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DOE'S OFFICE OF SCIENCE

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY

OF THE

COMMITTEE ON
ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

ONE HUNDRED EIGHTH CONGRESS

FIRST SESSION

ON

THE ROLE OF THE DEPARTMENT OF ENERGY'S OFFICE OF SCIENCE IN SUPPORTING BASIC RESEARCH IN THE PHYSICAL SCIENCES

JULY 29, 2003

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DOE'S OFFICE OF SCIENCE

TUESDAY, JULY 29, 2003

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

The subcommittee met, pursuant to notice, at 9:33 a.m. in room SD–366, Dirksen Senate Office Building, Hon. Lamar Alexander presiding.

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

Senator ALEXANDER. The hearing will come to order. Let me welcome you all to this hearing, where we are talking about the future of our country in terms of science and jobs, is the way I would like to put it. We especially welcome the Secretary of Energy, Spencer Abraham, and Dr. Orbach, the Director of the Office of Science in the Department of Energy. I think it says a great deal about the priority that the administration and the Secretary place on science that he would take the time to be here during a very busy week when the energy bill is before the Congress.

Dr. Grunder and Dr. Richter and Dr. Clough, who we will be hearing from a little later, we thank you very much. We thank you very much for coming.

I would like, before I present Secretary Abraham, I would like to begin this discussion with a story. I know the Secretary is going to try to put the subject today in some sort of more vivid terms than we sometimes talk about in science, but here is one way it is vivid, vivid to me. Over the last 20 years in my home State of Tennessee the automotive industry has moved in and today about a third of our manufacturing jobs are automotive jobs. 20 years ago virtually none of our manufacturing jobs were automotive jobs.

What that has meant for families in Tennessee over that 20-year period is that we have moved from about the third poorest State to one of the most rapidly growing States in family incomes.

One of our greatest challenges as a country is how do we keep our good jobs in America in a time of world competition. Well, the answer to that is technology and science. We see it in an everyday form in the nearly 1,000 auto parts suppliers we have in Tennessee. They could be anywhere in the world. There are some reasons they are in the United States. One is that auto assembly plants like just-in-time delivery. But there is another reason they are here and it is technology.

In those auto parts plants, which might be one, two, or 300 persons, the labor costs are typically only 15, 20 percent of their entire costs. So even though wages in other countries might be lower, it is not worthwhile to move somewhere else. The reason they are able to stay in our State, in our country, is because they have a technology advantage

The National Academy of Sciences has estimated that more than half of our economic growth since World War II has come because of advances in science and technology. What we want to talk about today is to look to the future, when we are sure that in a time of worldwide competition for jobs a big part of our chance to keep our high standard of living comes from our edge in science and technology, and we have what I would call some secret weapons in the pursuit of that science and technology.

One is the national laboratories, which Secretary Abraham and Dr. Orbach visited one of those at Oak Ridge on Friday, which we appreciated very much. And the other is our great research universities, which no other country in the world has quite as we have.

So we want today to look ahead, to look to the future, and talk about plans, ideas, concepts, and level of funding to support the physical sciences especially.

I want to again thank Secretary Abraham for being here. He is no stranger to the U.S. Senate. He has served here himself. When he was here he was a champion for science and technology. He has been an activist Secretary. Witness his visit on Friday to the Oak Ridge Laboratory and his many other visits.

Today we want to focus on arguably the brightest star in the Department of Energy, the Office of Science. Dr. Orbach, who heads that office, is here. Thank you for coming. The Department of Energy's Office of Science is the Nation's largest supporter of basic research in the physical sciences and plays a dominant role in supporting the activities in mathematics and computing. The office also plays a unique and critical role in scientific computation, climate change, geophysics, genomics, and life sciences.

The Office of Science is a key sponsor of research at our universities and national laboratories. I mentioned earlier that I view those universities—I was formerly president of one of those universities, those research universities—and our national laboratories as our Nation's secret weapons in our pursuit of a high standard of living for the future. They performed the basic research that leads to the technologies of tomorrow and educate our next generation of scientists. We cannot prosper if we do not invest in those research universities and national laboratories.

The Academy of Science estimates that more than 50 percent of our economic growth in the last half century is a direct result of investments in science-driven technology. Clearly, we must invest more to maintain and improve the quality of our lives.

Last fall, the President's Council of Advisers on Science and Technology reported that research and development funding was becoming dangerously imbalanced and recommended that the funding levels for physical sciences and for engineering be enhanced and that funding levels be brought to parity with the life sciences. We are fortunate to have Dr. Clough here to speak about this issue since he chaired the President's Council that made this recommendation to the President. He is the president of one of the great research universities, Georgia Tech.

The research and development title of the energy bill corrects the recent trend toward flat-lining funding for the basic sciences by substantially increasing the authorization levels for the Department of Energy in these areas, especially the Office of Science. The Nation must have a balanced investment to maintain the overall health of science and technology research.

The National Institutes of Health, the National Science Foundation, and the DOE Office of Science are the largest supporters of non-defense research and development. Recent funding increases in NIH and the National Science Foundation cannot compensate for the declines in funding at Federal agencies such as the Department of Energy. We have more than doubled funding for the NIH—we ought to give previous Congresses a pat on the back—and are on track to double funding for the NSF. Both of those have been a priority of President Bush and the Congress.

We must take action to address the funding situation for the DOE Office of Science. There is a chart that roughly gives a picture that is mostly good news. Let us not dwell on bad news. Let us focus on good news, that we have done a good job with NIH, we have done a good job with NSF, and our focus today is to try to put more attention to the Office of Science.

Much of the basic work in the physical sciences on which all other science, even the biological sciences, is based is supported by the Department of Energy. The Department conducts much of this work itself at the national laboratories, one of the crown jewels of our Federal Government. Harold Varmus, Nobel laureate and former Director of NIH, summed up nicely the unique relationship between the medical and physical sciences in an editorial in the Washington Post. He stated, and I quote:

"Medical science can visualize the inner workings of the body. These techniques are the work horses of medical diagnoses, and not a single one of them could have been developed without the contribution of scientists such as mathematicians, physicists, and chemists supported by agencies currently at risk."

This statement was made nearly 3 years ago, but it is still true today for the DOE Office of Science. Many examples can be cited to describe the impact of our past investments in science and technology on the quality of our lives and economy, and our witnesses will do that today. The contributions continue today. The scientific disciplines are working together on addressing the needs of our society.

Mr. Secretary, I look forward to learning more about the impact that the Office of Science has had on our economic growth and quality of life and about the vision for the future of the Office of Science. I look forward to hearing from you how we can work together, the administration and the Congress, to gain more support for the Office of Science.

From our other distinguished panelists, I look forward to learning about the role of the Office of Science and the role it plays in supporting groundbreaking research that has led to 75 Nobel Prizes for Department of Energy researchers, about the role of the national laboratories in supporting the mission of the office, and about the support that is provided to the colleges and universities to create the next generation of scientists. The quality of our lives and our prosperity can only be enhanced when we invest in the science and technology that is in large part sponsored by the DOE Office of Science.

We will hear from our witnesses today in two panels. Panel one will be the Secretary himself. Dr. Orbach is here with him. Mr. Secretary, I have really introduced you, but we welcome the former Senator and the activist Secretary and thank him for taking time to come during a very busy week.

STATEMENT OF HON. SPENCER ABRAHAM, SECRETARY, DEPARTMENT OF ENERGY, ACCOMPANIED BY RAYMOND ORBACH, PH.D., DIRECTOR, OFFICE OF SCIENCE

Secretary ABRAHAM. First of all, Mr. Chairman, I want to thank you for including us and for inviting both myself and Dr. Orbach to participate. I am going to comment on Ray Orbach in a moment when I finish my testimony, but I want to begin just by saying this, that you have demonstrated just in your opening comments and I think the members of the committee and subcommittee very much understand the critical role that our Department plays in fostering basic scientific research and how that of course is the foundation for national security and economic growth in this country.

As you know, when we were at Oak Ridge just a few days ago to celebrate the groundbreaking for one of our new nanoscience centers and to tour the Spallation Neutron Source, we saw first-hand in your State the remarkable projects that this Department oversees. I know that you share our enthusiasm and excitement over these projects because they really represent the future of science in America.

When I was invited to participate, I spent a fair amount of time trying to figure out how to write a speech that would encapsulate some of the exciting things that go on in the Department. I would have to say that one of the challenges we have is to give people a better understanding, not people who are directly involved in our programs but the wider audience of people who care about these issues, a better understanding about not just what our basic science and research programs themselves are, but how they relate, how they are applied to accomplishments that are more familiar to both members of Congress and the American people.

After a while, I realized that the enthusiasm and the excitement which we have is hard to convey in mere written words and so what we thought we might do is to sort of divide my opening presentation here into two parts. The first part and the longer part will be a video that I think gives a good sense of some of the things we have done and are doing; and then I will have a brief summary to offer at the very end before we might turn to questions.

So let me at this point cue the audiovisual experts who are here today and see if we can get this video to play on the screen.

[A videotape was displayed, the sound track of which is transcribed as follows:]

Voiceover: The Department of Energy's Office of Science is heir to the revolutionary work of Albert Einstein, Enrico Fermi, and E.O. Lawrence. The Department makes history every day, because we sustain their tradition of innovative basic scientific research that improves our lives. Witness the more than 40 Nobel Prize winners supported by DOE science.

We are the steward of America's national laboratories, the backbone of American science. At these labs and at universities in virtually every State, DOE supports research in materials science, fusion energy, high energy and nuclear physics, basic energy sciences, biological and environmental science, advanced computation, and more.

Our multidisciplinary approach brings together the world's best scientists to tackle national challenges—energy security, defense against terrorism, and environmental cleanup. Over the years our basic research has protected America's security, created new industries, new products, and boosted economic growth.

Of course, very often even our own scientists cannot anticipate the impact of their research. At the particle accelerators at Fermi, Brookhaven, and other national labs, we began work decades ago to understand the fundamental nature of matter and energy. But along the way, we also found the science used in our accelerators could provide miraculous new tools for the diagnosis and treatment of disease.

Development of PET scans and MRI's was underpinned by our nuclear, high energy, and condensed matter physics research. Every day 10,000 cancer patients are treated with electron beams from linear accelerators developed by this research, and PET scans help develop new treatments for everything from drug addiction to degenerative diseases.

