnetic Railguns
- Prevention of Nuclear Weapons Proliferation

Dr. Mark specializes in the study of spacecraft and aircraft design, electromagnetic rail guns, and national defense policy. He has served on the faculty of the Cockrell School of Engineering since 1988. He served as chancellor of The University of Texas System from 1984 to 1992. He previously taught at Boston University, Massachusetts Institute of Technology, University of California at Berkeley, and Stanford University. Dr. Mark has served as director of the NASA-Ames Research Center, Secretary of the Air Force, deputy administrator of NASA and most recently, the Director of Defense Research and Engineering. He has published more than 180 technical reports and authored or edited eight books. Dr. Mark is a member of the National Academy of Engineering and an Honorary Fellow of the American Institute of Aeronautics and Astronautics. He is the recipient of the 1999 Joe J. King Engineering Achievement Award and the 1999 George E. Haddaway Medal for Achievement in Aviation. He holds six honorary doctorates.

DISCLOSURE FORM FOR WITNESSES
CONCERNING FEDERAL CONTRACT AND GRANT INFORMATION

INSTRUCTION TO WITNESSES: Rule 11, clause 2(g)(5), of the Rules of the U.S. House of Representatives for the 112th Congress requires nongovernmental witnesses appearing before House committees to include in their written statements a curriculum vitae and a disclosure of the amount and source of any federal contracts or grants (including subcontracts and subgrants) received during the current and two previous fiscal years either by the witness or by an entity represented by the witness. This form is intended to assist witnesses appearing before the House Armed Services Committee in complying with the House rule. Please note that a copy of these statements, with appropriate redactions to protect the witness's personal privacy (including home address and phone number) will be made publicly available in electronic form not later than one day after the witness's appearance before the committee.

Witness name: Hans Mark

Capacity in which appearing: (check one)

(•) Individual

( ) Representative

If appearing in a representative capacity, name of the company, association or other entity being represented:

FISCAL YEAR 2011

federal grant(s) / contracts	federal agency	dollar value	subject(s) of contract or grant
BY10-016SP	Department of Defense	$500,000	System Engineering Design

FISCAL YEAR 2010

federal grant(s) / contracts	federal agency	dollar value	subject(s) of contract or grant

FISCAL YEAR 2009

Federal grant(s) / contracts	federal agency	dollar value	subject(s) of contract or grant

Federal Contract Information: If you or the entity you represent before the Committee on Armed Services has contracts (including subcontracts) with the federal government, please provide the following information:

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List of subjects of federal contract(s) (for example, ship construction, aircraft parts manufacturing, software design, force structure consultant, architecture & engineering services, etc.):

Current fiscal year (2011): Systems Engineering Design;
Fiscal year 2010: _____;
Fiscal year 2009: _____.

Aggregate dollar value of federal contracts held:

Current fiscal year (2011): $500,000;
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Federal Grant Information: If you or the entity you represent before the Committee on Armed Services has grants (including subgrants) with the federal government, please provide the following information:

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Current fiscal year (2011): One;
Fiscal year 2010: _____;
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Federal agencies with which federal grants are held:

Current fiscal year (2011): Dod;
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List of subjects of federal grants(s) (for example, materials research, sociological study, software design, etc.):

Current fiscal year (2011): System Engineering Design;
Fiscal year 2010: _____;
Fiscal year 2009: _____.

Aggregate dollar value of federal grants held:

Current fiscal year (2011): $500,000;
Fiscal year 2010: _____;
Fiscal year 2009: _____.

STATEMENT OF

MR. JEAN D. REED
DISTINGUISHED RESEARCH FELLOW
CENTER FOR TECHNOLOGY AND NATIONAL SECURITY POLICY
NATIONAL DEFENSE UNIVERSITY

BEFORE THE

EMERGING THREATS AND CAPABILTIES SUBCOMMITTEE
COMMITTEE ON THE ARMED SERVICES
UNITED STATES HOUSE OF REPRESENATTIVES

ON

DEPARTMENT OF DEFENSE INVESTMENT IN TECHNOLOGY AND CAPABILITY TO MEET EMERGING SECURITY THREATS

24 July 2011

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Introduction

Mr. Chairman and members of the sub-committee, it is an honor to be here today to speak to you about some of the potential emerging and future security threats and challenges facing the United States and the Department of Defense.

I am Jean Reed. I'm a distinguished research fellow at the National Defense University's Center for Technology and National Security Policy, one of the core strategic research centers of the University's Institute for National Strategic Studies where I focus on chemical and biological defense and related policy and program issues. I am also a senior fellow at the Potomac Institute for Policy Studies.

