APS physics

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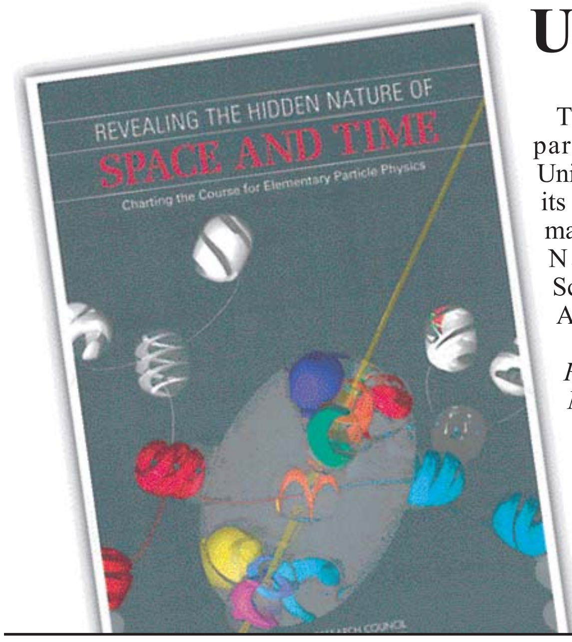

US high energy physics at risk, says NAS study

This is an exciting time in particle physics, and the United States should increase its investment in the field to maintain leadership, says a National Academy of Sciences report released in April.

The report, titled *Revealing the Hidden Nature of Space and Time,* observed that the field of particle physics is now at a crossroads, as several major experiments are scheduled to end soon. The report identified several priorities for US particle physics in the next 15 years.

The main recommendations, in priority order, are:

• First, support American scientists working at the Large Hadron Collider (LHC) in Geneva, Switzerland.

• Second, invest in the necessary research and development in order to make a compelling bid to host the International Linear Collider (ILC).

• Third, expand the program in particle astrophysics and pursue an internationally coordinated program in neutrino physics.

Harold Shapiro, an economist and former President of Princeton University, chaired the NRC's Committee on Elementary Particle Physics in the 21st Century which drafted the report. He announced the panel's recommendations at a press conference April 26 in Washington.

Not only will, several major particle physics experiments come to an end shortly, the committee noted. Fermilab, the flagship of US particle physics, is scheduled to shut down around 2010. Shapiro said he had been disappointed to learn that no plan was in place for the future. "When we looked at the status of high-energy physics in the US, we were sobered," he said. "We had no compelling follow-on program."

The report says that the US should play a leadership role in the worldwide effort to study Terascale physics, and accelerators are an essential component of this effort.

The panel recommends spending \$300 to \$500 million over the next five years on research and development for the accelerator for the proposed International Linear Collider. The panel also

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Physicist pulls some strings on the Hill

Alan Alda (left) talks with Brian Greene and Rep. Judy Biggert (Ill-13th) after the lecture.

In May, Columbia University string theorist and author of the bestselling book, *The Elegant Universe,* Brian Greene appeared at a special reception on Capitol Hill to talk to Congressional representatives and their staffers about the future of physics research. Audience members included former NSF director Neal Lane, Michael Turner, the former Assistant Director of the NSF for Mathematical and Physical Sciences, DOE's Ray Orbach, Greene s fellow string theorist Edward Witten, and the only two physicists currently serving in Congress, Rep. Rush Holt (D-NJ) and Rep. Vern Ehlers (R-MI). Actor Alan Alda, a strong proponent of science, was also in attendance.

The timing of Greene's talk couldn't have been more fortuitous, coming as it did on the heels of the recently released report of the National Academies' Committee on Elementary Particle Physics in the 21st Century, which makes the case for funding the next generation of particle accelerators.

Greene provided an excellent answer to the inevitable question: why spend billions of taxpayer dollars to construct a gigantic facility to detect exotic things we can't even observe directly. He did so via a story, namely, Einstein's persistence in developing general relativity over the course of 10 long years.