We do fundamental research in materials science to perfect everything from gas turbines to solar cells. Now we are applying what we have learned about materials to help blind people regain sight using an artificial retina. In early tests, a blind person has made out letters for the first time in 50 years. Eventually this technology may help restore sight to millions of blind and visually impaired people, and some day we may be able to adapt this same technology to help those with spinal cord injuries, Parkinson's disease, deafness, and almost any disease associated with the body's electrical system.

For decades we have also done basic research on radiation's impact on human cells. We have learned that the best way to understand the cell is to understand the genes that direct it. That led to our launching the Human Genome Project. DOE labs developed the technology used to speed the mapping process and because of our initiative others are now looking at gene therapies for cystic fibrosis, sickle cell anemia, diabetes and cancer.

This knowledge is now being applied in novel ways. We play to use genetic techniques to harness the power of a new class of microbes that can eat pollution, create hydrogen, and absorb carbon dioxide. Some day we believe a colony of specially designed microbes, living adjacent to the smokestack of a coal-fired powerplant, could eat all its pollutants, all its CO_2, and make it as clean a fuel source as hydropower. This is science, not science fiction.

DOE science is always looking toward the future. At Oak Ridge National Lab, we are building the largest civilian science project in the United States, the Spallation Neutron Source. Research there may lead to all sorts of advances—artificial blood, medical implants that last a lifetime, or superconducting wires to dramatically reduce energy costs.

Still more progress can be expected through the wonders of nanoscience, where DOE is already a leader. Five unique nanoscience research centers are soon to be built at our national labs that will help make computers the size of a grain of salt, sensor systems that detect emerging disease in the body, biodegradable chemicals for nourishing plants and protecting against insects, and machines so small they can enter a patient's bloodstream, fine clogged arteries, and clean them out. The potential of nanoscience is impossible to measure.

So is the promise of fusion, the power of the sun and the stars. Fusion energy is virtually emission free, has no long-term waste problems, and could produce the large amounts of electric power that the world needs. What is more, it can produce electricity during the day and hydrogen for hydrogen fuel cells at night.

Working at our labs and using our world-class facilities, men and women with extraordinary talent and dedication have done great science leading to great public benefits. From clean, abundant, and affordable energy to restoring our environment, to medical breakthroughs, DOE has looked to science for answers. Investment in DOE science will continue to pay off for us all.

[End of videotape.]

Secretary ABRAHAM. Thank you.

Senator ALEXANDER. Thank you, Mr. Secretary.

Secretary ABRAHAM. Mr. Chairman, thanks for letting us use the video. You may remember that in the video I made reference to the great promise of nanoscience, and you and I were at the groundbreaking for one of our tech centers in Oak Ridge just a few days ago. So you can imagine my surprise and delight when I saw the headline yesterday in the Science Notebook section of the Washington Post "The Smallest Synthetic Motor." Developed by our Lawrence Berkeley National Laboratory, the device is 300 times smaller than the diameter of a human hair. The potential of nanoscience as demonstrated in that announcement is already upon us.

Let me just conclude by stressing just how seriously we take our responsibility as stewards of science at the Department. We have established a special subcommittee of my secretarial advisory board under MIT President Chuck Vest to recommend how we can make our science program at the Department more effective. Under Dr. Orbach's leadership, we are looking at a 20-year road map for future scientific facilities to answer the question of which facilities should be built and in what sequence to maintain America's primacy in science and technology.

We have made a major commitment to the future of fusion this year by joining ITER and we are fully funding the construction, as I mentioned, of all five nanoscience centers, like the one which we broke ground on at Oak Ridge.

There needs I think, Mr. Chairman, to be a broader appreciation of the critical role that basic science research plays in future economic growth and national security. Quite frankly, there needs to be a greater appreciation of what the Department of Energy has done, both in the past and what it can do in the future for science, technology, and prosperity.

The Office of Science, as you have already indicated, is one of America's best kept secrets. With this committee's help, I hope we can change that. I think, Mr. Chairman, if we all do our job, perhaps in 20 to 30 years my successor can come before this committee and explain how the investments in science we made today and in the ensuing years have benefited the American people.

What might that Secretary of Energy say? I would hope that he or she could say that, after successful completion of the ITER experiment, we are now ready to build a demonstration fusion powerplant to deliver electric power to the grid, that the materials discovered by our nanoscience centers have made hydrogen storage a breeze, automobiles extraordinarily light yet safe and incredibly stronger, and have engines with virtually no friction.

That Secretary might report the end of our environmental cleanup program due to the appetite for waste of the genetically modified microbes at work at the contaminated sites around the Nation. And this committee might learn of the petaflop supercomputer recently deployed at one of our labs that has zeroed in on a host of climate mysteries and now lets us predict hurricanes weeks in advance.

This is just speculation, obviously, today. But given what the Department of Energy science has accomplished over the last decades, it may even be a conservative look at the future.

So, Mr. Chairman, I want to thank you for inviting me. I also want to acknowledge, as I did briefly, that joining me here today is Dr. Ray Orbach, who has done a terrific job in his tenure as the head of our Office of Science. He brings, like you, university presidency experience and so he understands not just how work gets done on the front lines as a scientist in his own right, but also how to manage a very large and diverse scientific community that he oversees. I want to thank Ray publicly for the great job he has been doing.

I also wish to just acknowledge, although they are not on this panel, but two of the people that I have come to know and have developed tremendous admiration for, part of our complex: Dr. Hermann Grunder, who heads our Argonne Laboratory, and he will be on the next panel; and Dr. Burt Richter, one of the laureates that I mentioned or referred to in our video. Really, I want to thank Burt for his leadership on the whole broad topic of how to better tell this story. I think it has really been in no small measure thanks to his commitment that we have been able over the last months to really get a broader audience for the work that we do.

So to all of the panelists in the next panel, I want to just thank them for their participation today.

[The prepared statement of Secretary Abraham follows:]

PREPARED STATEMENT OF HON. SPENCER ABRAHAM, SECRETARY, DEPARTMENT OF ENERGY

Mr. Chairman, members of the Subcommittee, thank you for asking me to testify today on the Department of Energy's Office of Science. I am joined by Dr. Raymond Orbach, who leads that office.

This Committee understands the central role DOE plays in fostering basic scientific research, which is the foundation for economic growth and national security in this country. In fact, just over a week ago the Chairman and I were at Oak Ridge National Lab to celebrate a ground breaking for one of our new nanoscience centers and to tour the Spallation Neutron Source. I know the Chairman shares my enthusiasm and excitement over these projects. They are truly the future of science in America.

So, I commend this Committee for its support of these labs and for its support of our Office of Science, which is charged with stewardship for 10 of our civilian laboratories.

When I was a member of the Senate, I was a strong proponent of federal support of science. I backed legislation doubling the budget for NIH and NSF.

We must, however, also pay greater attention to DOE's Office of Science, which has broad responsibility for the future of much of the physical sciences in America. I don't think there is a full appreciation of how the achievements and the public benefits in public health, telecommunications, supercomputing, to name just a few examples, are dependent upon progress in the physical sciences.

Mr. Chairman, no one has made this connection any clearer than former NIH Director Harold Varmus: "Medical advances," he wrote, "may seem like wizardry. But pull back the curtain, and sitting at the lever is a high-energy physicist, a combinational chemist or an engineer. Magnetic resonance imaging is an excellent example. Perhaps the last century's greatest advance in diagnosis, MRI is the product of atomic, nuclear and high-energy physics, quantum chemistry, computer science, cryogenics, solid state physics and applied medicine."

Particle accelerators, like those at Fermi, Brookhaven, and Stanford Labs have given us technologies to develop MRIs, and PET scans, as well as insights into the fundamental properties of matter and energy.

Fundamental research is going to help us move successfully toward a hydrogen economy, to effect carbon sequestration, and to the Generation IV nuclear reactor. Each of these Presidential initiatives will require that we solve some important challenges, particularly in the area of materials. Again, we will need to look to the physical sciences.

So, there is no question that the evolution of technology requires a robust basic research program in the physical sciences . . . that basic research program is my responsibility as Secretary of Energy and I want to ensure this committee that I take that responsibility seriously.

We have established a special subcommittee of my advisory board under MIT President Chuck Vest to recommend how we can make our science program at DOE more effective. We are looking at a 20-year roadmap for future scientific facilities to answer the question of which facilities should be built and in what sequence to maintain U.S. primacy in science and technology. We have made a major commitment to the future of fusion energy by joining in negotiations to construct ITER, and we are funding construction of all five nanoscience centers like the one you and I broke ground on at Oak Ridge.

There needs to be a broader appreciation of the critical role basic scientific research plays in future economic growth and national security, and quite frankly there needs to be a greater appreciation of what DOE has done in the past and can do in the future for science, technology, and future prosperity.

The Office of Science is one of America's best kept secrets in government. With this Committee's help, I hope to change that.

Let me give you some examples how we are making a difference in people's lives.

DOE science has helped to create an artificial retina that can restore sight to the blind. Why, some may ask, is the Department of Energy working on blindness? Because we are the primary home of the physical sciences in the United States, and you need chemists, material scientists, physicists, electrical engineers, and many other disciplines working together to make a device small enough and tough enough to live in a human retina and replace its functions. Five national labs, with Oak Ridge as the lead, Mr. Chairman, joined together with private institutes to build this retina, which in early tests has allowed formerly sightless individuals to see light and dark, to identify common objects by sight, and even to read large letters. And this is just the beginning.

We began the program to map the human genome when others felt it would be impossible, and we used our expertise in the physical sciences and computing to develop the techniques that allowed its completion two years ahead of schedule. We can now map 2 billion base pairs a month, or two human genomes a year.

I hardly need to remind this Committee of the impact DNA mapping has had. Gene therapies for cystic fibrosis, sickle cell anemia, diabetes and cancer are something we read about often now. Great advances are certainly on the way.

This knowledge is now being applied in novel ways by DOE science. We are going to attempt to use genetic techniques to harness microbes to eat pollution, create hydrogen, and absorb carbon dioxide. The possibilities here are tremendous. In the future, we may see communities of microbes absorbing the pollutants from coal fired power plants—including CO_2—making coal as clean a fuel source as hydropower.

I mentioned our five nanoscience centers. When they are all up and running by 2008, we'll have a suite of discovery centers unmatched by anything in the world. Each is connected to a major light or neutron source, allowing researches to literally see, move, and create at the atomic level. This is allowing design of nanoparticles that deliver medicines to specific cellular sites, such as cancer cells. I'm told they hope to develop materials that will self-repair stress cracks and other results of fatigue that can be used in aircraft and automobiles.

