

INNOVATION IN ENERGY TECHNOLOGIES

HEARING BEFORE THE COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE ONE HUNDRED NINTH CONGRESS

FIRST SESSION

TO

CONSIDER OUR NATIONAL CAPACITY FOR PRODUCING TECHNOLOGICAL
INNOVATION AND THE IMPORTANCE OF THIS INNOVATION TO OUR
GLOBAL ECONOMIC COMPETITIVENESS; AND TO RECEIVE TESTIMONY
DESCRIBING THE RESULTS OF A RECENTLY RELEASED NATIONAL
ACADEMY OF SCIENCES REPORT

OCTOBER 18, 2005



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INNOVATION IN ENERGY TECHNOLOGIES

TUESDAY, OCTOBER 18, 2005

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The committee met, pursuant to notice, at 3:35 p.m., in room SD-366, Dirksen Senate Office Building, Hon. Pete V. Domenici, chairman, presiding.

OPENING STATEMENT OF HON. PETE V. DOMENICI, U.S. SENATOR FROM NEW MEXICO

The CHAIRMAN. Why don't our two witnesses come up, please?

This will not be our last hearing, but it will be the kick-off hearing. So we are starting today with Dr. Ralph Cicerone. I think I have met you before. Nice to see you again. And Norm Augustine.

Each of us are going to make a statement, because the two Senators, the one on my left and the one on my right, have been asked to do this. They have both been working on it. I will let both of them comment. Normally that does not happen, but we are going to do that today.

I am concerned, as you are and everyone here on this committee, about the United States' competitiveness in relation to some of the other economies around the world. This committee gets involved in those issues as we follow the enormous energy and resource requirements of China and India, but many of the signals that we have put forth pose a problem. Clearly some of them go back, in my case, to the budget days and the Budget Committee.

I worry about the impact of competitiveness on our ability to afford many of the social programs that are very significant, like Medicare, Medicaid and Social Security. I worry about the lack of competitiveness and its effect on the balance of trade and the value of the dollar against foreign countries and currencies.

There are areas in which the United States seems to be the world leader in research and development, certainly in health care and medicine. Those come to my mind right off the bat. However, it does seem that our preeminence in the physical sciences is simply no longer there.

It seems that the very complex science issue is difficult for our government to manage and to put our arms around. The pursuit of scientific knowledge is frequently a wandering path. I know of technology developed in the nuclear weapons program being used to fight diabetes, for example.

Government has a hard time managing these sorts of things that shift from application to application across programs and across

agencies, but it does not mean that they should be avoided. We do need a major increase and new direction in the physical science programs of our country.

There is a lot in this report that I am especially intrigued by. It is a notion of goal-setting to orient our efforts, as you have proposed and discussed, by declaring an intent to address the Nation's need for affordable, reliable energy, which you have not yet recommended. Clearly it seems to me that in the past, goals have been terrific promoters and pushers of science advancement. You know better than I what those are, both of you.

It is a significant goal and it might well require what you have proposed. That is a new investment of about \$10 billion each year for scholarships and other investments. You have indicated a 10 percent increase in basic research funding each year for at least 7 years. Some people think that is way out of line, but just look at what we have done for far less important things, objectives, and goals.

So I am going to stay on this thought of energy independence for the moment. I have never thought that that was possible, but I do believe that, if pressed, we could find some way to generate all the energy we need. This challenge is "at what cost" and how the experts will tell us we will get there. It is not in the interest of our economy to generate domestic energy that imposes higher energy costs which are too hard and too high for our economy to be able to compete in the world. So the challenges for this goal are real.

But let us say we can produce all the energy domestically and cheaper than we can buy it now. I do not think we are ever going to get there unless we do something like you are talking about. So, as chairman of this committee, I am very enthusiastic.

I want to close by saying, to you and those who have helped you, one of our government's problems is when we got to funding medical research, that was an entity, the National Institutes of Health. One just started a resolution and said, let us double the funding of the National Institutes of Health. Then that is passed to each of the institutes. Basic research is not funded that way. You both know that. It is anywhere, everywhere, not in the right places. Too much in some places. But if you try to say, let us double it, we would not know what to double. So, it is not going to be easy, and your recommendations cross committee lines. But nonetheless, we know about it and we ought to move ahead.

Senator Bingaman, thanks for your work and for your suggestions. Would you give us your opening statement? Then Senator Alexander, and then we will proceed. Thank you again to both of you.

[The prepared statement of Senator Corzine follows:]

PREPARED STATEMENT OF HON. JON S. CORZINE, U.S. SENATOR FROM NEW JERSEY

Mr. Chairman, I first would like to thank you for holding this hearing. I also would like to commend Senator Bingaman and Senator Alexander, who asked the National Academy of Sciences to compile the report are reviewing. They deserve admiration and respect for their vision and dedication on this important issue. I also would like to thank the members of the Committee on Prospering in the Global Economy of the 21st Century. Few other committees have benefited from the breadth of expertise exhibited by its members. They have produced a report of special significance, and we should all pay careful attention to their recommendations.

The committee identified two challenges that are linked to scientific and engineering capability: The creation of high quality jobs for Americans and the response to

the nation's need for clean, affordable, and reliable energy. I will address the latter first. The need for America to reduce its dependence on foreign sources of energy is inexorably linked with the need for domestic innovation regarding our use and consumption of natural resources. I have long been an advocate for alternate sources of energy, and I believe that the development of such sources can be achieved through domestic innovation. We cannot simply drill ourselves out of our dependence on foreign oil. A diversification of our energy portfolio, founded in scientific innovation, can wean us from our oil addiction. A prime example of this innovation can be found in increasing fuel efficiency standards. The Energy Bill that recently passed, which I voted against, did not include any provisions that would improve automobile fuel economy, which could reduce the share of foreign oil that we consume by more than ten percent. These programs, which encourage forward looking innovation instead of maintaining the status quo, should be pursued more vigorously.

The task of creating high quality jobs for Americans should also be considered seriously. Though we currently lead the world in economic strength, this lead is not sustainable if we merely stay on the course. America's domestic innovation, the bedrock of our economic strength, needs to be fortified. The question will require a cohesive and deliberate policy, aimed to help the United States achieve prosperity in the 21st Century. Such a policy must be multifaceted and farsighted. I am heartened that the committee has suggested we strengthen our science and engineering education system at all levels. We must educate the next generation of scientists and engineers by providing them with opportunities and incentives to excel. Cutting the budgets for these vital education programs not only hurts the individual student, but also hinders the prospects for American technological ingenuity in the future. Furthermore, we must continue to support our budding scientists at the college and post graduate levels. In 2004, China graduated over 600,000 engineers, India 350,000, and America about 70,000. In addition, 12th graders in the United States recently performed below the international average for 21 countries on a test of general knowledge of science and math. All of us should pay close attention to the disturbing statistics included in this report. Not only do these findings highlight the poor overall education of our students, they also point to cracks in the long-term sustainability of America's leadership in these important fields. Establishing incentives for high school and college students to study science and engineering will increase the pool of talented scientists for both the private and public sector. Increasing the amount and size of scholarships will certainly help this effort. One particular program, the Math and Science Partnership Initiative, would increase funding for long term professional development for the country's teachers and for developing more rigorous math and science curricula. I have been a proud supporter of this program since the beginning of my tenure in the Senate, and believe that such programs will help alleviate the deficiencies we now see in the math and science education of America's students.

I also heartily agree with another tangential conclusion of this report; the federal government can actively work with state and local governments for educating and stimulating our globally competitive workforce. I have been extremely active in ensuring that my state remains competitive in the global economy by encouraging high tech industries to do business in New Jersey. The foundations of these chemical, pharmaceutical, and defense companies are its scientists and engineers. We should ensure that we continue to support the homegrown innovation of these workers.

Historians have often called the 20th century "America's Century." Indeed, during the last century the U.S. shaped the global landscape, leading innovation and ensuring its domestic economic prosperity. It will not be easy, but the vision that our elected leaders show at the beginning of the 21st century will have momentous consequences in the coming years. The report by the National Academies should be studied closely and its advice taken seriously in any future legislation. I again thank the Chairman and Ranking Member for allowing this Committee the chance to hear from these witnesses before us about this crucial topic and I look forward to their testimonies.

**STATEMENT OF HON. JEFF BINGAMAN, U.S. SENATOR
FROM NEW MEXICO**

Senator BINGAMAN. Yes, thank you, Mr. Chairman. Let me thank Senator Alexander for his leadership in getting us focused on this issue and thank both of our witnesses and the panel members that

worked with them. We had a stellar group of experts really who came together to reach these conclusions and recommendations.

Obviously, the specific recommendations are extremely important and we need to take them to heart and we need to implement, but I also think that this report is serving a very useful purpose in getting us focused on the important challenge we face long-term. I do think that we have a great tendency here in official Washington to wake up every morning and read the paper to see what we ought to be working on that day, and that is sort of the way we set the agenda around this place. We see who is saying what and who is attacking whom and then what investigations are revealing, and then decide what we ought to work on.

This is a set of issues that are extremely important, probably as important as any that we could identify for the country. But since they do not fall under the category of being on the front page of the paper every day, we do not ever get around to them. We always put them off and put them off and give them lower priority attention than they deserve.

So you deserve great credit for getting us focused on these issues again and I look forward to your testimony and then to additional opportunities, as we go through the next few months, to highlight what your recommendations are and hopefully get the administration and the Congress to embrace these recommendations and actually move out on them.