National Defense University (NDU) is the Department of Defense's pre-eminent academic institution for education, research, and outreach in national and international security. As the nation's senior institution for Professional Military Education, NDU prepares military and civilian leaders from the United States and other countries to think strategically and lead effectively across the range of national and international security challenges faced by this nation today and in the future. It performs research and develops issues in support of the national security strategy and national military strategy development needs of the Secretary of Defense, the Chairman of the Joint Chiefs of Staff, and the combatant commanders; and conducts outreach across the U.S. interagency community and internationally. The eight NDU research centers specialize in understanding the emerging strategic situation and the development of creative policy options for how the United States' might respond to the challenging, complex, multi-polar international environment that we face today and anticipate the challenges the Nation might face in the future. Having the advantage of being in-house and close to the

policy process while retaining its academic freedom and integrity, the NDU research team is poised to contribute fully to meeting the needs of the Department and the Nation. It is in that spirit that I appear before you today.

My remarks today will focus on future threats that I see and general trends with regards to areas of emphasis. They reflect my own views and are not necessarily those of the National Defense University, the Department of Defense, or any other organizations with which I am affiliated.

Thinking About Emerging and Future Threats and Challenges

A common theme in statements of the U.S. national defense strategy over the last several years recognizes that "increasingly, the Department of Defense will have to plan for a future security environment shaped by interaction of powerful strategic trends." Over the next 20 years, the confluence of trends with rapid social, cultural, technological and geopolitical change will present greater uncertainty. "This uncertainty is exacerbated by both the unprecedented speed and scale of change, as well as by the unpredictable and complex interactions among the trends themselves."

Defense policy must account for uncertainty by acting to reduce risk and by developing the capacity to hedge against it. Institutional agility, flexibility and resilience are key to dealing with uncertainty and the potential for strategic surprise.

Throughout history, planners have had a tendency to consider future threats within the context of what they knew about the current threat. The natural approach has been to focus on trend projections – predictable paths along which events are expected to evolve. Thinking about science and technology has been similarly linear and

compartmentalized, with projections within any scientific discipline being based on past progress. As a result, strategists and planners have been repeatedly surprised by the application of new technology to warfare, whether actual or economic, by the advantages conferred by the unique combinations of different technologies, and by the non-linear, often exponential, advances in science and technology.

Examples abound. Billy Mitchell demonstrated the vulnerability of battleships to bombs dropped from airplanes, yet the use of air power was largely ignored by the world's navies. The combination of aircraft, highly mobile armor and communications – known as *blitzkrieg* – took the Allied armies by surprise. More recently, use of precision guided munitions, armed drone aircraft and satellite global positioning has changed the complexion of today's battlefield. Advantages can be gained by ingenious use of low technology as well, such as delivering biological agents via the postal service, flying passenger planes into buildings or improvising roadside bombs.

Within the context of the Cold War, planners on both sides had a degree of confidence in the technological capabilities of their counterparts. Science, for its part, was highly "disciplinary" and progress was largely made in incremental fashion within a given discipline, allowing for reasonably accurate planning and the ability to integrate new advances into weapons platforms and defensive systems. Three things have changed all that. First, the bipartite, U.S. vs. U.S.S.R polarity vanished with the demise of the Soviet Union, and has been replaced by new transnational adversaries. Second, science underwent a dramatic paradigm shift in which trans-disciplinary research, with its ability to affect exponential advances within disciplines and, in fact, create entirely new disciplines, became the norm. Third, information has become ubiquitous, allowing individuals access to technology on an unprecedented scale. The world, in short, is a

much more unpredictable and chaotic place, and the emerging threats are equally problematic.

Current Department of Defense (DOD) programs are primarily threat driven, with knowledge of the potential threats being based both on intelligence and a technical assessment of the art of the possible in science. The spectrum of emerging threats has been enlarged by both the exponential advances in scientific knowledge, and its availability to a broader range of potential bad actors that no longer need to have advanced scientific training. Deciphering this threat spectrum will require a robust investment in science and technology, particularly in its evolving trans-disciplinary paradigm.

The concept of technological convergence is critical to understanding future threats, as there are some scientific disciplines which will be radically shaped by their convergence with other areas. The disciplines of nanotechnology, biotechnology, information technology and cognitive neuroscience, collectively known by the acronym "NBIC", are four areas which will be pivotal in anticipating and countering future threats, and NBIC Convergence is an apt metaphor for the paradigm shift in science described earlier. The classic example of NBIC Convergence was the convergence of genomics and information technology, which led to the elucidation of the human genome and which will be the basis for personalized medicine, but the flip side is the ability to manipulate the genomes of pathogenic organisms to create entirely new biological threat agents not found in nature. The ability to predict and plan for such optimal technological convergences will largely determine the technological leaders of the 21st century.

Nanotechnology has been much in the news as well as in popular culture, but is largely misunderstood. Scientists have been conducting work in nanotechnology for at

least three centuries, that is, as long as there has been a discipline called chemistry. The difference now is the ability to manipulate materials on the atomic scale, and to therefore create miniature devices too small to be seen by the naked eye. Such devices could have promising medical applications, such as creating artificial organs or repairing small structures within the body; they could be incorporated into materials and coatings to decontaminate environmental pollutants; or, they could be designed to kill people, disable equipment or have a deleterious effect on the environment. Further, materials which are benign when manufactured at the macro scale can have unpredictable and/or toxic properties when manufactured at the nano-scale, implying an entirely new spectrum of potential threats.