Our basic research has, of course, touched virtually every aspect of energy resources, production, waste, and storage. Examples include: High-energy lithium batteries, now in common use; non-brittle ceramics now used in engine turbines; and catalysts for more energy efficient processes in the chemical industry.

We are also exploring the most basic questions about the nature of our universe. Office of Science researchers from Lawrence Berkeley National Laboratory found that the expansion of the universe is being accelerated by a previously undiscovered force we are calling "Dark Energy", and at Brookhaven we recently re-created a state of matter comparable to that which existed a microsecond after the big bang nearly14 billion years ago in order to study the early evolution of the universe.

There is much more, of course. Our computers have given us greater technical confidence that fusion power could work; our combustion researchers are running diesel engines in their labs to boost efficiency and reduce emissions; and our labs are looking at revolutionary ways to store and move electricity.

In all these areas, and many others, the physical sciences are delivering clear and broad benefits to the nation. Still, the fruits of basic research are often hard to quantify because they are only realized over many years, sometimes decades. So all of us have to continue to make the case for fundamental research.

If we do that, perhaps in 20 to 30 years my successor can come before this Committee and explain how the investments we made today have ultimately paid off. What might that Secretary of Energy say?

I would hope he or she could say that after successful completion of the ITER experiment, we are now ready to consider construction of a demonstration fusion power plant to deliver electric power to the grid; that the materials discovered by our nanoscience centers have made hydrogen storage a breeze, automobiles extraordinarily light, yet incredibly stronger, and engines with virtually no friction.

The Secretary might report that the end of our environmental clean-up program is in sight due to the appetite for waste of genetically modified microbes at work at contaminated sites around the nation. And this Committee might hear of climate modeling on incredibly advanced supercomputers that has resolved a host of climate mysteries and now let us predict hurricanes weeks in advance.

This is just speculation of course. But given what DOE science has accomplished over the last decades, it may even be a conservative look at our future.

Thank you again Mr. Chairman for inviting me to testify today. I would be pleased to take your questions.

Senator ALEXANDER. Thank you, Mr. Secretary. I want to compliment you for your testimony and the way you presented it. In the end, what a hearing like this is about is more money, the idea that we could better fund the Office of Science over time. But everybody wants more money and so it is no great testimony to come up before the U.S. Senate or Congress and say we would like to have more money, which is not what you did.

You came up and presented a more important thing, which was to put in concrete terms some of the examples so that we could see in a more vivid way what we are talking about. Then at the end of your testimony you presented a vision for where we might be in 20 years. If that vision is presented in a compelling way time and time again, the money will come. The money follows great ideas. It follows great visions. So I am very pleased with that.

I would like to be able over time to borrow that vision of yours and repeat it and enlarge on it. I would encourage you to enlarge and elaborate on it and set that vision out. It may be that, because we have a deficit this year, that we cannot in this year or next year reach the funding levels that we would like. But if we set the vision out here, we will get there sooner or later, and my idea is sooner.

I wonder if we could take just a few minutes and almost engage in a conversation about your testimony, because you have a broad background in science and in jobs and in politics and government and are awfully well suited to this, to this discussion. For example, some of the major issues that are before this Congress right now come at the intersection of energy and environment. It almost brings us to an impasse, which is sometimes what I think we have on the energy bill.

But the President has tried to look beyond that and many others are. For example, in clean air. There are only so many scrubbers that we can put on the top of a coal smokestack, a coal-powered plant, coal-fired powerplant. There is a limit to that. And we can keep capping and limiting old technology or we can think boldly and try to think of new technology.

The President has recommended and I am glad to be the sponsor of the hydrogen car research which you mentioned. It may be 20 years away, but with the only emission as water. Just in very practical terms probably 40 percent of the ground ozone that we deal with in Tennessee in the air, which is too dirty, comes from emissions from cars and trucks. If we were all driving hydrogen vehicles, that would not—that 40 percent would not be there. You mentioned fusion, which you and the President have taken an important step on.

Talk for a moment, if you will, about how you see the investments that we might make toward your vision affecting our ability both to have an adequate supply of low-cost energy, which we need for jobs, and cleaner air, which we also need?

Secretary ABRAHAM. Well, first, what we have tried to do is look at the science investments in the context of the way our Department is structured of how they can be integrated with the work that is done by some of the other energy resource divisions. So a lot of the work done in the labs is supportive of some of these very specific projects you mentioned.

The Office of Science does a number of projects, works on a number of projects which relate directly to the development of the hydrogen economy that you referenced, that the President talked about in his speech. Areas of current research in the Office of Science alone involve work on catalysts and mechanisms for hydrogen storage, electrochemical energy conversion mechanisms, as well as projects that can lead to part of solving the riddle of hydrogen production at a competitive price.

On the fusion front, the Department in the Office of Science has been the leader, really the world leader I think, in terms of fusion investments. The Office of Science probably invests about $250 million a year in our domestic program and this year, with Dr. Orbach's leadership, we have rejoined the ITER project which we think will help expedite the evolution towards that as an energy source.

So if you just took those two alone—and we could talk about others, but just those two alone—we could talk about new energy sources which would be far cleaner sources of energy than virtually any today, or at least the energy sources they would likely replace. That would allow us on the one hand to have the affordable, available supply of energy we want. It would also lessen our dependence on foreign energy imports, while at the same time producing energy in an environmentally benign fashion.

So those are just a couple of examples. The list goes on. As you saw in the video, one of the really exciting applications of the Human Genome Project is our Genomes to Life project line, in which we hope to be able to utilize the sequencing skills that have now been developed and the science behind it to develop microbes that can serve literally as pollution-eating or consuming organisms. If we are successful in that application, we have the ability in a much different way, as opposed to the scrubber technologies that you reference, to address the challenge that we have in this country of having on the one hand a 250-year supply of coal and on the other hand an environmental, a set of environmental standards we must meet and wish to meet in order to protect our families and the health and safety of the American people.

So those are just some of the examples that the video mentioned and that you brought up, but there are others as well.

Senator ALEXANDER. At Oak Ridge—well, one of the things that the Office of Science does is become involved in large projects in applied research.

Secretary ABRAHAM. Right.

Senator ALEXANDER. We saw one such project at Oak Ridge on Friday with the Spallation Neutron Source. One of the most interesting things about that was the cooperation among different laboratories. You had the director of a laboratory from California there who had created one of the major installation which had been built there, then taken down, and then put back up at Oak Ridge.

In other testimony that I have heard there is a lot of suggestion that the future the laboratories will be enhanced if the laboratory directors are able to work together on large missions. What are you doing from a management point of view to make that easier for the directors to do and the labs to work together?

Secretary ABRAHAM. Well, we obviously on a frequent basis have the management together. The lab directors meet as a group with our senior leadership. I will maybe defer to Ray to comment specifically on some of the mechanical aspects of it. But you did mention, I think as a good example, the Spallation Neutron Source and how we have the partnership of Berkeley Lab and Oak Ridge as a key ingredient in its success, and I think that you see other examples of that.

Now, obviously in a project as big as that one it is sort of obviously beneficial to bring together several different leaders and organizations. But I think the same kind of—we expect the same kind of benefit to come from having established the nanoscience program with five lead laboratories, but we fully expect to see a certain integration, a certain synergy, that would evolve from having the experts at these different facilities in touch with each other and analyzing different project lines together.

Ray, do you want to?

Dr. ORBACH. Thank you, Mr. Secretary.

I would first like to thank Senator Alexander and yourself, Mr. Secretary, for your very kind comments about the Office of Science and myself in particular.

The Spallation Neutron Source, as you pointed out, Senator Alexander, is a perfect example of laboratories working together. Five of our national laboratories contributed essential elements to the machine itself, ranging from the accelerating portion that you saw that was developed by Berkeley to some of the RF cavities by Jefferson Laboratory to assistance from Argonne and from Los Alamos National Laboratory.

The laboratory directors in the Office of Science meet with me on a quarterly basis and we have frequent telephone conversations between us so that we stay in touch and talk about collaborative efforts that would enhance the value of the research of any given laboratory.

Another very good example is advanced scientific computation, where every laboratory is playing a role as we begin to experiment with new architectures in computation, and the laboratories are working together with the vendors to develop new architectures.

So we work very closely together, both at the management level and at the scientific level, between all the laboratories in the Department of Energy.

Senator ALEXANDER. Thank you, Dr. Orbach.

I have a couple more questions if I may and then we will go on to the second panel. Senator Domenici is holding a series of hearings on the governance of the laboratories which have been very interesting, very interesting hearings, trying to take a look at the future. I wonder, Mr. Secretary. I think about—I have thought about this often over the years as I have looked at the laboratories.

On the one hand, the laboratories have a set of responsibilities and in those responsibilities there can be no failure. That would be the objective. These have to do with security and these have to do with management and these have to do with cleanup of toxic wastes, and no mistakes has got to be the goal there.

On the other hand, the mission of the laboratory is a scientific-based mission and a big part of science is just failure after failure after failure. I mean, Edison talked about how he failed 800 times and then he invented the lightbulb, or whatever the story is.

How do you reconcile those two, those two activities at our laboratories? How do you keep from micromanaging the scientists while you are working hard to make sure that on the non-scientific operations you are avoiding failures of security, etcetera?

Secretary ABRAHAM. Well, first of all, I think that there is a clear distinction between the safety and security issues and the experimental work that is conducted. It is my observation to this point that that was always a challenge, but that most of the people who have been associated with these laboratories, whether it is the science laboratories or the weapons laboratories, over a long period of time have been able to appreciate and deal with that potentially challenging diverse set of circumstances.

We accept no tolerance or zero tolerance, if you would, for anything short of 100 percent effectiveness in terms of security and safety. Those levels are maintained at the highest possible standard and consequences ensue if that is not met. I do not think that is inseparable from having good science. I think it poses challenges that, fortunately, our excellent lab directors can and do have to work with.

But this Department's preceding or predecessor organizations dating all the way back to the Manhattan Project have had these kind of challenges, and we have had to work our way through them. I think we continue to do so. We have tried to certainly send a signal, though, that we want to stimulate as much creative thinking as we can, but within the context that the work we do has extraordinary national security and public safety implications.

But I think most people at the facilities appreciate that. I think we have also been endeavoring to make sure that people are aware. If things do not go well, people know about it, because we do not keep secrets. So whenever something does not go well, it is well known. But the many, many, many things which these labs do which work well tend not to be well known, which is why we appreciate the chance today to talk about it.