Thank you again, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Bingaman.

Senator Alexander.

**STATEMENT OF HON. LAMAR ALEXANDER U.S. SENATOR
FROM TENNESSEE**

Senator ALEXANDER. Thanks, Mr. Chairman.

I am really enormously pleased with what is happening here. I am the new kid on the block, and I enjoy being that at my age on any block. Senators Domenici and Bingaman have been working on this subject a long time. So has Senator Craig. So have many other Senators. But I have been working on it outside the Senate, and so I am delighted that Senator Domenici has chosen to encourage making this a priority of the U.S. Senate, not just of our committee, but of our Senate, as we work on it.

And it is already receiving, Mr. Chairman, more good comments among our colleagues than almost anything I have been involved in. Senator Mikulski and Senator Bond, for example, who have been interested in this subject, came up to me today and said, count me in. So I believe there is a consensus among the Senators that this is a subject matter that we should make a top priority.

As I have often said, most ideas in Washington fail for lack of the idea. What you gentlemen and your colleagues have done is given us the idea of what we ought to be doing for the next 10 years. If you stop and think of it, Senator Bingaman and I last May simply did a very simple thing. We walked over to the people who are supposed to know the answer and asked a question. The question was: What are the top actions in priority order that Federal policymakers could take over the next decade to help the United States keep our advantage in science and technology?

Now, we could have sat around the room and Senator Domenici would have said, well, let us do this, and I would have said that, and Craig would have said that. They might have been good ideas, but we are not the ones who ought to know the answer to the question.

And your response has really been remarkable. The fact that the National Academies of Engineering, of Sciences, and the Institute of Medicine would ask someone of Mr. Augustine's stature then to assemble, Mr. Chairman, in a short time, a matter of a few weeks, such a distinguished panel of university presidents and other academics, Nobel laureates, business leaders, government officials, and answer our questions. These are 10 things the United States ought to do to keep its secret weapon, which is brain power.

And you reminded us that 85 percent of the increase in our incomes in this country of ours has come from science and technology. I would like to remind us of how fortunate we are. I mean, we are 5 percent of the people in the world, and we produce about a third of all the money, compared to the gross domestic product. What we are focused on today is the secret weapon for our high standard of living and good jobs, and that is brain power, and what should we do over the next 10 years about brain power.

Mr. Chairman, I want to put my statement in the record, if I may, but I would like to say one or two more things from it, just as a matter of example.

You took our question seriously. And speaking as one Senator—and I believe there are many who feel the same way—I am going to take your recommendations seriously and work through the various committees and with Chairman Domenici and others to do our best on them.

Next, I think it is important to remember that this great advantage we have did not happen by accident. We have the best universities. We have this array of 36 Federal research laboratories. We have had, at least until recently, the best K-12 system. We poured Federal Government money into all this, \$22.5 billion for university-based research in science and engineering. 60 percent of our college students attend college with Federal grants or loans, \$52 billion of Federal student loans.

While we have been outsourcing jobs, we have been insourcing brains. 572,000 foreign students attend our colleges and universities here. Your report addresses that.

So we have asked the right people, the people who ought to know the answer. You have given us the answer and now it is down to us.

I suppose the other thing I would want to say is this. Someone says to me, well, where is the money going to come from for this? Well, we have a budget of over \$2 trillion every year. I have made budgets before. They have been a lot smaller. I was Governor and I always started by putting the most important thing in first, and then everything else, Mr. Chairman. You have been a budget chairman for a long time. Everything else comes in after that.

Well, I think if we can have a consensus about what the most important things we need to do are to keep this astounding standard of living we have, that we ought to say to the President, put

it in first. And then we will have a restrained spending budget over the next few years.

Now, my hope is not just that Chairman Domenici and Senator Bingaman and others of the senior members of the Senate get interested in this. I want the President to get interested. It is hard for us to organize ourselves around an agenda. We are legislators. This really cries out for executive action. I would hope that your report would be the subject of the President's State of the Union address and the thrust of his next 3 years. If he were to do that, I think he would find in the U.S. Senate a strong bipartisan core of people who agree with that thrust.

So I thank you very much for your hard work. I look forward to working with you on your recommendations, and I thank Chairman Domenici for giving this such a good start.

[The prepared statement of Senator Alexander follows:]

PREPARED STATEMENT OF HON. LAMAR ALEXANDER, U.S. SENATOR FROM TENNESSEE

In May, Senator Jeff Bingaman and I, with the encouragement of this Committee's Chairman Pete Domenici, asked the National Academies of Sciences and Engineering and the Institute of Medicine this question: "What are the ten top actions, in priority order, that federal policy makers could take over the next decade to help the United States keep our advantage in science and technology?"

To answer the question, the academies assembled a distinguished panel of business, government and university leaders headed by Norm Augustine, former chair of Lockheed-Martin, that included three Nobel Prize winners. They took our question seriously, and I intend to do everything within my power to take their recommendations seriously.

Today, the Energy Committee takes the first step in that response by holding this hearing to hear from Mr. Augustine and the academies. It will be the first opportunity Congress will have to hear their answer to our question.

This hearing is primarily about brainpower and the relationship of brainpower to good American jobs.

The United States produces almost one third of all the wealth in the world (in terms of GDP)—but has only five percent of the world's population. We are a fortunate country indeed. The academies explain this phenomenon in this way: ". . . as much as 85 percent of measured growth in U.S. income per capita is due to technological change."

This technological change is the result, in the report's words, of an outpouring "of well trained people and the steady stream of scientific and technological innovations they produce."

The United States has taken extraordinary steps to help create this outpouring of trained people and new discoveries that have given us such a disproportionate share of the world's wealth.

We have in our country almost all of the world's greatest research universities. We have a unique array of 36 federal research laboratories. More Americans attend college than in any other country, and the colleges they attend are the best in the world. We have had, at least until recently, a system of K-12 education unsurpassed in the world.

Government support for all these enterprises has been massive. In 2001, the federal government spent \$22.5 billion for university-based research in science and engineering. This year the government will provide 60 percent of American students with grants or loans to help them attend the college or university of their choice. The federal government will spend nearly \$17 billion on grants and work-study programs and will provide an additional \$52 billion in student loans. In my last year as governor of Tennessee, half of state dollars and a larger proportion of local tax dollars went to support education.

And our free market environment encouraged innovation and enterprise as well as billions of dollars invested in corporate research. Finally, to top it off, while we have been outsourcing jobs, we have been insourcing brainpower. 572,000 foreign students attend our colleges and universities. One half of the students in our graduate programs of engineering, science and computing are foreign.

There are three reasons I put this question to the National Academies:

First, Congress is facing huge budget challenges over the next decade as we grapple with restraining the growth of entitlement spending. I did not want tight budgets to squeeze out the necessary investments in science and technology that create good jobs.

Second, as the Augustine report details, there are worrisome reports from all sides that in the new competitive world marketplace, the United States will have to make an even greater effort to keep our high standard of living. To put it bluntly, people in India, China, Singapore, Finland, and Ireland know very well that since their brains work just like ours, that if brainpower is the secret weapon to produce good jobs, then there is no reason that they can't have a standard of living more like ours. They are working to develop better trained citizens and create their own stream of discoveries.

Third, I wanted to ask the question to those who should know the answer. Members of Congress are not the best ones to guess what the first ten things we should do to keep our scientific and technological edge.

Congress is not efficiently organized to deal with broad recommendations such as these. I intend to work with my colleagues to see that all of the recommendations in the report are introduced and given a fair hearing in the various committees that have jurisdiction.

But what really should happen is that President Bush should make this report the subject of his State of the Union address and the focus of his remaining three years in office.

This challenge cries out for executive leadership. This challenge is the real answer to most of our hopes and the solution to most of our big problems, from high gasoline prices to the outsourcing of chemical industry jobs, from the shortage of engineers to the growing number of lower wage jobs, from energy independence to controlling health care costs.

This is the challenge that most Americans wish their government would put up front. We have begun the discussion with a bipartisan question to the wisest Americans who ought to know the answer. We have a remarkable opportunity now to act on the recommendations in the same spirit.

The CHAIRMAN. Thank you.

Now we are going to proceed. I just want to say, Senator, you never are without—I will put it another way. You always shoot for the moon, and that is good. Your ideas about where we ought to go are terrific. Maybe we can.

Senator ALEXANDER. My grandfather used to say, Mr. Chairman—he was a railroad engineer. He said, aim for the top. There is more room there.

[Laughter.]

The CHAIRMAN. All right. Which of you wants to go first? Go ahead.

STATEMENT OF RALPH J. CICERONE, PRESIDENT, NATIONAL ACADEMY OF SCIENCES, AND CHAIR, NATIONAL RESEARCH COUNCIL

Mr. CICERONE. Thank you. I am Ralph Cicerone, president of the National Academy of Sciences. The National Academy of Sciences was chartered by Congress in 1863 and President Lincoln signed that charter. I also serve as chairperson of the National Research Council. Together with the National Academy of Engineering and the Institute of Medicine, we comprise the National Academies. We are private, nonprofit, and independent organizations and we respond to requests for independent and objective studies on challenging subjects involving science, technology, and medicine. Most of our work is by request of the Federal Government.

We are honored to undertake the task that is going to be reported to you today. It was directed to us, as Senator Alexander just recounted, by himself and Senator Bingaman, with strong en-

dorsements by Representatives Sherwood Boehlert and Bart Gordon of the House Science Committee.