First published in the mid-17th Century, Isaac Newton's *Principia* is among the most significant physics treatises ever written. He mapped out the law of universal gravity so precisely, that we can still use his fundamental equations today to predict where a ball tossed in the air will land. But when it came to explaining how gravity actually works, Newton declared that he would leave this question to the consideration of the reader.

Albert Einstein took up the challenge. According to Greene, Einstein kept asking why, pushing the envelope further, and in the process, he revolutionized physics. Newton believed gravity was a force, one object exerting a pull on another by virtue of their respective masses. Einstein figured out how it worked: an object's mass warps the fabric of spacetime, and this makes us feel the effects of gravity. ("Some of us feel it more than others," Greene quipped.)

Most importantly, Einstein laid out a testable prediction that light would follow the curvature of spacetime, and this was borne out in 1919 by observations made during an eclipse. Like Einstein 100 years ago, Greene hopes the scientific community won't be content to sit back on its laurels, but will keep asking those fundamental questions to push the envelope of scientific knowledge to the next "final frontier." Funding the next-generation collider is one way of ensuring continued progress.

Nuclear power expert testifies on safety and non-proliferation

Global electricity demand is expected to increase by more than 50 percent by 2025 and nuclear power is a primary carbon-free energy source for meeting that massive expansion. But, Iran and North Korea clarify the challenge: technologies used in peaceful nuclear power programs could be diverted for the production of fissionable material for nuclear weapons. That combination of facts led the APS Panel on Public Affairs (POPA) to issue a report titled *Nuclear Power and Proliferation Resistance: Securing Benefits, Limiting Risks.*

Nuclear energy has long been viewed with suspicion by the general public because of various health and safety concerns, but over the last decade, there has been a noticeable shift in public perception, according to Roger Hagengruber (University of New Mexico), who chaired the APS report. Nuclear energy is a viable option to carbon-based energy sources, in light of mounting public concern about global warming. Other countries recognize the value of nuclear energy and worldwide, more than thirty new nuclear plants are under construction.

"The intent of our report is to provide an informative, educational document to help Congress see the technical details supporting the issue, independent of any political agendas," said Hagengruber, emphasizing that the report is "a consensus document," and there were some dissenting voices during discussions.

The consensus that emerged focused on four main points:

• Safeguards technologies (see sidebar on page 3) are the first line of defense against proliferation. The current international safeguards program run by IAEA largely installs technologies that are the result of R&D carried out by the United States 10-20 years ago. The program in safeguards R&D needs to be revitalized.

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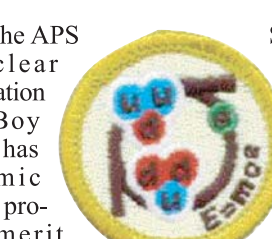
On the Back Page

• **Senator Pete V. Domenici** discusses... Meeting our long-term energy needs through Federal research and development

APS helps boy scouts explore nuclear science



With the help of the APS Division of Nuclear Physics (DNP) Education Committee, the Boy Scouts of America has revised its Atomic Energy merit badge program. The new merit badge, now called "Nuclear Science," updates the program and increases the emphasis on science.

Howard Matis, a nuclear physicist at Lawrence Berkeley Lab and member of the DNP Education Committee, noticed that the Atomic Energy merit badge program needed updating when a local scout troop visited his lab.

Matis has been involved with the Boy Scouts for a long time. He is an Eagle Scout (though he never earned the Atomic Energy merit badge), and now has a son who is a Boy Scout.

He and the DNP Education Committee wrote to the Boy Scouts of America, offering to help revise the handbook,

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APS Members in the Media

"We were all scientists and therefore really understood and appreciated the value this would bring to our colleagues in Iraq."
***Barrett Ripin** (MD-8th), US Department of State, on the Iraqi Virtual Science Library. (May 22, 2006)*

"This is a good example of something which is very counterintuitive that the laws of nature permit."
***-Robert Boyd,** University of Rochester (NY-28th), on a method of making light travel backwards. (May 16, 2006)*

"Many students have a fear of science, but if they come at it from a different angle, they sometimes find out they're interested in the subject and take more classes."
***Michael Dennin,** UC Irvine (CA-48th), on using comic book heroes to teach physics. (March 25, 2006)*