Senator ALEXANDER. My last question, Mr. Secretary, is this. I think back 10, 12 years ago when I was Education Secretary and after I was finished I looked back on that, and one of the failures I thought or one of the things I did not do as well as I thought I should have was to be more active in support of the research universities. As I looked through the organization of the first Bush administration, I am not sure we had anybody on point in terms of looking at the whole Federal Government's attitude toward and support for major research universities. We do with the laboratories. That is your job. That is the Department of Energy.

But when you go to research universities, and of course they do not want too much government attention, but at that time we were having a whole series of issues with research universities who had problems with the amount of overhead they had charged and most of that concern was lodged over in the Defense Department.

Well, the Defense Department does a lot of funding of our research, but I would think there would be, as we look ahead to major investments in science and technology, as we consider the fact that no other country in the world has anything quite like our major research universities, that there should be someone within a presidential administration on point to pay attention to the universities and in support of their research activities in the same way the Secretary of Energy does for the laboratories.

How is that organized in this administration? Who is on point?

Secretary ABRAHAM. I do not want to speak for people who are not here, but my impression has been at both the Department of Education—you would know that as well as anyone, but that also Jack Marburger, who is the President's Science and Technology Adviser, plays a role in this.

On the other hand, I think we should not underestimate the extent to which the laboratories that are part of the Department of Energy have a close working relationship with research universities all over the country. In fact, if you look at the outside users of the facilities which we provide, there has been a sharp increase in terms of that level of activity over the last 8 to 10 years.

Ray may want to comment on this in terms of how it is organized. I know that it is done in a very methodical fashion in terms of, for example, at our accelerator facilities, just our light sources and the use of those facilities, we have a very specific set of protocols that allow outside institutions, about I think 50 percent of which are research universities, to have access to that free of charge, to have access to those light sources for the kind of experimental work they might conduct.

Now, there are very clear protocols that have been established to determine who will be granted top priority in terms of that access. So some of that actually is done within our Office of Science and, Ray, maybe you would like to just go ahead.

Senator ALEXANDER. Dr. Orbach.

Dr. ORBACH. We have a peer review process for access to our facilities and the research universities fare very well. In fact, if you look at the users of our light sources only about 20 percent of those users are from the national laboratories. As the Secretary has said, more than half come from research universities.

Another interesting factor is that, of the users of our light sources, over 25 percent are funded by NIH and about 10 percent are funded by NSF. So it's not just the Department of Energy sources that are used to support university research at the facilities, but in fact it is the entire support structure of the Federal Government for research which helps the universities and university researchers come to the laboratories.

Senator ALEXANDER. Well, I thank you, Mr. Secretary, Dr. Orbach, for your excellent testimony. I welcome your vision of where we hope to go with the physical sciences and your explanation of how that affects Americans in our everyday lives. I look forward to working with you to develop the kind of funding base for those physical sciences to support that vision over the next few years.

Thank you very much.

Secretary ABRAHAM. Thank you, Mr. Chairman.

Dr. ORBACH. Thank you.

Senator ALEXANDER. If our next panel of witnesses will come forward, please.

Welcome to our next panel of witnesses. I will introduce them all now and then, starting with Dr. Grunder and Dr. Richter, then Dr. Clough, we will just—I will ask you to present your testimony. We have your full testimony. Let me suggest you take 5 to 7 minutes to summarize it if you would like and then we will have a conversation about that testimony.

Dr. Hermann Grunder is Director of Argonne National Laboratory, recognized expert in nuclear physics, former Director of the Thomas Jefferson National Accelerator Facility, former Deputy Director for General Sciences at Lawrence Berkeley National Laboratory.

Dr. Burton Richter, Nobel laureate and Emeritus Director of Stanford Linear Accelerator Center, winner of the Nobel Prize in Physics in 1976, member of the National Research Council, National Academy of Sciences.

Dr. Wayne Clough, president of the Georgia Institute of Technology, member of the President's Council of Advisers on Science and Technology. Were you president of that council?

Dr. Clough chaired the particular panel that dealt with the research and development, a member of the Executive Committee on the U.S. Council for Competitiveness, and a distinguished scholar.

Thank you, gentlemen, for coming to this important discussion. Dr. Grunder, may we begin with your testimony.

STATEMENT OF HERMANN A. GRUNDER, PH.D., DIRECTOR, ARGONNE NATIONAL LABORATORY

Dr. GRUNDER. Thank you, Mr. Chairman. It is an extraordinary pleasure to be invited to give testimony to this distinguished committee. I have prepared a written statement and with your permission I would like to enter it into the record.

Senator ALEXANDER. It will be done.

Dr. GRUNDER. Mr. Chairman, you have so eloquently summarized what I call the R&D establishment that I am not sure what new things I can add to it, but nevertheless let me try it.

Senator ALEXANDER. Well, the difference, Dr. Grunder, is that people might think you knew what you were talking about. So why do you not go right ahead.

Dr. GRUNDER. Thank you very much, Mr. Chairman.

Let me emphasize that we are very fortunate to have a Secretary who really appreciates research and development and the consequences of it, and we have an outstanding leader of the Office of Science, Assistant Secretary Orbach. He is not only a renowned scientist in his own right, he is also a good administrator, from one of our best research universities. He has indeed made a difference in streamlining the reporting procedure from the Secretary through Ray Orbach directly to the site. So let me just say that for the record.

You mentioned the research universities and indeed, of the three R&D providers, the research universities have a unique importance. After all, it is the graduate student who adds with an incredible efficiency new knowledge to our knowledge base. It is the research scientist who then for a life-long career is continuing and expanding this knowledge. So therefore, after you have made so eloquently the relationship between science, technology, and our prosperity, our security, and simply our wellbeing and standard of living.

We need to be sure that the graduate student at the beginning of this process has the most advanced research facilities in order to provide world-class science, because only on world-class science can we build world-class technology, and only on that is the accomplishment of economic growth.

Let us now forget industry and the private sector. They actually perform two-thirds of the $300 billion annually which the United States spends on R&D. We understand that the development the industry mostly performs is the advanced stage of transforming technologies into useful products. That is just exactly the way it ought to be. I for one am very thankful to you, your committee, and your counterparts in the Executive Branch for having supported the R&D establishment over many, many decades.

Now, as you know, the physical sciences, and as your chart shows—and again, I am superfluous from this aspect. This chart shows a worrying trend. Why so? Undoubtedly the 20th century was a century of the physical sciences, but the physical sciences have not only supported the technologies of today; they also have supported other sciences. The Holy Grail of biology in the 21st century, the complete simulation of a cell, would be unthinkable without the work, the instrumentation, and the computing capabilities the physical sciences developed over the last few decades.

So if you do not support the physical sciences, that would be a worrisome trend because a very important component of the research and development or S&T activities would be starved. I know, Mr. Chairman, you understand all this, so just let me add my voice to it.

Having said that, I would like to reemphasize the role of the national laboratories. The national laboratories come into play when multidisciplinary research teams, including engineering in its scientific aspect as well as engineering in its important role to build instrumentation and particularly large, one of a kind facilities, as you, the Secretary, and Ray Orbach alluded to, namely the user facilities. It is these facilities who give the researcher, be he or she out of industry, university, or national labs, an extended reach and an efficiency of completing the research, and in many, many cases, such as Burt and his Nobel Prize, was not possible without such facilities.

So that is one of the main roles, multi-disciplinary research and user facility construction and maintenance. The Spallation Neutron Source is a wonderful example at Oak Ridge National Laboratory.

What else can I say? If you want to know where at the moment we are concerned most about the funding, then it is on the long-term, high-risk research. It is that research which you on any one day can postpone, but in the long term it will have tragic consequences for the entire enterprise.

So how much is enough funding, Mr. Chairman? In my personal view, science is adequately funded if the best and the brightest of our young people are choosing a career in science, because those people will choose a career in science because it has a certain stability and there is the opportunity to do world-class research on facilities second to none.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Grunder follows:]

PREPARED STATEMENT OF HERMANN A. GRUNDER, PH.D., DIRECTOR, ARGONNE NATIONAL LABORATORY

Chairman Alexander and other members of this Subcommittee, thank you for inviting me to testify about the unique role that the DOE's Office of Science plays in supporting basic research in the physical sciences. I have prepared this written statement, and with your permission, I would like to enter it into the record. I will briefly summarize my statement this morning.

DOE's Office of Science has invested in basic scientific knowledge for more than half a century. Given the Department's dominant missions in national security and energy supply, DOE's Office of Science has become over this period the Federal government's primary sponsor of research in the physical sciences. Although DOE is a mission agency, its leaders have always recognized that it is impossible to know in advance exactly what discovery will prove crucial to its mission success. Therefore, DOE's investments through its Office of Science in research projects, facilities, and people have tended to broadly cover the physical, chemical, materials, and computational sciences and engineering, along with studies aimed at understanding and mitigating biological and environmental effects of its energy and national security work.

Studies by the National Academy of Sciences have shown that more than half of our nation's economic growth stems from research and development. The nation's R&D enterprise lays the foundation for the future products and technologies that will keep Americans safe, secure, healthy, prosperous, and intellectually alive. History has proven that the basis for all fruitful R&D is a fundamental understanding of the laws of nature—a field of inquiry where DOE's Office of Science is a recognized leader.

New fundamental facts are continually being discovered. They are continually leading to new technologies that benefit society often in surprising and unexpected ways. A telling example is Lord Rutherford's retrospectively naive comment, after discovering that there is a compact, massive nucleus deep inside every atom, that he was especially delighted to know that his discovery would have no practical application whatsoever. Of course, Lord Rutherford was wrong. What he considered knowledge for the sake of knowledge set the stage for nuclear medicine, nuclear energy, and many other modern advances.

The R&D enterprise has three main components:

1. Private-sector institutions and their research laboratories;
2. Universities and their research laboratories; and
3. Federally funded R&D centers, including the national laboratories.

According to the National Science Foundation, industry plays the major role in the U.S. R&D enterprise. In 2002, industry accounted for two-thirds of the nation's overall $292 billion R&D expenditure. But with a few notable exceptions, financial pressures force industry to focus on applied projects with relatively short-term payoffs. This means that industry is hard-pressed to pursue the longer-term, fundamental science that is so important to our nation's future.

Universities play a central role in the discovery of fundamental laws of nature. In a real sense, all R&D originates in universities, since they educate our scientists and engineers. It is the graduate students who carry the future of our R&D enterprise. To be at the frontier, they need research opportunities second to none. This is the reason why universities—and top universities in particular—need to be involved in the national laboratory system.