Usually we work through committees of experts in our studies of the National Academies and the National Research Council, experts who serve without pay. That is the case again with the report that you are about to hear summarized today from our Committee on Prospering in the Global Economy of the 21st Century. This committee is unusually distinguished. It is comprised of very, very busy men and women who are, individually and as a group, very extraordinary Americans. The group consists of several corporate CEO's, university presidents, three Nobel Prize winners, several past Presidential appointees, and distinguished teachers. The chairman of the committee is here with us today, Mr. Norman Augustine.

By way of background, Mr. Augustine was chairman of the board and CEO of Lockheed Martin earlier in his career. He was an Under Secretary of the Army and an Assistant Director of Defense for Research and Engineering of the United States. He is former chairman of the American Red Cross, former chairman of the Defense Science Board. He now serves on the Council of the President of the United States' Advisors on Science and Technology, and he is a winner of the National Medal of Technology. He is also an elected member of the National Academy of Engineering. And he had a good cast to help him. In just a moment, he will provide an overview of the report.

The committee worked over a very short period of time during which they analyzed data from a wide variety of sources, made their own observations, and read the views of and interacted with many other experts from all walks of life during the summer just past, and it was a short part of the summer. And then they responded to criticisms and suggestions from anonymous reviewers whom we at the Academy selected.

In looking over the data in this report, I think that each one of us would be taken by the variety of indicators that they have drawn from. There may be no one indicator that convinces you completely, but when you add them all together, I think the committee has come up with a rather compelling argument and case.

I would like to add just one more observation to all of the indicators that they summarized in this thick report. Namely, we at the National Academies asked 21 people to serve on this committee, to drop what they were doing in August, and work hard on this task because of the deadline and the time scale on which Senator Alexander and Senator Bingaman asked for recommendations on actions that the Federal Government might usefully take when the two Senators walked over and talked with us. You will notice that we ended up with 20 members on this committee. In other words, 20 out of 21 accepted under those conditions. That level of acceptance of our invitations by highly accomplished people, dropping all other commitments, personal, corporate, and otherwise, was truly amazing. It is a measure of the dedication to the task and their willingness to work, once again, on behalf of the country.

So if I may, Mr. Chairman, I could turn it over to Mr. Augustine now who will discuss the report.

The CHAIRMAN. Thank you very much, Doctor.

Mr. Augustine.

**STATEMENT OF NORMAN R. AUGUSTINE, RETIRED CHAIRMAN
AND CEO, LOCKHEED MARTIN CORPORATION**

Mr. AUGUSTINE. Mr. Chairman and members of the committee, thank you very much for the invitation to describe for you our report. Mr. Chairman, with the committee's permission, I would like to submit a formal statement for the record and then briefly summarize it now.

The CHAIRMAN. Your statement will be made a part of the record.

Mr. AUGUSTINE. As you have heard, our committee had 20 members. I think I can safely say that we all feel deep concern and that we also are all extremely excited about the opportunity that we have to deal with the problems we believe we face. Our work, of course, was conducted in response to Senators Alexander and Bingaman's suggestions.

The thrust of our findings is really quite straightforward. It is that individual prosperity of Americans in the future will depend very heavily on their having access to quality jobs, and our collective prosperity will depend upon having the tax revenues that are underpinned by Americans having quality jobs. And those collective concerns would include providing national defense, providing health care, and so forth.

But there has been a change that has taken place in terms of providing quality jobs. That change is attributable largely to new technologies. I refer specifically to the fact that in the information arena, the cost of providing telecommunications, of processing, and of storage has become almost free. The implication of this that jobs that used to require people to be in close physical proximity to one another no longer require that. That means that jobs are now open to candidates from around the world, and these are not just jobs at the so-called lower end of the employment spectrum, but they are jobs throughout the spectrum.

The change is that job seekers in America no longer have to compete only with their neighbors, but they have to compete with highly qualified people from around the world. They compete in a labor market where we are at a distinct disadvantage. I recently traveled to Vietnam where you can hire 20 assembly workers for the cost of the U.S. minimum wage. I was recently in India, where you can hire 11 engineers for the cost of one engineer in this country. They are fine engineers. And so if we are to compete, we have to compete on some other grounds, and that ground, as you have suggested, Mr. Chairman, and your colleagues, has to be our ability to compete, our ability to have knowledge that is fresh and new.

Very few jobs are what one might call "safe." I would cite just a few interesting examples. In many hospitals in this country, if one has a CT-scan, there is a very good chance it will be read by a physician in India.

Similarly, very near to where we are now sitting, there is an office building that the receptionist, who greets you at the door and controls access to that building, appears on a flat screen display on the wall. She is actually located in Pakistan.

If you call to find out where your lost suitcase is, as I had to do last week, the call center you talk to in this case was in India. They are now teaching people in India at call centers to speak with a midwestern accent.

Those are just a few of many examples I could cite.

Tom Friedman in “The World is Flat”, an extremely perceptive book, has pointed out that globalization has accidentally made people from Bangalore, Beijing, and Bethesda next door neighbors. When it comes to competing for jobs, that is certainly true since jobs are now just a mouse click away.

But is this not good that other nations are prospering? And the view of our committee is absolutely yes, it is very good. It probably portends a safer world. It suggests that American consumers will be able to buy products at less cost and American suppliers will be able to have a larger market to sell their goods and services.

But the problem is that, as with most change, there are likely to be winners and likely to be losers, and our goal is to be sure that America is among the winners when it comes to seeking jobs.

There is an enigma that, as you have pointed out, America is prospering today, but the reason we are prospering is largely because of investments made in the past. Many of those investments were in the area of science and technology, which underpins much of the opportunities and innovation. There will be no sudden warning in this case, no 9/11, no Sputnik, no Pearl Harbor. We will see a gradual erosion, and if we are to compete for jobs, we need to excel in innovation to offset the labor cost disadvantage we endure.

The indicators are not good frankly. We have been living, to a very large degree and to our very good fortune, off of foreign-born talent. 38 percent of the Ph.D.'s in science and engineering in America's work force today were foreign-born. 59 percent of the Ph.D.'s granted by American universities today go to foreign students, and increasingly, those students are going back home because of the great opportunities that are offered in other countries.

In a recent international test of mathematics, conducted with U.S. high school freshmen, the U.S. students, ranked among other countries in the world, finished in 29th place.

As another example, chemical companies closed 70 plants in the United States in 2004. They have announced their intention to close 40 more. In the world, there are 120 new chemical plants being built, with a value of each of more than \$1 billion. Of those, 50 are in China; one is in the United States.

U.S. companies spend more now on litigation expenses than they spend on research and development. Once one has lost the lead in R&D, it is very difficult to recover.

Our committee has produced four recommendations that are very broad, but we also have produced 20 very specific implementing actions. We refer to them as “go do's.” They focus heavily on the creation of jobs and on energy, and I can elaborate on that during the question period, if you wish.

Basically our recommendations are to fix the K-12 science and technology education process; to provide more money for research and the physical sciences, mathematics, engineering, and computer science; to provide more students studying those fields in undergraduate and graduate school; and to create an environment in

America that is world-class in terms of friendliness for innovators and for innovation.

Mr. Chairman and members of the committee, I thank you on behalf of my 19 colleagues, and on behalf of the National Academies, and the two of us would be very happy to answer any questions you might have.

[The prepared statement of Mr. Augustine follows:]

PREPARED STATEMENT OF NORMAN R. AUGUSTINE, RETIRED CHAIRMAN AND CHIEF EXECUTIVE OFFICER, LOCKHEED MARTIN CORPORATION; AND CHAIR, COMMITTEE ON PROSPERING IN THE GLOBAL ECONOMY OF THE 21ST CENTURY, COMMITTEE ON SCIENCE, ENGINEERING, AND PUBLIC POLICY, DIVISION ON POLICY AND GLOBAL AFFAIRS, THE NATIONAL ACADEMIES OF SCIENCE

Mr. Chairman and members of the Committee: Thank you for this opportunity to appear before you on behalf of the National Academies' Committee on Prospering in the Global Economy of the 21st Century. As you know, our effort was sponsored by the National Academy of Sciences, National Academy of Engineering and Institute of Medicine (collectively known as the National Academies). The National Academies were chartered by Congress in 1863 to advise the government on matters of science and technology.

The study had as its origin a conversation which took place at the National Academies with Senator Lamar Alexander several months ago. As a result of that discussion, the Academies were requested by Senator Alexander and Senator Jeff Bingaman, members of the Senate Committee on Energy and Natural Resources, to conduct an assessment of America's ability to compete and prosper in the 21st century—and to propose appropriate actions to enhance the likelihood of success in that endeavor. This request was endorsed by the House Committee on Science.

To respond to that request the Academies assembled twenty individuals with diverse backgrounds, including university presidents, CEOs, Nobel Laureates and former presidential appointees. The result of our committee's work was examined by over forty highly qualified reviewers who were also designated by the Academies. In undertaking our assignment we considered the results of a number of prior studies which were conducted on various aspects of America's future prosperity. We also gathered sixty subject-matter experts with whom we consulted for a weekend here in Washington and who provided recommendations related to their fields of specialty.

It is the unanimous view of our committee that America today faces a serious and intensifying challenge with regard to its future competitiveness and standard of living. Further, we appear to be on a losing path. We are here today hoping both to elevate the nation's awareness of this developing situation and to propose constructive solutions.