"It's amazing we are so uncertain about the most abundant substance on Earth. I have a feeling that, with water, there will be more surprises."
***Anders Nilsson**, Stanford University (CA-14th), on the structure of water. (March 10, 2006)*

" There are good reasons to think that the [Linear Hadron Collider] will produce major discoveries."
***Michael Dine,** University of California, Santa Cruz (CA-17th). (April 12, 2006)*

"They're not just Shiva the Destroyer; they're Brahma the Creator."
***Scott Hughes**, MIT (MA-8th), on black holes, which may influence galaxy development, according to new research. (April 29, 2006)*

SCOUTS continued from page 1

which was outdated and in some cases, simply wrong. It turned out that BSA was already in the process of updating the badge. Matis was able to serve as an advisor.

The old Atomic Energy badge program focused on engineering, and did not emphasize the science enough, said Matis. "We wanted to put science back into the requirements." He worked with a writer to help make sure the science in the new booklet was correct and included the most modern model of the nucleus. He also added some information, including a description of a career as a nuclear scientist.

The new *Nuclear Science* handbook is an 88-page booklet that covers nuclear science at a level accessible to 14-year olds with little prior knowledge. It includes topics such as the history of nuclear science, modern atomic models, particle accelerators, radiation and its uses, nuclear energy, and careers related to nuclear science.

REPORT continued from page 1

recommends that the US express its strong intent that the ILC be built in the US.

Shapiro noted that this is a risky strategy, but said that doing nothing would be even riskier. If nothing is done, US particle physicists will be forced to work abroad, and students will lose interest in the field, he said.

Experiments at the Terascale could provide the answers to some of the most challenging questions: where do particle masses come from, are the forces of nature truly unified; does space and time have extra dimensions, and what is the dark matter? The LHC, scheduled to begin operation in 2007, could discover the Higgs boson, a long sought after particle that is central to particle physics theory, or evidence entirely of new physics. The ILC, which will collide electrons and positrons, will be able to clarify and provide more details about any discoveries made by the LHC. "This might be the most exciting moment in particle physics in a generation" said Shapiro.

In the short run, the panel found, funds could be reallocated from experiments that are ending in the next few years. But an increase in resources will be needed to sustain US leadership in particle physics. The panel says the budget for particle physics needs to increase by at least 2% to 3% per year in real terms.

The committee also discussed how to avoid the kind of problems that led to the cancellation of the Super Conducting Collider (SSC) by Congress in 1993. Shapiro said that the committee believes the ILC is on a better path because it will be an international collaboration from the very beginning.

The 22-member committee included particle physicists, physicists in other fields, and non-physicists. This unusual composition of the committee meant that the physicists had to work harder to make the case for why particle physics is important. Committee member Jonathan Bagger of Johns Hopkins University said that it was clear that American particle physics is at a crossroads, and it was important to have people outside of physics look at the field.

The report is part of the Physics 2010 project, a series of National Research Council studies that will explore opportunities and priorities for many branches of physics.

This Quarter in Physics History

July 1977: MRI uses fundamental physics for clinical diagnosis

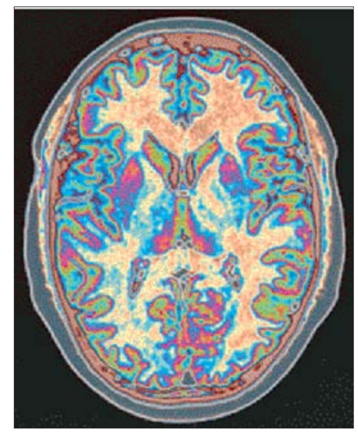
On July 3, 1977, the first magnetic resonance imaging (MRI) exam on a live human patient was performed. MRI, which identifies atoms by how they behave in a magnetic field, has become an extremely useful non-invasive method for imagining internal bodily structures and diagnosing disease. The life-saving medical technique has its foundations in the work of physicist I. I. Rabi, who during the 1930s developed a method of measuring magnetic properties of atomic nuclei.