National laboratories were created during the mid-20th century to provide centers of research excellence that could focus on problems of national concern and to create closely cooperating, multidisciplinary teams to address long-term scientific problems.

National laboratories also turned out to be ideal places to design, build and operate large national R&D facilities—we call them "user facilities"—which have become essential for forefront research in all the sciences. These are large, one-of-a-kind facilities that attract and serve industrial, academic and government scientists from all over the nation—indeed, from all over the world—to carry out cutting-edge research. These user facilities provide resources, such as intense beams of subatomic particles or electromagnetic radiation, that speed up experiments by orders of magnitude and open up otherwise inaccessible facets of nature to scientific inquiry. Many of the important discoveries made in the physical sciences in the second half of the 20th century were made at—or were made possible by—user facilities. Moreover, most of these user facilities, which were justified and built to serve one scientific field in the physical sciences, have made significant contributions to knowledge and technology in many other fields, including biology and medicine. Examples of great value to society and human health include medical diagnostics and treatment using physics accelerators, and protein crystallography at synchrotron radiation sources.

The design, construction, and operation of these multimillion-dollar facilities requires sophisticated, multidisciplinary science and engineering approaches and complex management structures that are well beyond the means of most academic institutions. Moreover, these facilities are too large and have too long-term an investment horizon to motivate industry to build and operate them.

Imagine that an advisory committee to the government recommended a national initiative in structural biology to lead to better diagnosis and treatment of diseases. This would be an initiative in both the physical and biological sciences to understand the structure and behavior of proteins found in the human body.

This initiative would be a billion dollar project with a 5- to 10-year construction horizon and a 20- to 30-year research lifetime. Because of the size of this initiative, funding would likely come from DOE's Office of Science, which, in fact, funds many user facilities. As you recognize, this example describes exactly what happens with major user facilities in our national laboratory system. And that's why DOE's Office of Science, under the leadership of Ray Orbach, is preparing a multi-year plan for the facilities of the future.

Scientists from academia and national laboratories use these facilities for the new research opportunities. Industry uses them for their importance in developing new products and technologies. More importantly, national laboratories build and operate such facilities, because they have the necessary management and technical resources and because they have the scientific and technical staff to support and partner with users.

The most effective way to pursue fundamental understanding and knowledge is through an open exchange of ideas that involves participation from all three components of the R&D enterprise: industry, academia and government. Scientists regularly collaborate with each other across these institutional boundaries.

This type of cooperation also extends across national borders. While the U.S. has been and continues to be the overall leader of the R&D community, we have a long-standing tradition of mutually beneficial international partnerships, especially in the physical sciences. Even during the darkest days of the Cold War, the U.S. and U.S.S.R. maintained a highly productive "Joint Program on the Fundamental Properties of Matter." This and other projects helped keep our important channels of communication open with our Soviet colleagues.

Of course, national laboratories, like all other institutions, must be held accountable for performing high-quality work on schedule and within budget. The contractors who operate them must be committed to being "best in class" in all aspects. Because science works at the frontiers of knowledge, it is not an easy task to develop metrics for measuring excellence, but a number of such metrics exist. Most important among these metrics are peer review, awards and prizes—such as the R&D 100 Awards, and the Fermi and Lawrence Awards from DOE's Office of Science—membership in prestigious professional bodies, such as the National Academies of Science, and citations in the professional research papers of colleagues.

Allow me to address the funding needs of the U.S. R&D enterprise. It is appropriate for industry to fund projects expected to have near-term, profitable outcomes, and thankfully, the Federal government accepts the responsibility for supporting and encouraging longer-term R&D for which the benefits are more likely to accrue to society as a whole than to any specific company or industry. Much of the strength of the U.S. R&D enterprise comes from its diversity. This diversity is reflected in the variety of fields, research-performing institutions, and R&D-sponsoring Federal agencies that make up our nation's R&D enterprise.

Over the last century, the physical sciences have provided the underpinning of our growing prosperity and security. Because of these impressive accomplishments, the "holy grail" of simulating a living cell in all its complexity is now a realistic goal. This leap in biological science would have been impossible without previous work in understanding the underlying physical laws, developing new instrumentation, and making huge advances in the computer sciences.

We can expect the physical sciences to continue to provide for advances in other sciences and medicine, as well as for the creation of new technologies and economic growth. But over the last decade, Federal funding for the physical sciences has been neglected. Unless this trend is reversed, the research engine will slow seriously that has driven more than half our economic growth for the last 60 years.

To maintain America's economic health, R&D requires a high priority. But how high? How do we know when the sciences are receiving adequate funding?

The total scientific enterprise needs enough support to attract and retain the "best and brightest" on a continuing basis. The way to do this is to offer them the resources they need to pursue exciting research opportunities. Bright young people are still challenged by careers in science and engineering, provided they have stable support and the opportunity to participate in world-leading research.

The DOE's Office of Science continues to be the largest source of Federal support for fundamental research in the physical sciences. As Chairman Alexander correctly stated in his letter to me, "The research of the Office of Science lays the foundation for many of the current and future developments in the applied missions of the DOE in energy, defense, and environmental issues." The Office of Science has built many of the big R&D facilities needed to advance the frontiers of knowledge in many fields. These facilities are used each year by more than 16,000 scientists and students from every state. In addition, the Office of Science supports a dynamic and diverse portfolio of forefront research done in universities and at national laboratories throughout the nation.

Compared to other Federal funding agencies, the significant role played by the Office of Science in America's R&D enterprise is not adequately appreciated. Although the Senate has passed an FY04 budget of $3.36 billion for the Office of Science, that office remains significantly underfunded. It's up to the Administration and Congress to ensure that the foundation for our future is strong; to neglect physical science is to jeopardize the entire enterprise.

My testimony has discussed the "why" and "how" of a well-functioning research establishment. In terms of dollars expended, the bulk of R&D in the U.S. continues to be performed by industry. The science, math, and engineering departments of our nation's top universities train the pre-eminent scientists, engineers and research managers in the government and other sectors. The role of the national laboratories is to expand the reach of universities and together to provide the foundations for future industrial enterprises. For our system to work, these entities, and the Federal government, must understand their respective roles, have the highest regard for each other, and deliver research results that will drive our future security and prosperity.

Senator ALEXANDER. Thank you, Dr. Grunder.

Dr. Richter.

STATEMENT OF BURTON RICHTER, PH.D., NOBEL LAUREATE, FORMER DIRECTOR, STANFORD LINEAR ACCELERATOR CENTER

Dr. RICHTER. Mr. Chairman, thank you for the opportunity to testify today. My written testimony includes some charts and I hope that you would print that in the record.

Senator ALEXANDER. We will be glad to.

Dr. RICHTER. I have been asked to testify about the impact of the DOE science programs. I know them, I know them first-hand. I have been supported by DOE and its predecessors, ERDA and the Atomic Energy Commission, for more than 4 decades and, as you said in my introduction, I have been director of one of DOE's science labs for quite some time.

According to the statistics of the National Science Foundation science and engineering indicators, the Department of Energy is the largest supporter of long-term research in the physical sciences in the Federal Government. It is also the largest in mathematics and computing and it is number three in engineering. DOE's large-scale research facilities are essential to the work of more than 18,000 scientists in many disciplines from universities, industry, and national laboratories.

Most of the DOE science activity is run through its Office of Science. The numbers spent are truly impressive already on these things. It is easy to spend money, but it is harder to spend it well, and so one needs to take a close look at the Department of Energy's programs and ask, are they, are these funds being well spent. And they are well spent indeed. You can look at any of the branches of the Office of Science and see them advancing the Nation's science and technology agenda.

In computing, the Office of Science operates the largest computing facility available for scientific work outside of the weapons laboratories. This facility is at the Lawrence Berkeley National Laboratory. It runs huge programs in simulation, combustion modeling, climate engineering, climate change research, etcetera. It is overloaded. Its speed is less than what is needed and a new and larger facility is badly needed.

In nuclear and high energy physics, DOE builds and operates some of the world's leading accelerator facilities. The scientific output is prodigious, as you can see by counting papers, Nobel Prizes, or the number of foreign scientists who come to use these facilities. The fusion program has been at the forefront of the scientific advances that have led the nations of the world to join together in the ITER project which you mentioned in your introductory remarks, coming together collectively to build the world's first burning plasma experiment, a crucial step on the road to learning whether fusion energy can really be supplied to energy generation for the world's economy.

Basic energy sciences programs have led to great advances in condensed matter physics, materials chemistry. Its synchrotron light sources with their X-ray beams millions of times the intensity of X-ray tubes have had a revolutionary impact, and among those is the development of the field of structural biology. About 35 percent of the DOE synchrotron light users are funded by the NIH to untangle the structure of biologically important molecules.

The biological and environmental research program was the engine for the start of the human genome project, something which is not widely appreciated outside of the Department of Energy. It was started at a time when the NIH was hesitant to begin what seemed to them to be a large, costly, and very long-term program. The biological and environmental research program has a broad portfolio. It plays a major role in climate change research and is critical to the development of biological remediation systems so important for environmental cleanup.

I said earlier that the DOE was the largest supporter of long-term research in the physical sciences in the Federal Government. In a time of large budget deficits, it may be imprudent to ask if this source support is enough, but the question needs to be asked and I think that is one of the points of this hearing. The President's Council of Advisers on Science and Technology thinks that it is not enough and it said so in its report of last fall, and I am sure Dr. Clough will talk about that.

Industry also thinks it is not. You mentioned the role of science and technology in economic growth. It is not just the National Academy that says that; it is industry itself that says that. It is an odd couple: The Brookings Institution and the American Enterprise Institute both agree that that is true.

As time goes on, the last big thing for industry, like telecommunications equipment, laptop computers, cell phones, all these become commodities and production and the jobs that go with them move offshore to lower cost places. What the U.S. economy needs is the next big thing, and the DOE's programs in such areas as nanotechnology, quantum computing, or perhaps something that has not yet emerged clearly, may very well supply it.

For the record, included in my written testimony is a letter to the President on this matter from a collection of Nobel laureates and CEO's of high tech industry.* This is also an interesting combination coming together to talk about the importance of physical science.

Mr. Chairman, Congress needs to take a hard look at the situation of the physical sciences in the Federal budget. Over the last 10 years, as can be seen clearly in the chart behind you, the NIH budget has gone up by more than a factor of two. That is a good thing. The National Science Foundation is on its way to doubling and that is a good thing. The Department of Energy's Office of Science is down by 20 percent and that is a bad thing.