The thrust of our findings is straightforward. The standard of living of Americans in the years ahead will depend to a very large degree on the quality of the jobs that they are able to hold. Without quality jobs our citizens will not have the purchasing power to support the standard of living which they seek, and to which many have become accustomed; tax revenues will not be generated to provide for strong national security and healthcare; and the lack of a vibrant domestic consumer market will provide a *disincentive* for either U.S. or foreign companies to invest in jobs in America.

What has brought about the current situation? The answer is that the prosperity equation has a new ingredient, an ingredient that some have referred to as "The Death of Distance". In the last century, breakthroughs in aviation created the opportunity to move people and goods rapidly and efficiently over very great distances. Bill Gates has referred to aviation as the "World Wide Web of the twentieth century". In the early part of the present century, we are approaching the point where the communication, storage and processing of information are nearly free. That is, we can now move not only physical items efficiently over great distances, we can also transport *information* in large volumes and at little cost.

The consequences of these developments are profound. Soon, only those jobs that require near-physical contact among the parties to a transaction will not be opened for competition from job seekers around the world. Further, with the end of the Cold War and the evaporation of many of the political barriers that previously existed throughout the world, nearly three *billion* new, highly motivated, often well educated, new capitalists entered the job market.

Suddenly, Americans find themselves in competition for their jobs not just with their neighbors but with individuals around the world. The impact of this was initially felt in manufacturing, but soon extended to the development of software and the conduct of design activities. Next to be affected were administrative and support services. Today, “high end” jobs, such as professional services, research and management, are impacted. In short, few jobs seem “safe”:

- U.S. companies each morning receive software that was written in India overnight in time to be tested in the U.S. and returned to India for further production that same evening—making the 24-hour workday a practicality.
- Back-offices of U.S. firms operate in such places as Costa Rica, Ireland and Switzerland.
- Drawings for American architectural firms are produced in Brazil.
- U.S. firm’s call centers are based in India—where employees are now being taught to speak with a mid-western accent.
- U.S. hospitals have x-rays and CAT scans read by radiologists in Australia and India.
- At some McDonald’s drive-in windows orders are transmitted to a processing center a thousand miles away (currently in the U.S.), where they are processed and returned to the worker who actually prepares the order.
- Accounting firms in the U.S. have clients tax returns prepared by experts in India.
- Visitors to an office not far from the White House are greeted by a receptionist on a flat screen display who controls access to the building and arranges contacts—she is in Pakistan.
- Surgeons sit on the opposite side of the operating room and control robots which perform the procedures. It is not a huge leap of imagination to have highly-specialized, world-class surgeons located not just across the operating room but across the ocean.

As Tom Friedman concluded it in *The World is Flat*, globalization has “accidentally made Beijing, Bangalore and Bethesda next door neighbors”. And the neighborhood is one wherein candidates for many jobs which currently reside in the U.S. are now just a “mouse-click” away.

How will America compete in this rough and tumble global environment that is approaching faster than many had expected? The answer appears to be, “not very well”—unless we do a number of things differently from the way we have been doing them in the past.

Why do we reach this conclusion? One need only examine the principal ingredients of competitiveness to discern that not only is the world flat, but in fact it may be tipping *against* us.

One major element of competitiveness is, of course, the cost of labor. I recently traveled to Vietnam, where the wage rate for low-skilled workers is about twenty-five cents per hour, about one-twentieth of the U.S. minimum wage. And the problem is not confined to the so-called “lower-end” of the employment spectrum. For example, five qualified chemists can be hired in India for the cost of just one in America. Given such enormous disadvantages in labor cost, we cannot be satisfied merely to match other economies in those other areas where we do enjoy strength; rather we must excel . . . markedly.

The existence of a vibrant domestic market for products and services is another important factor in determining our nation’s competitiveness, since such a market helps attract business to our shores. But here, too, there are warning signs: Goldman Sachs analysts project that within about a decade, fully 80% of the world’s *middle-income* consumers will live in nations outside the currently industrialized world.

The availability of financial capital has in the past represented a significant competitive advantage for America. But the mobility of financial capital is legion, as evidenced by the willingness of U.S. firms to move factories to Mexico, Vietnam and China if a competitive advantage can be derived by doing so. Capital, as we have observed, crosses geopolitical borders at the speed of light.

Human capital—the quality of our work force—is a particularly important factor in our competitiveness. Our public school system comprises the foundation of this asset. But as it exists today, that system compares, in the aggregate, abysmally with those of other developed—and even developing nations . . . particularly in the fields which underpin most innovation: science, mathematics and technology.

Of the utmost importance to competitiveness is the availability of knowledge capital—“ideas”. And once again, scientific research and engineering applications are crucial. But knowledge capital, like financial capital, is highly mobile. There *is* one major difference: being first-to-market, by virtue of access to new knowledge, can

be immensely valuable, even if by only a few months. Craig Barrett, a member of our committee and Chairman of Intel, points out that ninety percent of the products his company delivers on December 31st did not even exist on January 1st of that same year. Such is the dependence of hi-tech firms on being at the leading edge of scientific and technological progress.

There are of course many other factors influencing our nation's competitiveness. These include patent processes, tax policy and overhead costs—such as healthcare, regulation and litigation—all of which tend to work against us today. On the other hand, America's version of the Free Enterprise System has proven to be a powerful asset, with its inherent aggressiveness and discipline in introducing new ideas and flushing out the obsolescent. But others have now recognized these virtues and are seeking to emulate our system.

But is it not a *good* thing that others are prospering? Our committee's answer to that question is a resounding "yes". Broadly based prosperity can make the world more stable and safer for all; it can make less costly products available for American consumers; it can provide new customers for the products we produce here. Yet it is inevitable that there will be relative winners and relative losers—and as the world prospers, we should seek to assure that America does not fall behind in the race.

The enigma is that in spite of all these factors, America seems to be doing quite well just now. Our nation has the highest R&D investment intensity in the world. We have indisputably the finest research universities in the world. California alone has more venture capital than any nation in the world other than the United States. Two million jobs were created in America in the past year alone, and citizens of other nations continue to invest their savings in America at a remarkable rate. Total household net worth is now approaching \$50 *trillion*.

The reason for this prosperity is that we are reaping the benefits of past investments—many of them in the fields of science and technology. But the early indicators of future prosperity are generally heading in the wrong direction. Consider the following:

- For the cost of one engineer in the United States, a company can hire eleven in India.
- America has been depending heavily on foreign-born talent. Thirty-eight percent of the scientists and engineers in America holding doctorates were born abroad. Yet, when asked in the spring of 2005, what are the most attractive places in the world in which to live, respondents in only one of the countries polled indicated the U.S.A.
- Chemical companies closed seventy facilities in the U.S. in 2004, and have tagged forty more for shutdown. Of 120 *new* chemical plants being built around the world with price tags of \$1 billion or more, one is in the U.S. Fifty are in China.
- In 1997 China had fewer than fifty research centers managed by multinational corporations. By 2004 there were over six-hundred.
- Two years from now, for the first time, the most capable high-energy particle accelerator on earth will reside outside the United States.
- The United States today is a net importer of *high technology* products. The U.S. share of global high tech exports has fallen in the last two decades from 30% to 17%, while America's trade balance in high tech manufactured goods shifted from a *positive* \$33B in 1990 to a *negative* \$24B in 2004.
- In a recent international test involving mathematical understanding, U.S. students finished in 27th place among the nations participating.
- About two-thirds of the students studying chemistry and physics in U.S. high schools are taught by teachers with no major or certificate in the subject. In the case of math taught in grades five through twelve, the fraction is one-half. Many such students are being taught math by graduates in physical education.
- In one recent period, low-wage employers like Wal-Mart (now the nation's largest employer) and McDonald's created 44% of all new jobs. High-wage employers created only 29%.
- In 2003 foreign students earned 59% of the engineering doctorates awarded in U.S. universities.
- In 2003 only three American companies ranked among the top ten recipients of patents granted by the U.S. Patent Office.
- In Germany, 36% of undergraduates receive their degrees in science and engineering. In China, the corresponding figure is 59%, and in Japan it is 66%. In the U.S., the share is 32%. In the case of engineering, the U.S. share is 5%, as compared with 50% in China.

- The United States is said to have over ten million illegal immigrants, but the number of legal visas set-aside annually for “highly qualified foreign workers” was recently dropped from 195,000 per year down to 65,000.
- In 2001 (the most recent year for which data are available), U.S. industry spent more on tort litigation and related costs than on research and development.

As important as jobs are, the impact of these circumstances on our nation’s security could be even more profound. In the view of the bipartisan Hart-Rudman Commission on National Security, “. . . the inadequacies of our system of research and education pose a greater threat to U.S. national security over the next quarter century than any potential conventional war that we might imagine.”