Isidor Isaac Rabi was born on July 29, 1898 in Rymanow, Austria. In 1899 his family moved to New York, where they lived in poverty in the Lower East Side before moving to Brooklyn in 1907. Rabi's parents were Orthodox Jews, and though Rabi never practiced religion as an adult, he was always influenced by his religious upbringing. He felt that doing good physics was "walking the path of God."

Rabi graduated from Cornell University in 1919 with a degree in chemistry. But he wasn't really captivated by chemistry, and spent three years not doing much of anything before deciding to go to graduate school in physics at Cornell. After finishing his PhD in 1927, Rabi went to Europe, where he spent time working with the giants of quantum mechanics, including Sommerfeld, Bohr, Pauli, Stern, and Heisenberg.

Rabi was fascinated by quantum ideas, especially the Stern–Gerlach experiment. Otto Stern and Walther Gerlach had sent a thin beam of silver atoms through a non-uniform strong magnetic field, and observed that the beam separated into two distinct sub-beams, the atoms in the beam having been deflected slightly according to the direction of their magnetic moments.

When Rabi returned to the United States in 1929, he took a teaching position at Columbia University. After spending two years searching for a problem that interested him, in 1931 Rabi set up his molecular beam lab and took up the problem of determining the nuclear spin and asso-



An image of a brain from a MRI exam

ciated magnetic moment of sodium. The nuclear magnetic moment, much smaller than that of the electron, was difficult to determine precisely. Rabi and Gregory Breit figured out how to modify the classic Stern-Gerlach apparatus to find the nuclear spin of sodium.

Rabi, who was often viewed as lazy, was always impatient with routine experimental techniques and data analysis. He liked to say he wanted an answer at the end of the day, and was driven to design clever, clean experimental methods, methods that brought him "nearer to God."

Throughout the 1930s, Rabi improved the molecular beam method and used it to gather increasingly accurate values for the nuclear spin of atoms, including hydrogen and deuterium. The work culminated in the magnetic resonance method which is the basis for magnetic resonance imaging.

Magnetic moments tend to align either parallel or antiparallel to an external magnetic field, and tend to behave somewhat like tops, precessing about the direction of the magnetic field, with a frequency that depends on the magnetic field strength and the atom's nuclear magnetic moment. In 1937 Rabi predicted that the magnetic moments of nuclei in these experiments could be induced to flip their orientation if they absorbed energy from an electromagnetic wave of the right frequency. They would also emit this amount of energy in falling back to the lower energy orientation. Rabi would be able to detect this transition from one state to the other. He called his method molecular beam magnetic resonance.

Rabi and his team modified the molecular beam apparatus so the beam was also exposed to a radio frequency signal as it traveled through the magnetic field. Tuning either the external magnetic field or the radio frequency can produce resonance. They observed the first magnetic resonance absorption in 1938, with beam of lithium chloride molecules. Rabi was enthralled by the flopping of the magnetic moment, and the group held a party to celebrate the achievement.

Each atom or molecule has a characteristic pattern of resonance frequencies. Rabi detected a series of resonances in different molecules that could be used to identify the type of atom or molecule and give more detail into molecular structure.

After World War II broke out, Rabi left his molecular beam laboratory and went on to become Associate Director of the MIT Radiation Laboratory. He was awarded the Nobel Prize in 1944, for his resonance method for recording the magnetic properties of atomic nuclei.

In 1946 Edward Purcell and Felix Bloch independently found a way to study the magnetic resonance properties of atoms and molecules in solids and liquids, instead of individual atoms or molecules as in Rabi's molecular beam method. Later, nuclear magnetic resonance was further developed into the imaging technique that is now commonly used for medical diagnosis. The first images were produced in the early 1970s, and the first live human subject was imaged in 1977. MRI machines became commercially available in the 1980s, and are now commonly used for imaging internal body structures, especially soft tissues like the brain.

Shortly before he died in January of 1988, Rabi was imaged in an MRI machine. "It was eerie. I saw myself in that machine," he said. "I never thought my work would come to this."