Congress and the White House have got to address this together. The present situation is bad for the Nation's economy, bad for the Nation's security, bad for the long-term future of science, and bad for attracting the best and the brightest of the students into careers in science. I hope that hearings such as this one will initiate the changes that are required.

Thank you.

[The prepared statement of Dr. Richter follows:]

PREPARED STATEMENT OF BURTON RICHTER, PH.D., PAUL PIGOTT PROFESSOR IN THE PHYSICAL SCIENCES, STANFORD UNIVERSITY

Mr. Chairman, Members of the Committee, thank you for the opportunity to testify today. I've been asked to testify about the impact of the DOE science programs. I know them first hand, since my research has been supported by DOE and its predecessors, ERDA and the AEC, for more than four decades. I also directed one of DOE's science laboratories, the Stanford Linear Accelerator Center, for fifteen years.

According to statistics from the National Science Foundation's Science and Engineering Indicators, the Department of Energy is the largest supporter of long-term research in the physical sciences in the federal government (table attached). It is also the largest in mathematics and computing, and is number three in engineering. DOE's large-scale research facilities are essential to the work of more than 18,000 scientists in many disciplines from universities, industry and national laboratories. Most of the DOE's science activities are carried out through its Office of Science (SC).

These budgets are truly impressive. However, it is easy to spend money, but harder to spend it well. A close look will find that DOE's science funding has been well-spent indeed. One can look at any of the branches of Office of Science and see its leading role in advancing the nation's science and technology agenda.

* The letter has been retained in subcommittee files.

In Computing, SC operates the largest computer facility available for scientific work outside the nation's weapons laboratories, in the NERSC facility at the Lawrence Berkeley National Laboratory. Huge programs in physics simulation, combustion modeling, and climate change are being run. The computer is overloaded, its speed is less than what is required, and a new and larger facility is badly needed.

In Nuclear and High-energy Physics, DOE builds and operates some of the world's leading accelerator facilities. The scientific output is prodigious as can be seen by counting papers, Nobel Prizes, or the number of foreign scientists that come to use these facilities.

The Fusion Program has been at the forefront of the scientific advances that have led the nations of the world to international discussions on collectively building the world's first burning plasma facility. This $5 billion facility is a necessary prelude to the development of fusion as an energy source.

The Basic Energy Sciences Program has led to great advances in condensed matter physics, materials and chemistry. Its synchrotron light sources, with their x-ray beams millions of times the intensity of conventional x-ray tubes, have had a revolutionary impact. Among those impacts is the development of the field of structural biology, and 35% of DOE's synchrotron light users are funded by the National Institutes of Health to untangle the structure of biologically important molecules.

The Biological and Environmental Research Program was the engine for the start of the Human Genome Project at a time when the National Institutes of Health was hesitant to start what seemed to be a large, costly and long-term program. BER today has a broad portfolio and plays a major role in the U.S. Climate Change Research Program.

I said earlier that the DOE was the largest supporter of long-term research in the physical sciences in the federal government. In a time of large budget deficits, it may be imprudent to ask if this support is enough, but the question needs to be asked The President's Council of Advisors on Science and Technology (PCAST) thinks not and says so in its report of last fall, "Assessing the US R&D Investment". Industry also thinks not. Industry relies on government-funded research for the work that will be behind the "next big thing." As time goes on, the "last big thing" (telecommunications equipment, laptop computers, cell phones, for example) becomes a commodity, and its production (and the jobs that go with it) moves off shore to lower-cost locations.

The U.S. economy needs this next big thing. DOE's programs in such areas as nano-technology, quantum computing, or perhaps something that has not yet emerged clearly, may supply it. For the record, I have attached a copy of a letter to the President on this matter signed by a collection of Nobel Laureates and senior industrial personnel.

Mr. Chairman, Congress needs to take a hard look at the situation of the physical sciences in the federal budget. Over the last ten years the budget of the DOE Office of Science has declined, the budget of the National Science Foundation has increased by about 50%, and the budget of the National Institutes of Health has doubled (analysis attached). The increase in funding for the NIH and NSF has been a good thing. A recent bill, passed by Congress and signed by the President, authorizes a further doubling of the National Science Foundation's budget, also a good thing. However, because of the broad portfolio of the National Science Foundation, doubling its budget alone would increase the funding of the Physical Sciences by only about 15%. Thus, the DOE's Office of Science needs attention.

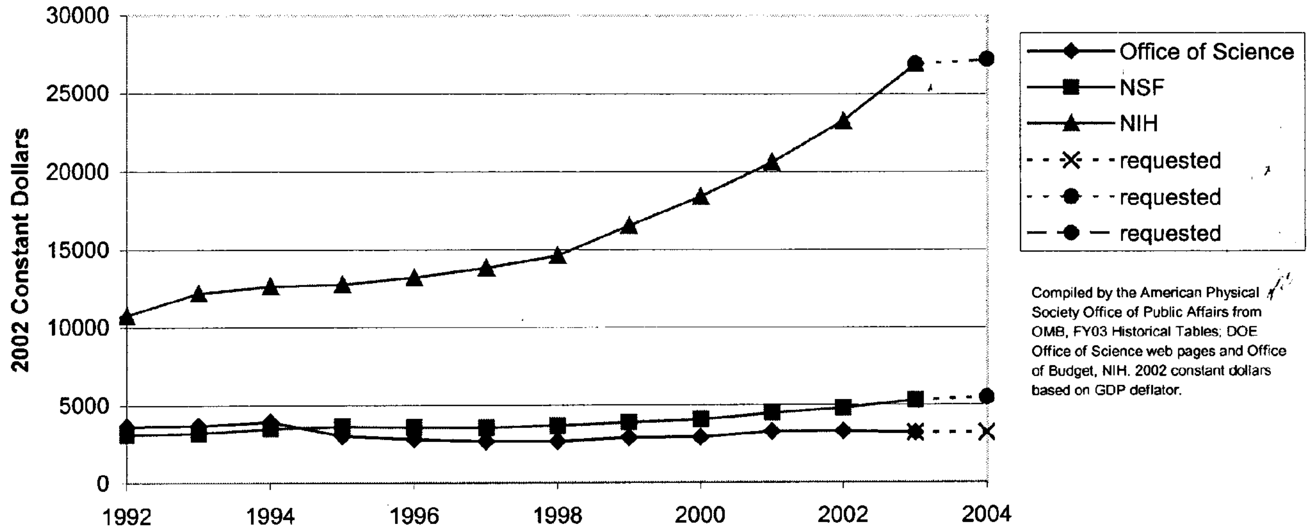
The present situation is bad for the nation's science, is bad for the nation's economy and bad for the nation's security. Action is needed and I hope that the lead is taken by the Administration and Congress together.

Supporting Agencies for Various Science Areas

Physical Sciences	Mathematics & Computing	Engineering	Life Sciences	Environ. Sci.	R&D Facilities
1. Energy (1,938)	1. Energy (861)	1. DOD (2,548)	1. HHS (18,216)	1. NASA (1,113)	1. NASA (2,437)
2. NASA (1,152)	2. DOD (861)	2. NASA (1,722)	2. USDA (1,342)	2. NSF (515)	2. Energy (973)
3. HHS (794)	3. NSF (515)	3. Energy (1,130)	3. DOD (615)	3. HHS (487)	3. HHS (414)
4. NSF (593)	4. HHS (181)	4. NSF (550)	4. NSF (500)	4. Commerce (389)	4. NSF (209)
5. DOD (364)	5. Commerce (78)	5. HHS (501)	5. VA (278)	5. Interior (353)	5. USDA (106)

** Numbers are FY 2002 Dollars in millions (R&D Facilities is FY 2000) - Source: NSF; Adapted from DOE Office of Science slide.*

Office of Science, NSF, and NIH



Compiled by the American Physical Society Office of Public Affairs from OMB, FY03 Historical Tables; DOE Office of Science web pages and Office of Budget, NIH. 2002 constant dollars based on GDP deflator.

Senator ALEXANDER. Thank you, Dr. Richter.
Dr. Clough.

STATEMENT OF DR. G. WAYNE CLOUGH, PRESIDENT, GEORGIA INSTITUTE OF TECHNOLOGY

Dr. CLOUGH. Thank you, Mr. Chairman. It is an honor to be here today to discuss a very important subject. It is certainly a challenge to follow my distinguished colleagues Dr. Grunder and Dr. Richter. It is an honor to be with them on this panel and also to follow two great leaders in Secretary Abraham and Dr. Orbach.

As you know, having been a former university president, that sometimes our job is to be the person who cleans up after the big elephant parade. So I feel a little bit like that today. Many important things have already been said, but I would particularly like to share with you some thoughts that have devolved from our discussions on the Science and Technology Advisory Panel for President Bush.

As you said so distinctly, it is really all about jobs, as we know that the shift today—we have seen thousands of manufacturing jobs and more recently technology jobs going overseas. This shift occurs when products that at one time were at the cutting edge become more of a commodity. At that point in time, countries where wages for skilled positions are much lower than ours become more competitive than we are for those jobs.

I think if we are going to maintain the vitality of our economy we have to be one of the nations where new and cutting edge technology and products are developed, and research and development is the key, as we know.

For the last 2 years it has been my pleasure to serve on the President's Council of Science and Technology Advisers, or PCAST, and one of the subjects we focused on was optimizing the benefit of Federal R&D investments for our Nation and its economy. That is certainly a reasonable proposition to pursue when you consider that President Bush and his administration, and with Congress' support, Federal R&D investment now is the highest it has ever been in total.

In the course of our work, though, it became apparent over time that spending patterns for many of the agencies that support R&D and the impact of appropriation trends over the last decade have kind of taken on a life of their own. A central question then arose: Is the Federal investment portfolio appropriately balanced to achieve our national priorities?

I was fortunate to chair the panel of distinguished scientists and businesspeople that focused on these topics. We held numerous hearings with private industry, national labs, and universities. As Dr. Richter said, there was a surprisingly strong unanimity among all groups from whom we received testimony. Our conclusions were sent to President Bush in a report filed last year. The primary findings are threefold:

First, over the past two decades Federal support for R&D has declined relative to industrial support overall, but Federal support remains the essential element in basic or long-term research and in funding research conducted at our Nation's research universities.

Second, the balance of the Federal investment package has tilted strongly towards the health and life sciences and away from the physical sciences and engineering. Funding for areas like physics and mechanical and electrical engineering have actually declined over the past decade. It has been noted that these fields are not only important to the obvious targets, such as semiconductors and computing, but also to the health and energy industries.