The good news is that there are things we can do to assure that America does in fact share in the prosperity that science and technology are bringing the world. In this regard, our committee has made four broad recommendations as the basis of a prosperity initiative—and offers 20 specific actions to make these recommendations a reality. They include:

- “*Ten Thousand Teachers, Ten Million Minds*”—which addresses America’s K-12 education system. We recommend that America’s talent pool in science, math and technology be increased by vastly improving K-12 education. Among the specific steps we propose are:
 - Recruitment of 10,000 new science and math teachers each year through the award of competitive scholarships in math, science and engineering that lead to a bachelor’s degree *accompanied by a teaching certificate*—and a 5-year commitment to teach in a public school.
 - Strengthening the skills of 250,000 *current* teachers through funded training and education in part-time master’s programs, summer institutes and Advanced Placement training programs.
 - Increasing the number of students who take Advanced Placement science and mathematics courses.
- “*Sowing the Seeds*”—which addresses America’s research base. We recommend strengthening the nation’s traditional commitment to long-term *basic* research through:
 - Increasing federal investment in research by 10% per year over the next seven years, with primary attention devoted to the physical sciences, engineering, mathematics, and information sciences—without *disinvesting* in the health and biological sciences.
 - Providing research grants to early career researchers
 - Instituting a National Coordination Office for Research Infrastructure to oversee the investment of an additional \$500M per year for five years for advanced research facilities and equipment.
 - Allocating at least 8% of the existing budgets of federal research agencies to discretionary funding under the control of local laboratory directors.
 - Creation of an Advanced Research Projects Agency—Energy (ARPA-E), modeled after DARPA in the Department of Defense, reporting to the Department of Energy Undersecretary for Science. The purpose is to support the conduct of out-of-the-box, transformational, generic, energy research by universities, industry and government laboratories.
 - Establish a Presidential Innovation Award to recognize and stimulate scientific and engineering advances in the national interest.
- “*Best and Brightest*”—which addresses higher education. In this area we recommend:
 - Establishing 25,000 competitive science, mathematics, engineering, and technology undergraduate scholarships and 5,000 graduate fellowships in areas of national need for U.S. citizens pursuing study at U.S. universities.
 - Providing a federal tax credit to employers to encourage their support of continuing education.
 - Providing a one-year automatic visa extension to international students who receive a science or engineering doctorate at a U.S. university, and providing automatic work permits and expedited residence status if these students are offered employment in the U.S.
 - Instituting a skill-based, preferential immigration option.
 - Reforming the current system of “deemed exports” so that international students and researchers have access to necessary non-classified information and research equipment while studying and working in the U.S.
- “*Incentives for Innovation*”—in which we address the innovation environment itself. We recommend:

- Enhancements to intellectual property protection, such as the adoption of a first-to-file system.
- Increasing the R&D tax credit from the current 20% to 40%, and making the credit permanent.
- Providing permanent tax incentives for US-based innovation so that the United States is one of the most attractive places in the world for long-term innovation-related investments.
- Ensuring ubiquitous broadband Internet access to enable U.S. firms and researchers to operate at the state of the art in this important technology.

It should be noted that we are not confronting a so-called “typical” crisis, in the sense that there is no 9/11, Sputnik or Pearl Harbor to alert us as a nation. Our situation is more akin to that of the proverbial frog being slowly boiled. Nonetheless, while our committee believes the problem we confront is both real and serious, the good news is that we may well have time to do something about it—if we start now.

Americans, with only 5% of the world’s population but with nearly 30% of the world’s wealth, tend to believe that scientific and technological leadership and the high standard of living it underpins is somehow the natural state of affairs. But such good fortune is *not* a birthright. If we wish our children and grandchildren to enjoy the standard of living most Americans have come to expect, there is only one answer: We must get out and *compete*.

I would like to close my remarks with a perceptive and very relevant poem. It was written by Richard Hodgetts, and eloquently summarizes the essence of innovation in the highly competitive, global environment. The poem goes as follows:

Every morning in Africa a gazelle wakes up.
It knows it must outrun the fastest lion or it
will be killed.

Every morning in Africa a lion wakes up.
It knows it must outrun the slowest gazelle
or it will starve.

It doesn’t matter whether you’re a lion or a
gazelle—when the sun comes up, you’d
better be running.

And indeed we should.

Thank you for providing me with this opportunity to testify before the committee. I would be pleased to answer any questions you have about the report.

The CHAIRMAN. Well, let me first say I have been here now in the Senate at the end of this year 34 years. Compared to what each of you have done in your fields, that is not anything more than you have done.

But I think we have made a terrible mistake. We have taken this American machine that produces goods and services and breakthroughs. We just assumed it would always happen, that we were just there. And frankly, myself as one Senator and one American, I have been terribly concerned that we are on the track to a second-rate economy, a second-rate country. And I blame it on all kinds of things in my mind. But many of them I do not know what to do about, but as a result of the request you have presented to us, I believe, a real opportunity exists to address that issue.

I think it is true that when we decided that we would go global—either of you might remember and correct me. This will sort of be my first question. I think we thought that we were going to be all right because we were going to keep the high-scale jobs, high-end jobs, and the low-end jobs were going elsewhere. So, America, do not worry about it.

What happened was at first that was our worry, but that worry changed because what happened in these other countries changed.

We assumed they would not catch on. We were the only one who would do accelerator technology. Right? It turns out we are second. They are first. And we can go through them all.

I think we are to the point where I would say it is no longer 20 out of 21 of you agreeing to meet and work because you see it better than I do, and I think the work is a labor of love, of concern that something is happening. Now, maybe that is overstating it and maybe I am saying more than we can do, but it is worth trying.

So might I ask, is my assessment of the situation, Mr. Augustine, correct, that when we went into globalization, when we thought that was a good thing, we were indeed ahead and we had high-scale jobs, and the others were the Vietnam kind of workers of today? But has that not changed in a very short period of time? And if it has, why did it change so fast?

Mr. AUGUSTINE. I think your assessment is extremely accurate. Initially we did believe that we could put low-end assembly work in plants in Mexico. Now Mexico is having trouble competing with Vietnam and China even. We then began to move office work into other countries. Today there is quite a market of doing our income tax by accounting firms in other countries. Your tax form may well have been prepared abroad. I could cite many such examples. I am sure you could as well.

The trend is one that really makes almost no jobs immune to foreign competition or to moving abroad. I have a friend who recently had surgery and the surgeon sat across the operating room from him on the other side of the room and operated on him using a robot. It is not a huge leap of at least this engineer's imagination that that surgeon, instead of sitting across the room, could sit across the ocean, could be an absolute world-class surgeon who specializes in this particular procedure. I could imagine that. I do not believe that has happened yet, but it could.

McDonald's is running an experiment now that if you go to a drive-in and order your hamburger at McDonald's drive-in, at some of the drive-ins they send your order from your voice up through a satellite 23,000 miles away back to the earth 1,000 miles away from where you were. They get the order right and they send it back to the person preparing the hamburger. That is happening today. So there are no jobs that are not going to be vulnerable to the kind of thing you have described.

You are quite correct. Our committee, I think it is safe to say, feels passionately in terms of our concern, in terms of the importance we assign to this. We recognize that you and your colleagues in the Senate and the House and in the administration face enormous challenges. We are aware of hurricanes, and we realize there are two wars going on. But this is a war too, but it is one that is on a longer time scale. It is a war that if we lose, we likely will lose the fundamental strength of our economy which underpins most everything else we do. So I would say your assessment was very accurate.

The CHAIRMAN. Senator Bingaman.

Senator BINGAMAN. Thank you very much. And thank you again for the wonderful testimony and the report.

Let me ask about a few of these specific recommendations you have here. One is that we establish an ARPA-like entity within the Department of Energy or focused on energy-related issues. I just would ask, Mr. Augustine, if you would elaborate on that as to how that would work, who it would be reporting to? It is clear under DARPA that they are doing the work of the Department of Defense, and there is no question as to whom they are reporting and working for. How would you see this other entity operating?

Mr. AUGUSTINE. Senator Bingaman, I guess I should first indicate why we felt it was important to have this capability. One of the concerns we have had is that as we produce new scientific ideas, particularly in the energy area, the idea of transferring those ideas into practice—there is a large gap in terms of funding and capability and responsibility to do that.

We are looking in this idea of ARPA-energy, as we call it, ARPA-E, for breakthrough technologies, transformational technologies, things that really change the whole paradigm. The DARPA of the Department of Defense has been extremely effective, as I think you might agree. You do just that.

I should say also that our focus on energy really has its origin in the fact that we view energy to be one of the principal factors in America's competitiveness in the years ahead. Our ability to provide energy at a reasonable cost, provide it reliably, cleanly, and also to remove the threats to national security that are so closely associated to energy all argue that it is a key part of competitiveness and of prosperity.

Beyond that, as you would know so well, energy research is so closely affiliated with the very areas of science and technology about which we are concerned, mainly the physical sciences, mathematics, computer science, and engineering. I separate those from the biological sciences which have been reasonably well cared for by the National Institutes of Health.

With regard to the specific proposal, it would be our belief that an ARPA-E would report to the Under Secretary of Energy for Science, that it would have a staff that rotated. The people would stay maybe 4 years, much like at DARPA. It would do no research of its own. It would fund the innovative breakthrough high-risk, high-payoff research and applied development. That work would be performed actually at universities, at companies, at startups, established companies, and at the national labs. It would be awarded competitively. We believe by so doing, we can take a major step forward in improving the health of our physical science, math and engineering fields and address an important problem at the same time.

So I hope that answers your question.

Senator BINGAMAN. It does and I thank you for that answer.

Another big thrust of your report, as you describe it, is to urge some specific actions we can take to get our training of people in science and mathematics up to where it ought to be or at least closer to where it ought to be in the near future. You have one recommendation in here that I heartily endorse. I just think it sounds pretty ambitious, and again, I would like your comments on it. It says, by 2010, increase the number of students in advanced placement and international baccalaureate mathematics and science

courses from 1.2 million to 4.5 million and set a goal of tripling the number who pass those tests to 700,000 by 2010.