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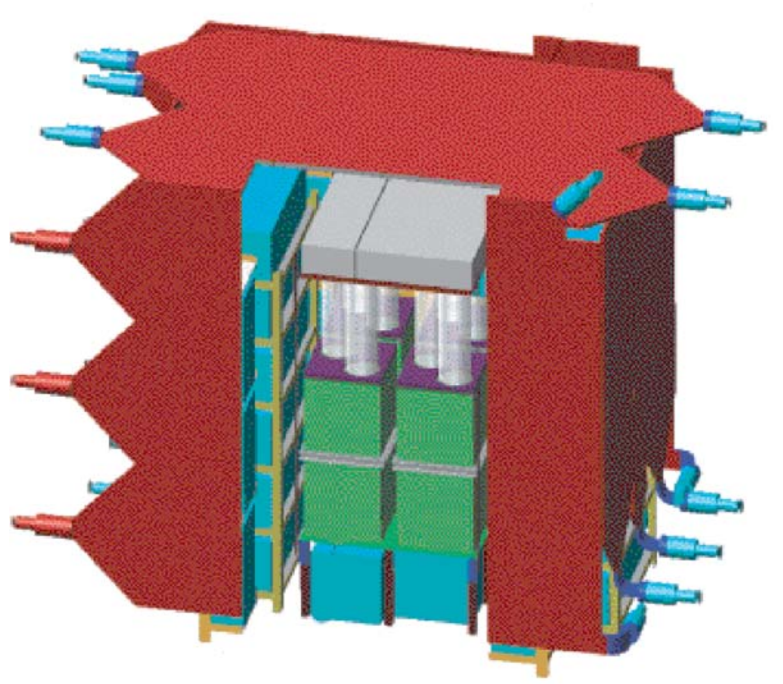
Physics helps bolster homeland security

Many physicists are applying basic physics in unexpected ways to homeland security problems, and several groups reported their progress at the APS April Meeting in Dallas. For instance, a group of researchers from Sandia National Laboratory and Lawrence Livermore National Laboratory has proposed building small neutrino detectors for monitoring nuclear reactors.

Nuclear reactors that produce electric power must be monitored to make sure that fissile materials are not diverted for weapons purposes. Currently, the International Atomic Energy Agency (IEA), monitors nuclear reactors with regular detailed inspections, which are time-consuming and costly.

Now, Nathaniel Bowden of Sandia National Laboratory and his colleagues have proposed a new method for real-time monitoring of nuclear reactors. A smaller version of the same type of detector that scientists use to study solar or atmospheric neutrinos could detect the antineutrinos produced by nuclear power reactors and give a measure of the amount of plutonium in the reactor core, Bowden and colleagues suggest.

A prototype antineutrino detector.



Neutrinos interact infrequently and are hard to detect, Bowden points out, but they are also impossible to shield, so it would be impossible to hide the antineutrinos produced in a nuclear reactor.

Bowden and colleagues have already built a prototype detector, which they have installed near the San Onofre nuclear generating station in San Clemente, Calif. The prototype detector is small and researchers believe it could be made even smaller.

About 1026 antineutrinos are emitted by the reactor each day, and several thousand interact with a proton in the detector. With the prototype, the researchers can clearly see the reactor turning on and off, and they have preliminary indications of sensitivity to production of plutonium.

If the IAEA could adopt this system, it would allow real-time monitoring of plutonium production that could greatly reduce the need for inspections, Bowden says. He and colleagues plan to carry out a cost-benefit analysis to determine whether this method of monitoring reactors would be practical.

In another example of basic science being applied to security problems, seismologist Paul Richards of Columbia University discussed using earthquake detectors to sense nuclear explosions.

To a non-specialist, an earthquake looks very similar to a nuclear explosion, but scientists can tell them apart because of the different patterns of shear and compression waves. Even if a country attempts to evade detection, tests above 1 or 2 kilotons cannot be confidently hidden, said Richards. There is already a large seismic monitoring infrastructure already in place that can detect explosions from a distance, and seismologists can distinguish a nuclear explosion from the 200 earthquakes that occur every day. In fact, seismology has turned out to be the most important way of monitoring nuclear explosions, said Richards.