Third finding: Too few U.S. students are going into fields like the physical sciences and engineering. As Dr. Grunder indicated, that is a sign that something is not right. It is going to be accentuated by the declining interest of international students in studying here, which we are already seeing, or staying here if they do study here, another trend we have already seen that is documented by the National Science Foundation.

I would say that the decline in funding for research in the physical sciences and engineering and the commensurate significant decrease in funding for Federal scholarship and fellowship programs is playing a strong role in this decline. I believe that changing these trends is crucial to our Nation's future.

There is some good news on the horizon, but we should be aware that the R&D funding for physical sciences and engineering comes from a number of different agencies, not one. Already, support for NSF has increased, as has been noted, with a commitment to future increases, and that is good. But NSF is not the only primary support agency for many fields of engineering and physical sciences and, as has been noted, the DOE Office of Science is the single largest supporter of the physical sciences and a strong supporter of engineering research, and much of this research funding that comes from DOE goes directly to universities around the Nation.

I would particularly like to commend the Office of Science for developing a plan that goes a long way towards addressing the issues identified by PCAST. It is seeking to expand funding in areas that have been left behind, while adding new support for internships, scholarships, and fellowships that will help attract U.S. students to pursue studies in areas critical to our future.

The investment plan creates programs that not only will engage our research universities, but also will involve less research-intensive institutions with predominantly minority enrollment, an important aspect for our future.

The influence of the Office of Science goes well beyond that of the traditional granting agency, however, in its support for the national laboratories and the encouragement of universities to use the unique facilities found there. In my written testimony I provide details of some of this in the national picture.

But since I have a short time here, let me focus on the experience at George Tech, one of our southeastern institutions. Four years ago, George Tech became one of six southeastern universities in an innovative program to create a formal partnership with Battelle, the University of Tennessee involved as well, to participate in the operation of the Oak Ridge National Laboratory. As you know, Mr. Chairman, both of us coming from the South, the Southeast has been behind the curve for many, many years in its use of the national labs and its science research.

This year, George Tech chairs the science and technology board of the Oak Ridge National Lab. This enlightened approach has allowed six universities to share in operation of the laboratory and has substantially increased our active involvement, as well as that of our partners that we work with around the Southeast and elsewhere.

It has also led to a willingness to invest our own funds in connections to the laboratory. Last year we connected George Tech and the lab with a high-speed computer link that is 200,000 times faster than the fastest dial-up connection. The next step involves a new initiative, organized in the Southeast and around the country by other universities, but in the Southeast with our partners Virginia Tech and Duke University, to create the next generation high bandwidth Internet system, presently called the National Light Rail System. We will bring this to ORNL to allow researchers at George Tech, Duke, Virginia Tech, and other universities we will collaborate with to provide even more efficient remote access to the wonderful new facilities being developed at ORNL, to spread the geographic influence of the national lab, particularly at ORNL.

In conclusion, let me add my endorsement to the proposal for the funding of the R&D budget for the Office of Science. It is designed to address the Nation's most critical needs and will have far-reaching positive impact on a range of universities and colleges while assisting in developing the next generation workforce.

Thank you for allowing me to have this opportunity.

[The prepared statement of Dr. Clough follows:]

PREPARED STATEMENT OF DR. G. WAYNE CLOUGH, PRESIDENT, GEORGIA INSTITUTE OF TECHNOLOGY

Senator Alexander and members of the Senate Committee on Energy and Natural Resources, Secretary Abraham, Director Orbach. . . . It is an honor to be here today and have an opportunity to discuss the importance of basic research in the physical sciences and the role of the Office of Science in the Department of Energy in supporting it. I have been asked to speak more specifically to the importance of basic research and a balanced research portfolio from the perspective of the President's Council of Advisors on Science and Technology (PCAST), of which I am a member, and to the importance of the relationship between research universities and the Office of Science from the perspective of a research university president.

Over the past century, research and innovation in science and technology have become the source and driving force of the leading-edge products and services that have given the United States is economic and military leadership. Our continued economic prosperity, national security, and energy sufficiency are based on our ability to discover new knowledge and develop new technology, and increasing competition from around the world means we cannot afford a leisurely approach to that task. I serve on the executive committee of the U.S. Council of Competitiveness, whose research indicates that the United States needs to be among the leaders if not the leader in every major field of research if we are to sustain the innovation that drives our prosperity and world leadership.

As a member of PCAST, I have a unique opportunity to look broadly at the federal government's research and development portfolio as a whole. When you do that at the 30,000-foot level, three important, overarching characteristics emerge:

First, the portfolio must have length. The time span from the basic research to the working implementation of a technological application is often decades. It will be too little too late if you wait until the need is pressing to ramp up the research. For example, it took Raymond Davis, Jr. thirty years of research at DOE's Brookhaven National Lab to capture solar neutrinos, proving that fusion provides the Sun's energy—an achievement that won him the 2002 Nobel Prize for Physics—and his research was based on other work conducted 70 years ago. Similarly, today's semiconductors emerged from basic research in quantum mechanics in the 1940s. The Internet that is so essential to so many commercial applications today is based on research from the 1960s and 70s. Basic research in fields related to energy has become especially important. According to the advisory committee for Basic Energy Sciences, which is the largest program in the Office of Science, world energy needs are expected to more than double over the next 50 years and the technology does not yet exist to meet them. Creating that technology depends on significant scientific breakthroughs generated by fundamental research, primarily in the Office of Science.

The largest provider of the fundamental research on which industry bases its innovations is research universities and national laboratories, and it is funded largely by the federal government. Industries are reluctant to do basic research, because it is seldom clear exactly who will profit or when, and industry labs to conduct long-term research have all but disappeared. According to the National Council on Research, for example, the computing and semiconductor industries devote less than five percent of their research budget to basic research. Yet Council on Competitiveness studies indicate that almost three-quarters of industrial patents cite publicly funded research as the basis for their invention. Much of this research is conducted or sponsored by the Office of Science. It is the "seed-corn" on which the next generation of industry products and services will be based and which will provide the solutions to problems like national security and an ample supply of clean energy.

The second characteristic of our national research portfolio must be breadth. Many of the problems and opportunities facing us today require the collaboration of multiple disciplines, and the detrimental impact of an unbalanced R&D portfolio will be much broader than the individual disciplines that are short-changed. Last fall, PCAST cautioned that the federal R&D portfolio was becoming unbalanced as a result of the doubling of the budget for the National Institutes of Health. Advances in biomedical research are grounded in fundamental research not just in biology, but also in chemistry and physics, and in electrical and mechanical engineering, which provide insight into the operation of living systems. These disciplines have seen a declining level of federal support over the past decade, and their continued neglect will have a negative impact on the life sciences as well as the physical sciences and engineering.

However, correcting that imbalance will not be a neat and tidy exercise, because research in the physical sciences is spread across a number of agencies and funding for it passes through a number of different Congressional committees. Congress is presently focused on increasing the budget for the National Science Foundation, which is laudable but by itself will not do the job. The single largest supporter of basic research for the physical sciences for the past decade is not the NSF, but the Office of Science in DOE, which provides more than 40 percent of the funding. For example, although the NSF sponsors some research in physics, 70 percent of the federal physics portfolio is in the Office of Science, including 90 percent of the research in high-energy physics and 85 percent of the research in nuclear physics.

Third, any research program is only as good as the researchers who do the work. Over the past several decades, the United States has grown increasingly reliant on foreign talent in its science and engineering research. By the late 1990s, almost half of the Ph.D.s awarded by U.S. universities in computer science, engineering, and mathematics went to international students. Now, however, R&D operations are beginning to move abroad and international universities are improving the quality of their educational programs. As a result, fewer international students are coming to the United States for graduate study and an increasing number of them return home upon graduation. The number of Ph.D.s award in the United States in the sciences peaked in 1998. Engineering Ph.D.s peaked in 1996 and had declined by more than 15 percent by 1999. White males have traditionally comprised the science and engineering workforce, and these sectors are falling behind as women and minorities increase in the overall workforce.

Federal funding of university research is seen by graduate students as a bellweather for career opportunities in research. They flock to fields in which federal R&D funding is strong and shun those for which it is stagnant or declining. This trend is not merely a reflection of the increase or decrease in graduate fellowships that accompany federal R&D funding. It holds for the broader graduate student body and is, in fact, strongest among students who are not receiving any federal assistance at all. As research emphasis shifted to the life sciences, the number of full-time graduate students in the physical sciences declined. From 1993 to 2000, the number of full-time graduate students in physics declined by more than 20 percent and the number in chemistry declined by almost 10 percent. Federal support for basic research in the physical sciences is very important to producing the talent the nation needs in these fields.

While federal funding for research conducted at universities invariably involves graduate students, we have been witnessing the erosion in recent years of federal support specifically for fellowships and dissertation awards. The funds appropriated to support DOE fellowships and dissertation awards saw an especially dramatic decline during recent years when the focus has been on the life sciences. DOE fellowship and dissertation award recipients decreased from more than 1,000 students in 1995 to less than 170 in 2000, and that number is even smaller today. This decline in federally funded fellowships is of particular concern to PCAST.

If we want to maintain our standard of living and our position of world leadership, it is crucial that we invest in long-term, fundamental research, which is conducted largely at universities and national labs; that we maintain a balance across the disciplines so that they move forward together; and that we pay attention to the education of the next generation of scientists and engineers. All of these things on which the well-being of future generations depends are essentially in the hands of Congress.

All three of these essential characteristics of a vibrant federal R&D program also come together in the DOE Office of Science. The Office funds basic research that will both provide the necessary balance in our national portfolio and lay the groundwork for the innovations on which our national security, energy efficiency, and economic prosperity rest. The Office also promotes the education of the next generation of research scholars in the physical sciences by providing opportunities for them to engage in research, counteracting to some extent the declining number of DOE fellowships. One-third of the $3 billion budget of the Office of Science supports university research involving approximately 250 universities in 49 of the 50 states and engaging tens of thousands of graduate and post-graduate students. The Office also offers students opportunities for engagement at its national labs.

The Office of Science has multi-faceted relationships with the nation's research universities that are unique among federal agencies. Beyond the usual avenue of providing grants and contracts for research conducted at universities, the Office offers university researchers access to the extraordinary facilities of its system of ten national laboratories and fourteen technology centers. This unique arrangement allows for maximum utilization of expensive research tools like the Spallation Neutron Source at Oak Ridge National Lab, the National Synchrotron Light Source at the Brookhaven National Lab, and the Nuclear Magnetic Resonance Spectrometer at the Pacific Northwest National Lab. Some of these facilities are one-of-a-kind in the world, and no other entity in the world controls the range of them that the Office of Science does. Access to unique research resources like these provides incredible opportunities for university research scholars to move their work forward—opportunities that are not available through any other means.