It is easy to talk about these things. It is easy to set goals. It is harder when you get down to saying, okay, now how many of those increased AP or IB students are we going to have in this high school or that high school and how are we going to get them there. Any comments you would have about the achievability of that kind of a very ambitious goal?

Mr. AUGUSTINE. We believe it is achievable, but we would share your characterization of a very ambitious goal. That was my intent. It is nearly a factor of four increase in students in that area.

We made the recommendation because experiments at various State and local levels have indicated that having more students exposed to the AP programs has a major impact in terms of their overall level of education, how they score on examinations, college boards and the like, and on the international tests.

To accomplish this goal, though, I think we have to start—and our committee proposes this—with teachers. We first have to train the teachers to teach AP programs. We have made a recommendation as to how to go about doing that. We believe if we can train those teachers, they can, in turn, train the students and we will get much better graduates in the process.

With regard to the ambitiousness of our proposal, to some degree we have scaled the experience of other programs along this line, one particularly in Texas that has been very successful. We scaled the school population in Texas with what it has done in the way of growth that it has actually accomplished with what we are proposing. Given that, we feel that with a significant effort, we can do at least as well.

Senator BINGAMAN. Thank you very much. I think my time is up although nobody seems to be keeping time around here. Let me go ahead and defer to Senator Alexander.

Senator ALEXANDER. Thank you, Senator Bingaman.

A couple of comments and then a couple of questions. \$10 billion a year. I spent a lot of time as Governor trying to restrain the growth of Medicaid so we could create centers of excellence at the universities. We had these choices to make. Over the next 5 years, Medicaid spending will grow 41 percent in the Federal budget. Restraining that by 1 percent, 40 instead of 41, would produce \$10 billion new Federal dollars a year, in other words, enough to fund everything you have said here. So I think we have to think about whether even in the end putting the \$10 billion into roughly the recommendations you have made might not do more to help transform the health care system in America and reduce medical costs and improve health care than spending another \$10 billion just on the system we have got. So the amount of money is well within the reach of this country.

No. 2, maybe Senator Bingaman and I and the staff of the committee and the chairman can talk with you more about this. I think it would be helpful to have a follow-up group from the Academies to provide technical advice to us as we work through trying to develop the legislation to implement these recommendations because just as you have been able to sort out among all these various ideas that people throw at us 10 or 4 broad categories, once we get down

to how do we deal with teachers, there are 100 ideas out there about how to do things, programs going on. It would help us to have evaluations. So that is one thing I would ask you to consider. What would be the appropriate way, working between the Academies and here to have the follow-up?

Now, let me just go to the questions. Should we not be thinking about using the national labs in a big way here? I have had some experience with dealing with programs for outstanding teachers and students, and summer academies are great ways to deal with that. If they were affiliated with the labs, it would give a luster and a prestige and a place to go and a new way to deal with issues about career paths and satisfactory performance and how to pass out stipends and make sure we were not wasting money in a way that would really encourage the students and honor the teachers. We have these labs and they could conduct it. I think of the Governor's schools for teachers of math and science that we had at Knoxville at the University of Tennessee. They were inexpensive, easy to do, enormously well attended, and competitively sought. So should we not use the labs?

And my second question is: Should we not be more ambitious about insourcing brains? I mean, you have suggested we would attach a green card, in effect, to somebody who gets a graduate degree so they can stay another year. Well, why do we not give scholarships to the 2,500 most outstanding engineers in the world in hopes they come here and stay? While we do it for liquified natural gas, we might as well do it for scientists, at least in the interim until we grow our own. Should we insist that every foreign student who comes here swears that he does not plan to stay here when, in fact, we hope that the smartest of them would stay here and help improve our standard of living instead of going home and improving India's standard of living?

So should we not use national labs, and should we be more ambitious in terms of insourcing brain power?

Mr. AUGUSTINE. I would turn to my colleague who has experience, particularly on the latter topic.

Mr. CICERONE. Why do we not deal with the national labs first? Because the report does speak quite a bit about the roles of the national labs in hosting teachers in the summertime, in student research projects, and in the research and development. Do you want to handle that first?

Mr. AUGUSTINE. All right. We did address the national labs and view those labs as a national asset. Of course, there are programs such as the one at the University of Tennessee, when you were president of the University of Tennessee, that was a cooperative arrangement of this type.

The national labs have a huge collection of extremely talented people. They have the stability that industrial laboratories tend not to have. The national labs tend to be working at the very leading edge of the state-of-the-art, so they do provide a great resource not only to provide research itself, but as a training ground.

With regard to bringing foreign students in and trying to get them to stay, I must confess that when I first learned a little bit about this question—I am told that when a foreign student applies at our embassy for a student visa, the person in our embassy has

to certify that that student intends to go back home when they get their degree.

Senator ALEXANDER. That is the law.

Mr. AUGUSTINE. My reaction was that if I had been a foreign student that wanted to come to America and I had been asked that question, my reaction would have been to say, oh, yes, I promise to stay and get a job in America and help start a company and make America great. If I answered that way, I would not have been permitted to come into the country. There is something backward with this that really does need to be changed.

Ralph, do you want to comment?

Mr. CICERONE. I do not think I have ever heard the idea before of having a scholarship program to try to attract the top, let us say, engineering students from around the world. So that is a new idea as far as I know.

I think it, obviously, could be implemented. Now, what would go through the minds of young students—I just left a campus after 20 years to come here, so I have been in touch with a lot of students. The things that we all know well. They are interested in what they think the future of careers are, where would their best chance at a career be, what kind of financial aid is available so that when they emerge as a student, they will not be in debt too much. Are they going to encounter a welcoming atmosphere in this new place, and then what would be the opportunity for a really stimulating experience, for example, doing research as a student? And then in each one of those cases, they make a comparison to what they think the opportunity would be either in their home country or increasingly in other countries that are having English-speaking instruction, that is, instruction at the undergraduate or graduate level offered in English.

In the last few years, one unfortunate side effect of our making it more difficult for foreign students to come here is that programs have grown up in England, Australia, Canada, and Japan, for example, where students are offered instruction in English and they are being actively recruited away from American universities. This was an unintended consequence of making it harder for foreign students to come here.

It is a great idea and I think that is what would go through the minds of the young students whether or not they should come here or go somewhere else.

Senator ALEXANDER. Mr. Chairman, while you were out of the room—and I want to make you aware of this—I suggested to Dr. Cicerone and Mr. Augustine that they might want to consider setting up a follow-up group to their report that could provide technical advice to our committee and other Senators, when asked, as we work through developing legislation, whenever that is appropriate. So I wanted you to know that I asked that question.

The CHAIRMAN. Very good. Did they say no?

[Laughter.]

Senator ALEXANDER. They did not say.

Mr. AUGUSTINE. We said yes.

The CHAIRMAN. They are captive. They have no chance.

[Laughter.]

The CHAIRMAN. One of the items that you recommend is to allocate a minimum of 8 percent of Federal research funding to high-risk, high-payoff research. If the Federal research agencies are under-investing in high-risk research now, first, why is that under-investment occurring? And second, do you know whether the Office of Management and Budget's PART process—they have a process—as used now, discourages high-risk research? The first one you probably can answer. If you do not know what PART is, you cannot.

Mr. AUGUSTINE. Let me begin and I will ask my colleague to continue.

With regard to the deterrents to high-risk research, there are many deterrents. One of the deterrents, of course, is that our society has become very failure intolerant. The media is a part of that. We put far more attention on our failures than on our successes, in many cases. And if you are a researcher trying to build a career, it is probably easier to take the safe route than to try something that might be a total failure.

We also have a peer review system that, by and large, is very effective, but the peer review system and the people who lead our laboratories too are pressured to not have failures. So they tend to bet on the safer thing so that at the end of the year, they will have something to show that worked.

These things tend to combine to make our researchers reluctant to take chances.

Also, it has another effect, and that is, it tends to make it difficult for younger researchers to compete for grants because they do not have a track record, and that is in spite of the fact that it has been shown by many studies that some of the greatest innovations have occurred by people who are quite young. So these things have combined to be, I think, a real problem.

Do you want to add to that, Ralph?

Mr. CICERONE. Very briefly on your last point, Mr. Augustine. Younger researchers are feeling this discouragement, and it is a disincentive to stay in the field not just from a financial point of view that they have difficulty obtaining financial grants, but in terms of getting their own independence to be able to try out their own ideas and to run their own laboratories at universities. When they cannot get their own grants until age 42, which is, I think, now the median at which an NIH investigator gets his or her own grant, it is a real disincentive to this field as a career opportunity.

I think Mr. Augustine is right. Some of this is self-imposed where with our peer review system everybody is trying so hard to avoid making mistakes, that we are discouraging people from taking risks.

And then finally, there probably are some things that have been imposed by different administrations and different Congresses, like the GPRA, the Government Performance and Results Act. The Federal agencies, including the ones that support basic research, have tried very hard to avoid making any mistakes. So in an effort to prevent anything bad from happening, they have prevented a lot of other things from happening too.

The CHAIRMAN. You note in the report that as of 2007 the United States, for instance, will not have the world's most advanced high

energy particle accelerator. Will the U.S. researchers not have access to the new world-class accelerator, even though it would be in Europe? Should we be concerned about losing our status as the world's leader in high energy physics? And how does that affect or relate to what we are talking about here today?