However, locating an explosion precisely enough is still challenging. Richards and others are working on techniques for solving that problem. In addition to improving the monitoring of nuclear testing, the research is also leading to improvements in seismologists' ability to precisely locate earthquakes, he said. Richards received the Szilard Award for his work in this area.

These are all examples of how scientists working on basic research can apply their knowledge to problems in homeland security, said Edward A. Hartouni of Lawrence Livermore National Laboratory. By supporting scientists to do basic research, "we produce a large reservoir of knowledge which we can draw from," he said.

NUCLEAR EXPERT continued from page 1

• Increase the priority of proliferation resistance in design and development of all future nuclear energy systems.

• Develop and strengthen international collaborations on key proliferation-resistant technologies.

• A policy decision about reprocessing should not outpace the science. Since there is no urgent need for the US to initiate reprocessing, the Department of Energy should take sufficient time to identify the most cost-effective technology that would also be the most resistant to threats of proliferation.

These four steps won't solve the proliferation problem. "No single diplomatic, military, economic, or technical initiative alone will be able to fully deal with the proliferation challenge, " said Hagengruber. "The best prospect for achieving non-proliferation goals while expanding nuclear power is to engage all appropriate means and to maximize their respective contributions."

In February of this year, President Bush announced a new Global Nuclear Energy Partnership (GNEP). Like the POPA report, it identifies a pathway to globally expand nuclear power while limiting proliferation risks. A key element of GNEP is the creation of a fuel services program that would provide nuclear fuel to nations in exchange for their commitment not to develop enrichment or reprocessing technology. In addition, GNEP contained the first three POPA recommendations, but differed on the fourth point, laying out a more aggressive plan for reprocessing.

Hagengruber was invited to testify before Congress on the issue of reprocessing. "Let me be clear," he explained to Members, "we do not oppose eventual reprocessing, but we believe that a premature decision could diminish the growing momentum for nuclear power among the general public."

When GNEP was first announced, Secretary of Energy Samuel Bodman declared that the program "brings the promise of virtually limitless energy to emerging economies around the globe, in an environmentally friendly manner while reducing the threat of nuclear proliferation. If we can make GNEP a reality, we can make the world a better, cleaner, safer place to live."

GNEP's progress through Congress thus far has been less than smooth. Many members support nuclear energy, but there are concerns that GNEP might not be ideally formulated. Representative David Hobson (R-OH), chair of the House Energy and Water Development Appropriations Subcommittee publicly expressed "serious policy, technical and financial reservations" about the reprocessing plan in GNEP.

The House Energy and Water report for FY2007 "strongly endorses the concept of recycling spent nuclear fuel," but finds GNEP lacking in its strategic plan for achieving this. For instance, GNEP favors an alternate recycling process using fast burner reactors, which might be technologically desirable, but which the Committee feels "adds significant cost, time and risk to the recycling effort."

Nonproliferation and national security issues are also a concern, particularly with regard to the need to integrate spent fuel recycling, "keeping sensitive materials and facilities within a secure perimeter and minimizing offsite transportation of special nuclear materials."

A final Committee concern centers on the lack of a requirement for interim storage of spent nuclear fuel, particularly in light of delays and mounting costs of the planned high-level nuclear waste facility at Yucca Mountain.

Hagengruber's panel is now doing a study of interim storage of spent nuclear fuel. He anticipates that the report will be completed by the end of the year.

Hagengruber is practical about the limitations of technical solutions. "In the end, technology alone can't stop proliferation, and some sort of long-term institutional changes will be needed," he observed. "That was part of the rationale for GNEP. Nuclear energy will go forward whether the US pursues it or not. Perhaps if the US takes a leadership role, it can shape that agenda."

Next-generation safeguards technologies

• "Use controls" that impede operation if a nuclear facility is operated in a manner that strays from peaceful use.
• High-speed data recovery and on-line alerting that allow a transition from the current system of periodic IAEA inspections to a system of continuous remote monitoring.
• Radiation activated nuclear fuel tags.
• Advanced automated air samplers to detect diversion of nuclear material.