Biotechnology has been largely focused on medicine, but is increasingly finding applications in materials science, alternative energy, agriculture and industrial manufacturing. The tools of biotechnology are ubiquitous and available to anyone in the world. While the Human Genome Project will be the underpinnings for the development of new therapeutic drugs, the "dark side" of biotechnology is its ability to manipulate life, to create new life forms, and to imbue them with pathogenic characteristics. Beyond classical biotechnology, the new field of synthetic biology will be the next revolution in the biological sciences. Synthetic biology is currently in a nascent stage in which genes from one organism are used to create new metabolic pathways in another organism. Used properly, synthetic biology offers the promise of greatly enhanced manufacturing processes for high value biological products such as vaccines. Alternatively, synthetic biology could be used to create entirely novel synthetic systems which have some of the characteristics of living systems, but which are tailored to possess characteristics which would make them a threat to people, agriculture or materials.

With the evolution of the internet, information technology has brought technology to the masses in a very efficient manner. The dependence of the economy on information which has high fidelity and is uncorrupted cannot be exaggerated, and the constant cyber attacks by hackers, whether individual or state sponsored, has both economic and military significance.

Finally, within the concept of NBIC, cognitive neuroscience is probably the least mature but most rapidly advancing discipline. The ability to fully image the brain will dramatically increase our understanding of cognitive function, and will facilitate the development of therapeutic approaches to mental disease. There is also the potential to degrade cognitive function, interfere with decision making, and inhibit performance of the civilian and military populations.

The exponential advances in scientific knowledge, its broader range of availability, and technological convergence for the paradigm shift in science could yield capability outcomes for the good, or that could be a future threat, as noted in my comment about NBIC Convergence. The ability to predict and plan for such an outcome is the question.

Some of my colleagues at NDU suggest navigating through this increasingly complex environment using "foresight" — a structured effort to think about potential security challenges from several –to-many years in the future. Foresight is not about making predictions, but is meant to help decision-makers under conditions of uncertainty by conceiving and testing options and exploring consequences. Foresight helps us think about what we don't know by examining alternative futures. NDU and the Department of State have been running a project exploring the idea of "Actionable Foresight"— the

disciplined analysis of alternative futures that would provide decision makers with the understanding needed to better influence the future environment. Some of the key findings of this project highlight the need to use foresight to identify alternative possibilities in an increasingly complex, interconnected global security environment. Both consumers and producers of foresight need to recognize the speculative nature of foresight as opposed to evidence based recommendations. The interface between foresight and policy should occur regularly and be linked to ongoing decision making processes. Informal, persistent and diverse networks of foresight should include the whole of government and society. Foresight should be linked to current events in order to gain the attention of the policy maker. A venue or central hub is needed for facilitating and coordinating foresight. Finally, foresight should be used to identify opportunities (preventive and responsive) to inform policy makers of actions that would help achieve specific goals.

Another NDU effort, "Anticipatory Governance," would make foresight a component of the policy process; using networked systems to support whole-of-government responsiveness, applying feedback systems to monitor performance and speed up learning from the results. The guiding premise of each of these NDU initiatives is that the United States is confronted by a new class of complex, fast moving, cross-cutting challenges that simultaneously engage our social, economic, and political systems and that challenge our traditional boundaries of national security. Foresight, as a structured effort to think about evolving trends and future possibilities, can inform decision making related to threat prevention, preparedness, and response management.

Conclusion – Anticipating and Responding to the Threat

I believe that the DOD has recognized the changes in the threat landscape and understands the paradigm shifts which have changed both the way science is conducted, and also its potential to generate new threats. There is also a clear awareness that the DOD needs to continually invest in its laboratory infrastructure in order to stay abreast of exponentially increasing scientific advances and, perhaps more importantly, to invest in training the next generations of scientists and engineers. There is also a science-driven emphasis on strategic research investment planning with a focus on key, emerging scientific areas with disruptive potential.

While it is virtually impossible to predict *a priori* what the future threats will be, maintaining clear scientific superiority with a strategic investment based on technology convergence offers the best chance to drive and exploit scientific advances, and to anticipate and respond to new threats based on these technological advances. In addition, foresight, as a disciplined analysis of alternative futures may help us make sense of emerging trends and threats, and better anticipate the future.

Finally, if I may be allowed to add a philosophical caveat, the uncertainty and disruption caused by the context of accelerating changes puts a greater emphasis than ever on our core values. As time goes on, there will be less and less time to think through the larger implications of our vision for the future; so it is increasingly important that we articulate with clarity and precision, exactly what principles we believe should govern our policies as they develop and adapt. The more quick, flexible, and agile our movements, the more important it is that we keep track of where we are and where we want to go.