Mr. AUGUSTINE. Indeed, the most capable high energy accelerator in the world will go on line probably in 2007. It will be in Bern in Switzerland and will be operated by the European countries. The United States has been permitted to put its researchers there, as you pointed out, and one of the concerns is that for high energy physicists in this country, if they want to have any chance of a Nobel Prize for the 5 or 10 years after 2007, the place to be is in Europe, not in the United States. And our researchers are voting with their feet. They are going to where these facilities are. So I think we will, if we do not take drastic steps, likely lose the lead for the first time in high energy physics research as these people go to Europe to use this facility.

The CHAIRMAN. I was out a short time and this might be repetitious on DARPA. But I know, Mr. Augustine, you have been a staunch supporter if not even an admirer of DARPA as a modus operandi. It might not be the most direct, but considering how the Government has to do business with all of the entanglements, it has been rather successful in your opinion.

Mr. AUGUSTINE. Indeed.

The CHAIRMAN. Now, who would be the customer of these technologies that are developed at this new ARPA-E? If the customer is the private sector and not the Government, then is this the right approach? Maybe you have already answered that. Did Senator Bingaman ask that?

Mr. AUGUSTINE. We did not address that specific aspect.

The CHAIRMAN. Would you tell me that?

Mr. AUGUSTINE. The customer would, indeed, be those organizations generally in the private sector that will provide the energy we need to run our country in the years ahead. That is somewhat different, of course, from the Department of Defense model where the DOD, by and large, is the customer for the work of DARPA. Nonetheless, we have a lot of experience with organizations such as the NIH that does basic research that supports products that are built, say, by the drug companies and pharmaceutical companies in that case. So that aspect was not of great concern to us, although we discussed it at some length.

The question implicit in some of your comments is also a very good one. Why should the private sector, if it is to be the beneficiary, not pay for this research? If I might, Mr. Chairman, in answering your question, I would like to share with the committee a story. I may have shared it with you in the past, in fact. It occurred when I was working for Martin Marietta, the aerospace firm that is the predecessor of Lockheed Martin.

Our company had some opportunities for some very exciting research, research that we thought held such enormous promise. We called a meeting in New York of stock analysts, and we sent our company's president there to tell them about this exciting research we were going to do. He made a wonderful presentation. At the end of the presentation, the analysts got up and literally they ran out

of the room and they sold our stock. Our stock dropped 11 percent in 3 days and continued to decline for another year before we got it turned back around.

When I asked one particular analyst—I remember almost verbatim what he said—I said, what did we say that was wrong? And his answer was, do you not understand that it takes 10 or 15 years for research to pay off? And your average shareholder holds his stock about 18 months. So by the time your research pays off, they could care less about what you have gained. They will probably own your competitor's stock by that time. They certainly do not want to pay for the research now. And he concluded by saying to me that our firm does not invest in managements with such short-sighted viewpoints. That was his characterization.

So the fact is, with the pressure of the stock market on quarterly earnings, it is just very hard for a corporation and its board to spend much money on basic research. Development is a different story. Basic research has an additional disadvantage that you never really know who it is going to pay off for. It is general. It is generic. And it may pay off for your competitor and not for you, and that is why organizations such as Bell Labs and such as GE Labs, many of which exist in some form, but I think no one argue that they are what they once were.

The CHAIRMAN. I may have missed this somewhere in this big report. I am not seeing it just today. I have looked at it briefly. It seems to me that one of the areas where we have a built-in duplication, if not triplication, and whatever the next word is, is in the university system. We take a great deal of pride in having many, many universities, and it is obvious that on basic things that each one has—that you spend many times over to have the same kind of facilities. I guess, in general, I would look out there and say where the Government is involved in some institutional process that has long tales that has been there a long time, even the National Institutes of Health, there may be an opportunity, if not a necessity, in our country to reassess the allocation of resources so as to move in the direction you are speaking of in two ways, with new assets and converting older assets to the right thing. I do not know enough about that, but it is just patent to me that the one thing we have plenty of is our universities.

Could you kind of talk to my notion? Did you comment on re-allocation of resources in the whole, broad field so we could do more of what you are talking about?

Mr. AUGUSTINE. Well, we did discuss allocation in general. We talked about the fact that some of the funding that we have proposed that—I should mention some of our proposals do not require additional funding. They would require other kinds of actions. But before we put new funds in, some of which will be certainly required, we should examine places where we do have duplication or triplication or what have you. Some of that does exist.

We also have in our proposal to establish a new fund for facilities for research, many of which would be at universities. Also, that the Government create a new office, probably in the Office of Science and Technology Policy, to oversee the planning for this additional fund so that you do not wind up with the situation you described where you have similar facilities, particularly expensive facilities.

There is no reason why they cannot be shared among universities, as far as I know. Dr. Cicerone knows more about universities than I do, so I will defer to you.

The CHAIRMAN. Doctor, would you comment please?

Mr. CICERONE. I think there is good potential for sharing the expense of facilities and a good deal of it is already being done. I think that that goal could be worked into these plans.

Having just been in charge of a campus with a total budget of a little over \$1 billion a year, I was sitting here, since you asked, Mr. Chairman, trying to think of any examples I could come up with quickly of facilities that I think where we were duplicative, and I honestly cannot think of any. I can think, instead, of having people fighting for access to every computer, every mass spectrometer. But there is potential and I think people would take that challenge seriously.

The CHAIRMAN. The last one. Do either of you or both of you or any of you know about this program within the laboratories called LDRD? That is the one where the—

Mr. CICERONE. Laboratory Directed Research Directives or something.

The CHAIRMAN. In disclosing my vintage, I remember when that was a very prominent part of the DOE's nuclear laboratories. 12 or 15 percent when Agnew was at Los Alamos was left up to the discretion of the director to put into science that was promising, maybe even directed at the goal, but not provided for explicitly. Somehow or another that has turned around up here, and the U.S. House thinks of it as—what do they call it?

Mr. AUGUSTINE. A slush fund.

The CHAIRMAN. Yes, a slush fund for the director. Frankly, I saw it as something spectacular, but I have more confidence in the projects.

Could you kind of assess that and just talk about it a minute?

Mr. CICERONE. Mr. Chairman, about 10 or 15 years ago, I served as a reviewer for a request coming into those LDRD project funds at the Lawrence Livermore National Lab and a little bit at Los Alamos. The results were stunning. Those little bit of funds that the laboratory directors had at their discretion were dangled in front of people and all the best ideas came out of the woodwork. Teamwork came out of the woodwork. Some new technologies, some of the best work that I ever saw. I had nothing to do with the laboratories except being called in as an outside reviewer. The results were stunning for the reasons that you said. I agree with you completely.

The CHAIRMAN. They are down now. They have chipped it away. What is it?

Mr. AUGUSTINE. 1 to 3 percent now. Our committee addressed that. It is about 1 to 3 percent in most places today. We recommended increasing it to 8 percent. Some argue it should be still greater.

But it is true that has been a source of some of the greatest payoff of all. The reason for that is that nobody knows what the good ideas are better than the people who are creating the good ideas.

The CHAIRMAN. Senator Bingaman.

Senator BINGAMAN. Let me ask about two of the issues that you discussed a little bit there. This national coordination office for research infrastructure that you recommend. You have been around this city quite a while and watched the Congress in action. How can we conceivably legislate something that we would give \$500 million to and keep it all from being earmarked for the particular institutions that various members of the appropriations committees here want it earmarked for? Is there any way to actually do what you are recommending here? It seems to me to be a great concept but very hard to accomplish, given the reality of how this place functions.

Mr. CICERONE. From a university perspective, right now there is no such capability for pay for major facilities. So the only alternative is earmarking. So I think instead, the lack of such of a fund is what is causing earmarking to increase. By setting up this kind of an operation and potentially having it go through high-level peer review, I think we could prevent some of the least productive earmarking.

Senator BINGAMAN. Well, I like the concept. I hope that that would be the result. I do not know that setting up an additional fund would prevent earmarking or be an invitation to earmarking, but I wanted to raise it as an issue.

Mr. AUGUSTINE. If I might, Senator Bingaman, I believe that if the legislation could specify the money is to be allocated based on peer review, you could do a lot to insulate against earmarking.

Senator BINGAMAN. Well, I would hope that would work.

The CHAIRMAN. What was it he said was an answer?

Senator BINGAMAN. He said that we could specify in the legislation that the funds within this pool of \$500 million per year would be allocated on the basis of peer review and that would help to guard against earmarking, which as I say, I would love to see happen.

On the tax incentive recommendation here, provide tax incentives for U.S.-based innovation, you talk about provision of incentives for the purchase of high-technology research and manufacturing equipment. I was fortunate to travel to India in January and to visit a couple of the large research facilities, centers in Bangalore, that our own U.S. companies have established; General Electric's research center; the Jack Welsh center; and Intel's new center. I am sure there is a whole raft of others that I did not get the chance to visit.

Are there tax reasons why those are located there? My impression was that they were there because of, No. 1, the talent and, No. 2, the cost of the talent, but primarily the availability of the talent was what caused them to establish those centers in those locations. Is there also a tax reason, as you see it?

Mr. AUGUSTINE. I cannot speak to those specific centers, but I have talked to enough people and have lived in this world long enough to know that you don't put facilities someplace just to have a view. I think there are a lot of factors that go into that decision, but I think you have got it right, particularly the research facility. The No. 1 issue is the quality of the people, and if you can get the highest quality people, that sort of eclipses everything else.