But the relationship between the national labs and research universities extends beyond allowing access to unique facilities. Five of DOE's national labs and technology centers are located at research universities, and others have close working relationships with research universities. Georgia Tech, for example, has a close working relationship with Oak Ridge National Laboratory in Tennessee. We are one of six universities that as a consortium have a formal partnership with Battelle to participate in the operation of the Oak Ridge National Laboratory and to help promote and manage collaborate partnerships among 87 members of the Oak Ridge Associated Universities and the national lab. Last year we connected Georgia Tech and Oak Ridge National Lab with a high-speed computer link that is 200,000 times faster than the fastest dial-up connections typical of home computers. In addition to promoting collaboration and data sharing between researchers at Georgia Tech and Oak Ridge, this powerful computer link also forms the connecting point between the Department of Energy's ESnet and Internet2, which is a high-speed network that connects the nation's top-tier research universities. Establishing this broader link through Georgia Tech and Oak Ridge National Lab was a logical step because Georgia Tech is the hub through which research universities throughout the Southeast are connected to Internet2, and Oak Ridge's Center for Computational Sciences is the primary site for DOE's Scientific Discovery Through Advanced Computing, an initiative that involves extensive partnerships between 13 DOE labs and technology centers and about 50 universities to address computing problems of national importance. The new high-speed connecting linking two powerful computer networks will allow the partnership between the Office of Science and the nation's leading research universities to evolve to a new level of collaboration in research and education.

This multi-faceted working partnership between Georgia Tech and Oak Ridge National Laboratory is just one example of many similar relationships between universities and the national labs of the Office of Science. These close relationships are essential to the important task aligning the research work of the national labs and the work of the nation's research universities, so that our efforts are correlative and collaborative, and we realize the maximum progress and potential from our work.

Senator Alexander and members of the committee, this concludes my prepared statement. I will be glad to answer any questions you might have.

Senator ALEXANDER. Thank you, Dr. Clough.

Senator Levin of Michigan and I have introduced legislation that would increase funding for the physical sciences from about $3.3 to $5.4 billion by 2008, which are the authorization figures in the energy bill that is being debated on the Senate floor this week.

I have a couple of questions I would like to ask the three of you. It was mentioned that two-thirds of research is done by industry. What is the Government then uniquely suited to do? I heard the words "long-term," "high risk," "large." Maybe there are some things that are more of a public character than a private character.

If one-third of the research is government-supported, what should be the characteristics of that research?

Dr. RICHTER. The part that the Government supports is really the critical part, the high risk part, the kind where you do not know what the payoff is going to be where you start it. There is a study that was done and published a few years ago that said about 75 percent of the prior art cited in industrial patents comes from government-funded research. So the foundation on which industry builds is actually the 25 percent. If you wipe out the 25 percent, the engine is going to run out of gas and it is going to run out of gas in some time like 10 or so, 10 or 15 years, and then the innovations of our industry will start going away.

Senator ALEXANDER. Dr. Clough or Dr. Grunder, do you have any?

Dr. GRUNDER. Very adequately described. I mean, the Federal Government should fund this high risk, high payoff research because it accrues to the society and the economy as a whole and not to specific individuals. It is very essential for the whole enterprise.

Senator Talent: I would say also when we speak about industry funding research, that they do a certain amount of that with universities. Georgia Tech for one, we are usually in the top 5 percent of work that we do with industry, but even so that is only about 25 percent of our funding at tops. So the Federal Government is a key to sustaining the research that we do at universities and encouraging our collaboration with private industry.

I guess the one signal difference between the research private industry would do and the research universities would do, other than what my colleagues have said, is we educate the workforce of the future. When we do research we are educating young people. We are preparing them to take important roles in society. And if we are not doing that, you are going to lose the seed corn for the future.

Senator ALEXANDER. This chart really tells the picture of the subject of our discussion: the excellent commitment our country has made with NIH and NSF, those lines are going great; but the Office of Science is not so good. It looks to me, looking at the years we are talking about, like fairly bipartisan neglect.

How did that happen? What is the explanation for that? Sir, Dr. Grunder?

Dr. GRUNDER. Mr. Chairman, the relationship between fundamental research in technology and the economic wellbeing of the Nation is not as apparent as the health of the Nation and therefore neither to the man on the street nor to the Senator or Congressman as evident. So that is certainly one factor.

The second factor is with having done marvelously in the 20th century and sort of laid a foundation, is that not enough? You know, do we not have the foundation now and can we continue building the house?

Of course, reality is you do need to enlarge your foundation to carry the ever-increasing economy of the Nation and, for that matter, of the world, because what has not been mentioned, the early R&D is indeed international, worldwide in character.

Senator ALEXANDER. Dr. Richter.

Dr. RICHTER. I think there is another problem and that is a misunderstanding of who is funding what when Congress appropriates money. If you look at that chart, you see the National Science Foundation going up by more than the DOE is going down. But what is not recognized is that the NSF funds a lot of things and not very much is in the physical sciences.

When I talked to the OMB people about 6 months ago, their analysis said if you doubled the NSF and they kept their proportion of funding the same you would increase the funding for the physical sciences by 15 percent. So I think people really think if they put a lot of money into the NSF they are taking care of science. In fact they are taking care of a lot of fields of science and they are not taking care of the physical sciences.

Senator ALEXANDER. Dr. Clough.

Dr. CLOUGH. If I might extend that also to engineering. If you look at NSF, engineering is about 10 percent of the NSF budget. So again, while I applaud the support for NSF and the PCAST effort and we have supported that increase for sure, it does not touch all the bases. If you look at an agency like DOE, it is much more targeted, much more specific, and it will get directly at some of the issues related to the physical sciences and areas like electrical and mechanical engineering where Federal funding has actually declined in the past decade.

So I think there was a period of time when we had the Cold War, we had an enemy, we had the attention of almost all the members of Congress on a focused issue. As that went away, it became less focused, and I think it has taken some time to regroup and begin to realize that there is a next generation of problems and this next generation of problems require a balanced approach to funding all of the aspects of the R&D enterprise.

Senator ALEXANDER. The President's Council of Advisers on Science and Technology and I am sure many other groups have an answer to this question: If this is what we have been doing for 10 years with Office of Science investments and if the President were to call you into his office and say, okay, I hope to be here 6 more years, I would like to correct this, I would like to correct the imbalance gradually as the budget permits it, where would we start? What would we do first?

Dr. CLOUGH. I think a good start is the Senate's proposal for support of the Office of Science. That is a strong proposal. Obviously, we cannot do it all at once and it probably would not be advisable. But at the same time, you have got to begin and you have got to begin strongly, and you have got to recognize the nuances of how you are going to get the portfolio balanced.

I think we have got two good trends going. NIH has components in it that are quite positive for engineering and physical sciences. The NSF does. But we need to branch out at DOE and the Office of Science is another important area that must be brought up to speed if we are going to get this semblance of parity that we spoke about on the President's Council in that report that we sent to President Bush.

Senator ALEXANDER. Dr. Richter, just following that, the Office of Science has some line items. Which line items would you add or increase? Where would you start?

Dr. RICHTER. The American Physical Society did an analysis of DOE's budget and we put out a booklet on the first of the year. I would like to submit it for the record, because we address just your question where would you put the money. And where we got our input is looking at the highest priority recommendations of the advisory committees.

We also discovered something which surprised me even though I have been involved in the DOE for a long time. The DOE university grant proposals, only 10 percent of them get funded. If you increase the grant success rate at DOE to the same as it is at NSF and NIH, which is about 30 percent, you would have to increase the DOE budget by over a billion dollars just for that alone.

If you ask which are the high priority things that I would fund, well, I would have my own list. Ray Orbach is doing a very brave job of trying to get an interdisciplinary priority list. I think Ray and I probably agree on a large fraction of it. We will disagree on some of it. But it is his job to do that cross-disciplinary prioritization and I am interested in seeing what comes out, what he comes out with, and I probably will not fight with him too much.

[Laughter.]

Senator ALEXANDER. Dr. Richter, would 30 percent of the grant requests be worth funding?

Dr. RICHTER. If you look at the proposals that come in, there are an awful lot of terrific proposals that come in where there simply is not enough money. The NIH says the same thing and they fund 30 percent. The NSF says the same thing and they fund 30 percent. They could easily fund a lot more which get an excellent rating in peer review.

The DOE is anomalously low and they simply do not have the funds to handle all the dimensions of their job.

Senator ALEXANDER. So they are not inferior. I mean, there is room for funding some superior proposals that the money is not available for?

Dr. CLOUGH. Absolutely. The DOE has got the national laboratories, it has got big user facilities. These are unique. The DOE's responsibility is to maintain those and it has to do the best it can on individual grant proposals. It would be nice if it had a lot more money to do better than it is doing now.

Senator ALEXANDER. Dr. Grunder.

Dr. GRUNDER. With our economy being dependent on creativity and innovation, we need to start on two places. First, we need to utilize what we have, and that is the grant proposals and other mechanisms. Secondly, of course we need to plan for the future, and this is the aforementioned projection of facilities in the foreseeable future, because, as you know, these facilities take a long time to be realized in a cost-effective way.

Senator ALEXANDER. Well, I would like to thank the three of you for your complete testimony and for the conversation we have had this morning. This is the beginning of an interest by this subcommittee and our full committee and the Congress in trying to correct the imbalance we have in the funding that has put physical sciences at a disadvantage for the last dozen years or so.

I think what we have learned today is that perhaps the most important thing we can do, those of us who believe that the imbalance should be corrected, is what the Secretary did a pretty good job of, I thought, toward the end of his testimony, which is present a compelling vision of where we hope to be; and then, second, offer some vivid examples that help those who pay the bills, the taxpayers and their representatives, members of Congress, understand that our gains in restoring sight, in cleaning the air, in creating jobs, in keeping our standard of living, all depend at base on the physical sciences and that they are an important part of the mix, and that over the last 10, 12 years we lost sight of that a little bit.

So it may take a few years to correct. Now is a good time to put the spotlight on and your testimony today has been a very helpful contribution. I thank you for coming.

If you have anything else that you would like to submit for the record, we would be glad to have it. Thank you very much.

The hearing is adjourned.

[Whereupon, at 10:55 a.m., the hearing was adjourned.]