Mr. Chairman, this completes my prepared remarks and I will be happy to answer your questions.

Mr. Jean D. Reed
Distinguished Research Fellow
Center for Technology and National Security Policy
National Defense University

Mr. Jean D. Reed came to the National Defense University's Center for Technology and National Security Policy in October 2010, following a distinguished career of four and one-half years as Deputy Assistant to the Secretary of Defense for Chemical Biological Defense and Chemical Demilitarization (DATSD(CBD/CD)) and almost fifty years combined military and civilian government service

Prior to his appointment as DATSD (CBD/CD) in December, 2005, Mr. Reed served for 15 years as a professional staff member of the U.S. House of Representatives Committee on the Armed Services, where he had principal responsibility for staff oversight of Navy research and development, Defense-wide science and technology, chemical-biological defense, and chemical weapons demilitarization programs. He was a principal member of the Committee staff team on the Persian Gulf War; principal staff member for the Committee's special inquiry into the chemical and biological threat and co-author of the inquiry's 1993 report, "Countering the Chemical and Biological Weapons Threat in the Post-Soviet World;" and also principal staff member for the then Research and Development Sub-Committee's series of hearings on Countering Weapons of Mass Destruction Terrorism and Information Assurance.

Mr. Reed served 30 years in the United States Army, retiring as a Colonel in 1990. His military career included 30 years progressive experience in a succession of line and staff positions of increasing responsibility, including field artillery battery command and battalion command, two combat tours in Vietnam as an advisor to the Vietnamese Army and with the U.S. 1st Cavalry Division, combat developments staff officer at the U.S. Army Field Artillery School, Defense Advanced Research Projects Agency, two tours in Germany including Deputy Commander of VII Corps Artillery, commander of major Army research and development laboratory at Picatinny Arsenal in New Jersey, and two tours on the Department of the Army General Staff.

Mr. Reed is an alumnus of the University of Oklahoma, where he was awarded a BS in Physics (with Distinction) in 1960 and an MS in physics in 1963. He did post-graduate work in physics at Georgetown University in 1970-1971. He is a graduate of the National War College, the Army War College, and the Army Command & General Staff College, where he earned the degree of Master of Military Art & Science. He was a Senior Army Fellow at the Army's Strategic Studies Institute. He is also a senior fellow at the Potomac Institute for Policy Research. He is a member of the American Physical Society and Phi Beta Kappa. His decorations include four awards of the Legion of Merit, the Purple Heart, and other military awards and the Defense Exceptional Civilian Service Medal.

Mr. Reed lives in Arlington, Virginia, with his wife Lucy-Lee. They have two children.

Testimony of
Alfred R. Berkeley III

Before the United States House of Representatives
Committee on Armed Services
Subcommittee on Emerging Threats and Capabilities

July 26, 2011

Chairman Thornberry, Ranking Member Langevin, Members of the Committee, my name is Alfred R. Berkeley. I am honored to be here as a private citizen. I plan to address, from the business perspective, several areas of your concern. I will speak from my own knowledge and experience, not representing any organization. I have spent my career looking for promising investments in technology companies.

I am a member of Business Executives for National Security, a non-partisan organization of business executives concerned about national security. I am not representing BENS' views today, but appreciate BENS suggesting me to you as a witness.

I will speak specifically to several areas of research and development, but first must tell you that the business executives with whom I talk are far more concerned with several fundamental security issues than with the development of specific capabilities or technologies.

Let me tell you up front that my approach to "What is the proper role of government in fostering innovation?" is simple. Government needs to foster needed innovations that the private sector cannot or will not foster itself. This committee is the focal point of funding such technologies.

I plan to talk about specific technologies, but in preparation for appearing here, I reviewed several ideas that are recurring themes in conversations among business leaders. These ideas are bigger than specific threats or specific capabilities.

1. Creating enough Economic Opportunity to Insure a Committed Citizenry
Business executives that I talk with are concerned that we are not creating enough economic opportunity to insure a committed populace. There are two basic tools to achieve civil stability: a) a good job and b) the opportunity to own something of value, preferably a productive asset.

For better or for worse, a good job has been the bedrock of personal identity and commitment to the community. A military career is a good job, but we need vastly more jobs than the military can offer. Only about 25% of the 18 to 24 year old cohort even qualifies for military service, and the ones that cannot need a productive role in society. We are not creating enough jobs because other countries are doing a better job of creating those same jobs. I am not talking about the short term issue of creating jobs to recover from a recession; I am talking about creating enough jobs to reverse the estrangement of millions of unemployed and under employed whose discontent is warping their sense of belonging to our society.

Economists tell us that here are three factors of production: Men, Materials and Money. Men become useful producers when they are educated. There is a market for talent, and opportunity flows to the hardest working, best educated. Materials are available in the market until they are not available. Our dependence on foreign energy is symptomatic of our problem. We are dependent on sources of many critical materials that may not be reliable. Money is available where there are well functioning capital markets. We may be

on the verge of losing our dominant position as the capital market of choice for risk equity.