Now, the cost of the people is obviously a major factor because research facilities tend to be rich in people costs. But I think that beyond that—and it is included in the appendix to our report—when companies go through and look at where do we want to be located, they look at, for example, for a factory, the capital gains tax and so on. We are not competitive with much of the world. In places like Ireland and Singapore and India and Japan, they figured this out. And Finland, some very surprising places, have turned their economy, as you know, by just offering extremely attractive packages, some total tax forgiveness for a period of years. And that is what we have to learn to compete with.

Senator BINGAMAN. Thank you very much. Thank you, Mr. Chairman.

The CHAIRMAN. Senator Alexander.

Senator ALEXANDER. Thank you, Mr. Chairman.

The CHAIRMAN. It is getting late, but it is too exciting to quit, is it not?

Senator ALEXANDER. Senator Domenici is always worried that I may go on for a while.

The CHAIRMAN. I went longer than you just a little while ago and said less.

Senator ALEXANDER. We are all very excited about this. Did I gather you said that you would be willing to work with Senator Domenici and Senator Bingaman to set up a technical advice follow-up group so that as we work with the committee, we can continue to get your advice?

Mr. CICERONE. Certainly.

Senator ALEXANDER. Let me ask you about your very interesting idea about a core curriculum for math and science. I want to suggest—and this is the reason that the technical advisory group might be good—you work with the Governors on that. Going back to 1997, we had the national education goals. They included math, science, English, history, and geography. Then under the first President Bush, when I was Education Secretary, we proposed creating voluntary national standards and worked in each of those areas to do so. I guess, getting to the bottom line, what we found was that we cannot impose that on the States and the local school districts, but it seems to me that it can be made so attractive that many States and school districts would want it.

For example, if there were—and there may be—an engineering and science core curriculum that were approved by the National Academy of Sciences, just had your stamp on it—maybe that exists today—then Governors I think would compete to see how many States could adopt those statewide standards. In Maryville, Tennessee, where we think we have a great high school, we would probably want to say, well, we have those standards. We have the National Academy core curriculum. And if there were other parts to it, such as AP courses, as Senator Bingaman mentioned, and if that were integrated into a program with the national labs—in our case, it would be Oak Ridge. In other cases, it would be other ones—or certain research universities where outstanding teachers and students could go, I could see how, instead of imposing such a core curriculum, you might just create one. And it would be such a powerful idea that the forces that exist within our society, when

combined with the efforts we are making for teachers and students, could within 10 years make it something every school would be embarrassed not to have.

So what was the discussion that you all had about this core curriculum?

Mr. AUGUSTINE. You have given a very good description of exactly what we had in mind. Our thought was to collect from around the Nation world-class experts in teaching and in the fields themselves to prepare a curriculum in science, technology, mathematics for K-12 that would be strictly voluntary, as you suggest, such that we were advising the Federal Government. The Federal Government obviously cannot impose this. But if it were so good, then we would think that States and local communities would voluntarily want to adopt it. And the idea of having the Governors take some ownership for this would be a tremendous promotion for it.

Senator ALEXANDER. Did you find, Mr. Augustine, that this curriculum exists today at all?

Mr. AUGUSTINE. There are pieces of it. There are pieces, but there really is not an integrated curriculum of the type that we think is needed. It is important that we have not only the curriculum but that we have standards and that we measure the standards. We have means of measuring them. So that would be our hope.

Senator Alexander, if I might footnote this with an answer to an earlier question you asked about should we not be offering scholarships and encouraging foreign students more actively to come here. I wanted to relate an experience.

Recently in Singapore, where I visited Biopolis, which has to be one of the world's finest biological research facilities I have ever seen—it would make anyone in this country envious. The leader of that laboratory showed me a three-hole notebook he had about 2-3 inches thick. In it were tabs for different countries: United States, Israel, Germany, France. He opened it up and in it on each page is a student, a junior in high school in that country that they have spotted as one of the real outstanding science/technology students coming along. And they are going to encourage them to come to Singapore for the last years of high school. They will pay them to do that. They will pay their way through college. They will pay them to get a Ph.D. as long as they stay at the top competitively. Their belief was, he said, that if you can encourage someone to come before they are done with high school and stay through a Ph.D. and you have a good job for them when they are done, they will probably stay. So there is no requirement that you stay. They just think you will. So others have tumbled your idea. We are just behind on this one.

Senator ALEXANDER. Well, the Soviets used to do that with gymnasts, and Duke University does it with 8th graders. So it is a good recruiting tool.

Mr. AUGUSTINE. My son-in-law played for Duke, so I will stay out of that.

[Laughter.]

Senator ALEXANDER. But, Mr. Chairman, I would conclude with just as you are answering our question, by saying not a lot of gobbledegook, but here are the 10 things that you need to do, then

that gives policymakers, who really do not know that, a place to go. We are not the only ones like that. School board members are being elected. Governors are being elected. They all really do not know what to do. So if in math and science they could turn to the National Academy of Sciences and you could say, here is what we recommend you do, I think you would be astonished at how many people would adopt that curriculum.

The CHAIRMAN. And they are perplexed out there. They are hungry, confused. They are put upon. I taught a little math when I was just a youngster. Before I went to law school, I was a math teacher at a junior high school. The only reason I got the job is because I agreed to coach baseball free. They had a lot of applicants for my job. It is not like today. I tell you, even then the bucks they gave you to teach with are just incredible. I did not know much about it. I never did much in education. I was a math and science guy, and at the end I said, well, I do not know if I want to be in a laboratory, so why do I not get an education certificate. Then they said, well, we will hire you if you coach baseball. That sounded neat. Then somebody talked me into going to law school, and that is how I got to where I am.

Anyway, I want to revert back to goals. In this Energy and Natural Resource Committee, we have some innate jurisdiction because we have a lot of science. Nobody knows us as a science group. It could have been called that, but that was not this committee's name.

Now, we are involved, while we have this crisis that we are speaking of, in competitiveness and standard of living and maintenance. In fact, I would just say when we are talking, before I get to my point, about bringing more young people to come and live here, if things do not change pretty quick, they are not going to be interested in coming here. They are going to be interested in going elsewhere. There is already competition for certain kinds of students. Where students know they can come here even with our ridiculous rules, they are choosing someplace else. So that is over on the side.

But let me ask on energy. I know you did not come out and recommend that we change our course on energy and go ahead and say we want to build this whole physical science and competitiveness challenge around a goal as big as energy independence. Talk about that just a minute here, each of you. I do not know what to do about it. I am excited and encouraged, but I am wondering. Let us start with you, Norm.

Mr. AUGUSTINE. All right, Mr. Chairman. We did address the question of what should we build this around. I speak particularly to those things that affected the Department of Energy and specifically the ARPA-E proposal. It has been most of our experience that innovation occurs best when you are trying to solve a specific problem and not just when you go out and say I will go in the laboratory and see what I can learn. That is quite the opposite to basic research. So we needed some focal point for our work. As we tried to address what is the most important problem we could think of—and the remarks of Chairman Greenspan just yesterday certainly reinforced the importance of the energy problem, if anyone ever questioned its importance—we felt that provided a good centerpiece

for our work. As I mentioned, it also is the place that the physical sciences, mathematics, computer science, engineering, all tend to come together. Much of that is in the Department of Energy. As you know so well, most of the research or much of the research in the country today in those fields is sponsored by the Department of Energy. So to us it was an important problem. It was appropriate to our goal, and so it was sort of a natural focus for us.

So if I were to say what are the two focuses, if I were limited to only two things about what is our effort about, the first is to create jobs for Americans and the second is to provide affordable energy.

The CHAIRMAN. Doctor.

Mr. CICERONE. I will just add something briefly that I think most people would agree that the new sources of energy and higher efficiency have become a necessity rather than just a research luxury. So as a focal point, I think the committee felt that there is an increasing amount of necessity here, very interdisciplinary involving all kinds of research and instruction at the same time. So it was just an appropriate focus and it will be. We may be entering a high-price energy future where the matter of necessity will become even higher.

The CHAIRMAN. I guess what bothers me is people have thought for so long that it is unachievable. We pop out of the box here. We think we have got something exceptional by way of the dedication and quality and the timing. We pop out of the box and say now we are going to convert to energy independence. What would happen?

Mr. CICERONE. It is also a large goal. If this situation were easy, I think the problem would have been solved. I think people are anticipating that the easy sources of energy have already been found and exploited, and now we are in for a tougher time and that is why it has to be part of the research agenda.

The CHAIRMAN. How about you, Norm? Do you think it would be a joke? Do you think people would take it seriously? How do you feel?

Mr. AUGUSTINE. My view, Mr. Chairman, would be that people take this terribly seriously when people pay \$50 to fill their gas tank and it is likely they are going to pay something like that for quite a while.

The CHAIRMAN. And shortages.

Mr. AUGUSTINE. And shortages, and when you know what it implies, the instability in the world politically, I think people will take this very seriously. Now, how easy the problem is to solve is another story, but we will not solve it if we do not try. I think there are things that we can do. We will run out of fossil fuel energy, as you know. I am not qualified to say whether it is 20 years from now or 40 years from now, but we will run out. So we better get started on solving the problem.

The CHAIRMAN. Anything else? We stand adjourned.

[Whereupon, at 4:55 p.m., the hearing was adjourned.]