The opportunity to own productive assets is as important as having a job. It is very hard in America to "make it" on wages alone. Citizens need to save to fund their own retirement. We will be thrown out of the labor markets in our sixties and live to our nineties. That is frightening.

Our forefathers wisely understood that waves of disenfranchised immigrants, mainly from class-stratified Europe, needed to have a vested interest in the stability of our nation. The various Homestead Acts gave everyone the opportunity to own productive assets. It is important for people to feel they have something of value and a place in the community. It is important to have something that you do not want to lose; something that you can invest in and make more valuable. We have a substitute for the Homestead Act for many years in stock options. Stock options were a way to earn access to ownership of productive assets. We have made it progressively harder for ordinary workers to own equity. In an information age, the next version of the Homestead Acts is a good education.

I believe that the combination of not creating enough jobs and making ownership more difficult means that it is harder and harder to make the licensed economy, the legal economy, available to people, particularly poorly educated people.

Look around you. See the growth of gangs as a way to have a sense of belonging and protection. Look around you. See the growth of criminal enterprises as sources of employment for people with out access to a legitimate job. Look around you. See the profound alienation that infects so many people with cynicism and hopelessness. This is not the path to a stable society. Being the world leader in incarcerating our people is not the right answer. These may be symptoms of "evil people." More likely, they are symptoms of an underground economy that arose because the licensed economy failed to provide enough jobs. I have no hesitancy in saying that many business leaders see our inability at creating enough good jobs, and the resulting rise of the illegal economy, as the major threat to our national security.

If we parse this problem, we can be more specific. The best opportunity to save ourselves comes from improving the education system.

My business friends find the state of public elementary and secondary education mind-boggling. Where is the science on how people learn? Where is it applied? The military has a good record of taking recruits and educating them in specific skills. Notice that I focus on science. Where is the relevant science? We would not dream of letting our children take untested medicines, but we let then take untested curricula. Many in the business community think it is a betrayal of our fundamental values to use our children's learning years receiving an education that is not globally competitive.

Here the DOD recognizes the problem and is acting to find answers. I participated in the initiative that Army Chief of Staff General George Casey created to enable Army resources to enhance local school capabilities and encourage students to stay in school. Lt. General Benjamin Freakley of the Accessions Command is actively focusing resources in South Carolina, among other states that have reached out to embrace the Army programs. I would encourage you to do the relevant science, implement it in the military's internal education programs and show the individual States and the nation what is possible.

The business community I know looks at the Federal Government and sees a massive organization essentially operated to optimize the power of the Secretarial Departments, not designed to optimize the delivery of integrated solutions to national problems. I do not have an answer for this, but you asked for business views of our most pressing national problems.

Initiatives that involve more than one Department of government are hard to implement, but there are examples of success. The Administration's recent changes to the Export Control regime are worth mentioning. Outdated export control attitudes were crippling our long term economic growth. A concerted effort and a solid National Academies study laid the ground work for a new policy that offers a better balance between short term security needs and long term security needs. It is important to recognize that short term security needs can be and often are at odds with long tern security needs.

2. Energy Independence

After the concerns about our ability to create enough jobs, enough economic opportunity, my friends in the business rank gaining more energy independence. You are as aware of these issues as I am, but I am here it tell you that my business associates think energy is a root cause of conflict, that it is not an emerging threat but a resident threat, and needs addressing. I am aware of Jonathan Silver's good efforts at the Department of Energy to fund creative approaches to this problem. I suspect sensible technologies already exist in the DOD, for example, nuclear power from small reactors.

3. Cyber Industrial Espionage

Some members of the business community are aware, and many more will be aware of the massive economic losses we are suffering as a result of the theft of our intellectual property. Research, blue prints and designs, negotiating positions, and schedules are all targets of state actors. Protecting these assets is probably beyond the capability of most businesses. There is a role for Federal in spotting suspicious patterns and alerting business to known threats. I encourage you to fund the National Counterintelligence Executive's effort's to raise business awareness on this trillion dollar drain on our resources and attack on our future. Cyber espionage affects the Defense Industrial Base as directly as any threat that exists.

I believe that the basic paradigm for securing data must change. Interestingly, I believe the solution is already in the market and will see wide acceptance as business and government becomes aware. The current paradigm tries to protect the operating system

and applications code. The new paradigm will protect the data itself through what is called "bit splitting." I am making investments in this area. Since the new paradigm is already in the market, the USG need only give it an honest evaluation. No government funding is necessary.

4. Cyber Crime

My own industry, financial services, is the target of massive thefts of cash, principally by criminals living in corrupt sovereignties. Government as a criminal enterprise is something that business cannot solve alone and for which it needs sophisticated diplomatic, law enforcement and military assistance.

5. War on Drugs

We are not solving the problem of drugs. We are filling the prisons with minor offenders and then excluding them from productive citizenship for the rest of their lives. We need to rethink the whole approach. It will be hard, as two whole industries have emerged to profit on the drug trade and the fight against the drug trade.

6. Economic Warfare

Economic competition is one of the "ultimate chess games," and, over time, determines our standard of living and our national security. Understanding economic competition is as complex a task as exists. Complex adaptive systems are devilishly hard to understand. When I was at NASDAQ, we developed agent based models and generated useful predictive models on a narrow range of policy issues.

Technological innovations in research, development, production, sales, marketing, distribution and service can create competitive advantage. In many ways, economic warfare is more difficult to win than physical war. It is a grinding, relentless game, played every hour of every day, involving the whole population, without end. It is a fundamentally distributed, decentralized game, not particularly susceptible to centralized command and control.

America's "Value Proposition"

It is important to understand the role of ideas in economic competition. Ideas are one of the main theaters of competition. Physical goods and services are important, but hearts and minds are motivated by ideas. Democracy, personal liberty, individual rights and rule of law are our most powerful tools, but only if the lower order needs in Mr. Maslow's hierarchy of needs are provided.

The business community believes that America's approach needs to deliver more value to individuals than the competition: a higher standard of living, a sense of belonging and a sense of purpose. If we can deliver on these "value propositions," we may have fewer physical battles to fight. These are not DOD's traditional deliverables. We need an integrated solution with State and Commerce.

What should we invest in to deliver on these values?

In a digital world, where we have a strategic advantage, we need to deliver as much value as we possibly can digitally. The ubiquity of connectivity is creating a new battle space in the war of ideas.

Language

Language is the barrier that we never think of, the barrier that is so much a part of the world that we assume it will be there forever. We can attack the biggest barrier to human understanding and remove the fear and distrust that comes from strangeness if we develop language translation for most of the world's languages.

Language is man's old curse. The stories of Tower of Babel understood that language is a root cause of mistrust. We are close to being able to obliterate that barrier between people. A world wide effort to let anyone talk with anyone, each in their native tongues, would be an extraordinary tool. Technologically, it is close. It is all about synonyms, homonyms and contextual disambiguation.

We need to think big here. Language tools are a new class of weapons that attract people to the benefit they deliver. The ubiquity of connectivity, particularly the smart phone makes it possible.

Education

Higher education is a notional strength. We need to create an "all education, all the time" web site. We need to offer a complete education in a growing number of languages, for anyone in the world that wants to use them.

This concept includes computer adaptive teaching and computer adaptive testing, approaches that the DOD pioneered. Let anyone in the world test themselves and get an honest answer as to how much they know and where their weaknesses are in math, science, and many other courses. The Council on Competitiveness experimented with such a site, with good results. There is unlimited capacity on the web and we need to think big. Education is also a weapon in the war of ideas that attracts people to the benefits it brings. The increasing ubiquity of connectivity, particularly smart phones makes it possible.

Medicine

Similarly, we should deliver the best information available to win hearts and minds through a subject that people really care about, health. The ubiquity of connectivity, particularly smart phones makes it possible.

Near Field Communications

A more general capability, a platform for many applications, is Near Field Communications. The world is on the edge of the next revolution in communications, the mating of sensors and RFID tags with cell phones. The current generation of phones is being manufactured with the ability to read sensors and RFID tags in close proximity to the phone. I have read that 90% of the world's population lives within range of a cell tower. Smart phones will be the

natural delivery method for the language tools, the education tools, the health tools and the dozens of specific sensor and interactive applications discussed above. In ways we probably do not understand now, these applications will change the balance of power between people and between people and governments. The USG needs to deliver *value* and to deliver *values* through these new mechanisms. Digital connectivity can allow us to win hearts and minds one at a time at almost no marginal cost, and with no intermediaries warping the message. These technologies present a wide open playing field, with the opportunity to gain share of mind in important applications. The ubiquity of smart phones makes it possible.

Predictive Analytics
The science of prediction is becoming robust. It has been under development for decades and is about to "burst" onto the scene. The DOD has been a pioneering leader in the technologies and uses of predictive analytics. Many human problems can be mitigated with statistically accurate anticipation. These capabilities are part of the value proposition that the United States can deliver in the war for hearts and minds.

Agent Based Modeling
Agent based modeling is a specific technology that holds great promise for understanding complex systems. The DOD has many agent based modeling activities underway. It is unlikely that we can understand the complex game called economics without agent based modeling. If a vibrant economy truly undergirds notional security, we need to understand economics. Much of what we believe comes for oversimplified models based on old technology and know how.

On the issue of our global competitiveness, which is part of the jobs conundrum, I refer you to James Case's book, entitled Competition, The Birth of a New Science. Incidentally, there is a chapter in Case's book that addresses the underlying question before this committee: what is the role of government in fostering innovation and economic growth? Mr. Case goes back to Alexander Hamilton's "Report on Manufactures" in 1797 and highlights Hamilton's opposition to Adam Smith's free market approach to fostering innovation. Some things never change!

What does business need from the US Government and the Department of Defense?

Predictability
Business needs predictable inputs and outputs to justify investing. Because there is so much we cannot predict, we crave predictable where we think it should be. I believe that much of the hesitancy that retards investment now comes from uncertainty over interest rates, tax rates and currency values.

Access
At the DOD level, business wants predictable funding, predictable revenues and predictable access. The access issue does not cost much to fix: finding the right person to whom to present new ideas is hard, but can be facilitated. The DOD should be a predictable, reliable customer wherever it can. Evaluating new companies' products and giving honest feedback also helps.

I mentioned the improvements in the export control regime, making larger markets available in many cases, which justify larger investments.

Time horizons
The American financial services industry creates many of the unfortunate incentives that make our businesses so short term oriented. A whole series of public policies that favor speculation over investment combine of force businesses to avoid investments that take long horizons to be profitable or face significant technology risks. We will not solve those issues today, but it is important to recognize that our short term horizons, combined with intense global pressure on prices, has forced companies like AT&T to sell Bell Laboratories and reduce expenditures on research. This has made government support even more important. Furthermore, we are in a period where the investment community feels there are fortunes to be made exploiting applications that address the enormous markets that are relatively newly connected to the World Wide Web, crowding out investments farther down the technology stack, particularly investments in component parts.

Vibrant Capital Markets
This is a complex issue and David Weild at Grant Thornton has studied it seriously. Something changed with Sarbanes Oxley and our ability to fund equity Initial Public Offerings was damaged. That market is a principal source of funding for technology companies. We should try to fix it.

Property rights
The Bayh-Dole Act of 1980 gave universities the property rights in inventions funded by Federal dollars and spawned thousands of technologies. There is nothing better than a bit of self interest to engender hard work. Efforts to change this act should be resisted.

University Affiliated Research Centers
I served on the board of Johns Hopkins University's Applied Physics Laboratory for about 12 years. I was impressed by the breadth and depth of the Laboratory's inventions and contributions, and particularly by the way the laboratory transferred completed development projects to for-profit companies for production. It is a good model for getting commercially hard to justify development done to wring the risk out and then transfer to the tax-paying sector. It is great leverage for the tax-payers' dollars.

Conclusions

I recognize that my comments have not been as specific about individual technologies as you may have expected and may receive from other witnesses. You asked me for a perspective from the business community. The business leaders I talk with are vitally concerned with making our economy vibrant and supportive of innovation and growth. They recognize that a powerful military is necessary but not sufficient to assure our security. You should be concerned that I am bringing you concerns like lawlessness, like criminal enterprises, like gang activity and like cyber espionage. These would not likely have been on business's agenda a decade ago. We are afraid that we are reaching tipping points that are truly dangerous for a democracy.

The DOD has some of the best analysis capabilities in the world. I hope the Department will use its powerful intellectual capabilities to document these issues for the nation, to frame solutions for the nation and offer thought leadership. I believe the situation is so bad that it is a national security issue. I agree with General Casey that having less than a quarter of the 18 to 24 year old cohort eligible for military service is a national security issue. While I believe that this committee must identify and fund the specific capabilities for kinetic and information warfare, I will tell you that the business leaders I know want these larger issues on your agenda.

Thank you for having me.

Alfred Rives Berkeley III

Education

Episcopal High School, Alexandria, VA, Diploma 1958 – 1962

University of Virginia, BA, 1962 – 1966

University of Pennsylvania, MBA, 1966 – 1968

Employment

Pipeline Financial Group, Inc., Chairman, 2003 – Present

NASDAQ Stock Market, Inc., President and Vice-Chairman, 1966 – 2003

Alex. Brown & Sons, General Partner, Managing Director, 1972 – 1996. (CEO of Rabbit Software, Inc., a public telecommunications software company, from 1989 to 1991, while on leave of absence from Alex Brown & Sons.)

USAF, 1968 – 1972, Captain USAFR, 1978 – 1980, Major

Public Service

National Infrastructure Advisory Council, Member, Vice – Chair and Acting Chair, 2001-present

City of New York, Financial Industry Advisory Committee, 2009- present

National Medal of Technology Evaluation Committee, Member, Vice-Chair 2004+/- to 2010

US Department of Homeland Security, Homeland Security Advisory System Working Group, 2009

US Department of Homeland Security, Homeland Security Advisory Council, ex-officio, 2011 – present

Bi-partisan Homeland Security transition panel, 2008- 2009

US Department of Energy, Task Force on the Future of Science, 2001 +/-

US Department of Education, Task Force on Mathematics, 2007 +/-

National Academies, Committee on Scientific Communications and National Security; Committee on Science, Security and Prosperity, 2006- 2009 +/-

National Science Foundation, Public Affairs Advisory Group, 1997 – 1999 +/-

US Department of the Army, Chief f Staff's working group on What It Means to Be an Educated Individual in the Twenty First Century

State of Maryland, Coastal Resources Advisory Council, Baltimore City Citizen Representative, 1957 – 1977 +/-

State of Maryland, Maryland-India Roundtable, Co-Chair

Board Seats, Non-Profit, Current

Allen University, Columbia, South Carolina, Trustee, an historically black university

World Economic Forum, USA, Director

XBRL US, Inc., Chairman (past) and Director (standard setter for Security and Exchange Commission's EDGAR modernization program)

XBRL International, Inc., Director, (International Standard setter for XBRL language world wide.)

Outward Bound of Maryland, Trustee

Board Seats, Non-Profit, Former

Johns Hopkins University

Johns Hopkins University Applied Physics Laboratory

The Nature Conservancy, Trustee

The National Association of Securities Dealers, Inc., Governor

The Episcopal High School, Trustee

The Center for Excellence in Educations (formerly the Rickover Foundation), Trustee

Mathematical Sciences Research Institute, Trustee

The Baltimore Symphony Orchestra, Trustee

University of South Carolina Research Foundation, Trustee

NASDAQ Education Foundation, Inc., Chairman

Council on Competitiveness, Executive Committee, Member

Board Seats, For-Profit, Public Companies, Current

ACI Worldwide, Inc., Director

Realpage, Inc., Director

Edgar Online, Inc., Director

Fortegra Financial, Inc.

Board Seats, For-Profit, Former

I have served on eleven other public company, for-profit boards

Board Seats, For-Profit, Private Companies, Current

Security First Corp., Director

Knewco, Inc., Director

Advisory Boards, Not Legal Boards

Washington National Cathedral, Dean's Advisory Board, Member, about 2002 to 2004

American Red Cross, Blood Board, Baltimore Washington area, Member

Camden Partners, Baltimore, MD, Member

Monetary Authority of Singapore, International Advisory Board, Member, 1999 -2000

DISCLOSURE FORM FOR WITNESSES
CONCERNING FEDERAL CONTRACT AND GRANT INFORMATION

INSTRUCTION TO WITNESSES: Rule 11, clause 2(g)(5), of the Rules of the U.S. House of Representatives for the 112th Congress requires nongovernmental witnesses appearing before House committees to include in their written statements a curriculum vitae and a disclosure of the amount and source of any federal contracts or grants (including subcontracts and subgrants) received during the current and two previous fiscal years either by the witness or by an entity represented by the witness. This form is intended to assist witnesses appearing before the House Armed Services Committee in complying with the House rule. Please note that a copy of these statements, with appropriate redactions to protect the witness's personal privacy (including home address and phone number) will be made publicly available in electronic form not later than one day after the witness's appearance before the committee.

Witness name: Alfred Rives Berkeley, III

Capacity in which appearing: (check one)

(•) Individual

( ) Representative

If appearing in a representative capacity, name of the company, association or other entity being represented:

FISCAL YEAR 2011

federal grant(s) / contracts	federal agency	dollar value	subject(s) of contract or grant
not applicable			

FISCAL YEAR 2010

federal grant(s) / contracts	federal agency	dollar value	subject(s) of contract or grant
not applicable			

FISCAL YEAR 2009

Federal grant(s) / contracts	federal agency	dollar value	subject(s) of contract or grant
not applicable			

Federal Contract Information: If you or the entity you represent before the Committee on Armed Services has contracts (including subcontracts) with the federal government, please provide the following information:

Number of contracts (including subcontracts) with the federal government:

Current fiscal year (2011):_____;
Fiscal year 2010:_____;
Fiscal year 2009:_____.

Federal agencies with which federal contracts are held:

Current fiscal year (2011):_____;
Fiscal year 2010:_____;
Fiscal year 2009:_____.

List of subjects of federal contract(s) (for example, ship construction, aircraft parts manufacturing, software design, force structure consultant, architecture & engineering services, etc.):

Current fiscal year (2011):_____;
Fiscal year 2010:_____;
Fiscal year 2009:_____.

Aggregate dollar value of federal contracts held:

Current fiscal year (2011):_____;
Fiscal year 2010:_____;
Fiscal year 2009:_____.

Federal Grant Information: If you or the entity you represent before the Committee on Armed Services has grants (including subgrants) with the federal government, please provide the following information:

Number of grants (including subgrants) with the federal government:

Current fiscal year (2011):_____;
Fiscal year 2010:_____;
Fiscal year 2009:_____.

Federal agencies with which federal grants are held:

Current fiscal year (2011):_____;
Fiscal year 2010:_____;
Fiscal year 2009:_____.

List of subjects of federal grants(s) (for example, materials research, sociological study, software design, etc.):

Current fiscal year (2011):_____;
Fiscal year 2010:_____;
Fiscal year 2009:_____.

Aggregate dollar value of federal grants held:

Current fiscal year (2011):_____;
Fiscal year 2010:_____;
Fiscal year 2009:_____.

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