On the Web

POPA Report: http://www.aps.org/public_affairs/proliferation-resistance
Hagengruber Congressional testimony: http://www.house.gov/science/hearings/energy05/june15/Hagengruber.pdf
GNEP: http://www.gnep.energy.gov
House Report 109-474: http://thomas.loc.gov

TALKING POINTS: *with* Admiral Richard Mies

Editor's Note: The following is an edited excerpt from an extended Q&A interview with Admiral Richard Mies, Commander in Chief of Strategic Command, the operational commander of US nuclear forces, from 1998 until 2002. Mies helped shape post-9/11 US nuclear strategy. The full interview can be found online at www.aps.org/apsnews/0606/060619.cfm

US nuclear threat can enhance stability

Q: *What is the nation's nuclear use policy, as you understand it?*

A: The primary value of nuclear weapons is not in their use; it's in the threat or potential of their use. They are primarily instruments of war prevention rather than war fighting and in my estimation, serve only as weapons of last resort when deterrence has failed. Our nation's nuclear weapons policies are intended to deter potential adversaries' use of weapons of mass destruction and even large-scale conventional aggression against the US and our allies.

Q: *Do you see any contradiction between the US policy of advocating nuclear nonproliferation around the globe while pursuing more usable nuclear weapons options at home?*

A: I strongly disagree with the contention that nuclear weapons are more usable just because they have improved capabilities and are tailored to a broader range of threats. The history of our stockpile was one of improved capabilities throughout the Cold War. Those weapons helped keep the Cold War cold. Nuclear weapons with tailored capabilities are more likely to deter your adversaries than simply maintaining a stockpile that was designed against a very different Cold War threat. The threshold for using a nuclear weapon is very, very high.

Around 1945, there's a dramatic decrease in deaths in combat as a percentage of the world's population. Warfare has fundamentally changed in the nuclear era. In earlier history, warfare didn't have the potentially dire global consequences that it has today. Today, the level of conflict may escalate beyond a nation's control and lead to unacceptable consequences, giving nations pause. I would argue that one of the primary reasons for the dramatic decrease is the existence of nuclear weapons has caused great nations to behave more responsibly and to even seek to avoid conventional war for fear it could potentially escalate into a nuclear one.

Q: *Does developing a new inventory of nuclear weapons with a different set of capabilities violate the terms of the nonproliferation treaty: that those countries with weapons should be working toward disarmament?*

A: Improving some of the capabilities of the stockpile is not in conflict with the long-term objective of total disarmament. Frankly, I'm not sure that the world will ever be capable of achieving that idealistic objective. Nuclear weapon technology cannot be disinvented. Imagine a world where no one had nuclear weapons, except for one rogue nation that acquired a small number of nuclear weapons. That would be a very dangerous world compared to the one we presently live in. Even though there are a larger number of nuclear weapons, our situation is far more stable.

As we move toward this idealistic goal of disarmament, we need to be realistic and never lose sight of the principle of enhancing stability. That ought to be the over-riding criterion. As Sir Michael Quinlan has stated: "The absence of war between advanced states is a key success. We must seek to perpetuate it. Weapons are instrumental and secondary; the basic aim is to avoid war. Better a world with nuclear weapons but no major war than one with major war but no nuclear weapons."

Q: *North Korea and Iran are moving toward the development of nuclear weapons. Do nonproliferation policies need to be changed or strengthened?*

A: There needs to be continued assertion and reinforcement of those principles. The nonproliferation regime has had a fairly good record despite Iran and North Korea. To the degree that we can maintain a credible nuclear deterrent without underground testing, I support the current moratorium. But there's a great danger when you lock yourself into treaties that attempt to establish absolutes such as the Comprehensive Test Ban Treaty. There are certain legitimate scenarios where we might have to perform a limited test if we had grave concerns about the reliability of our stockpile.

It's not that we want to conduct nuclear tests. But we've always held as a principle that we will take whatever actions are prudent and necessary to defend ourselves. As a nation, we are very reluctant to surrender that right of self-protection. We are wary of locking ourselves into international agreements that could constrain us should we need to exercise that right, in some unforeseen world that we can't predict today.

The Back PAGE

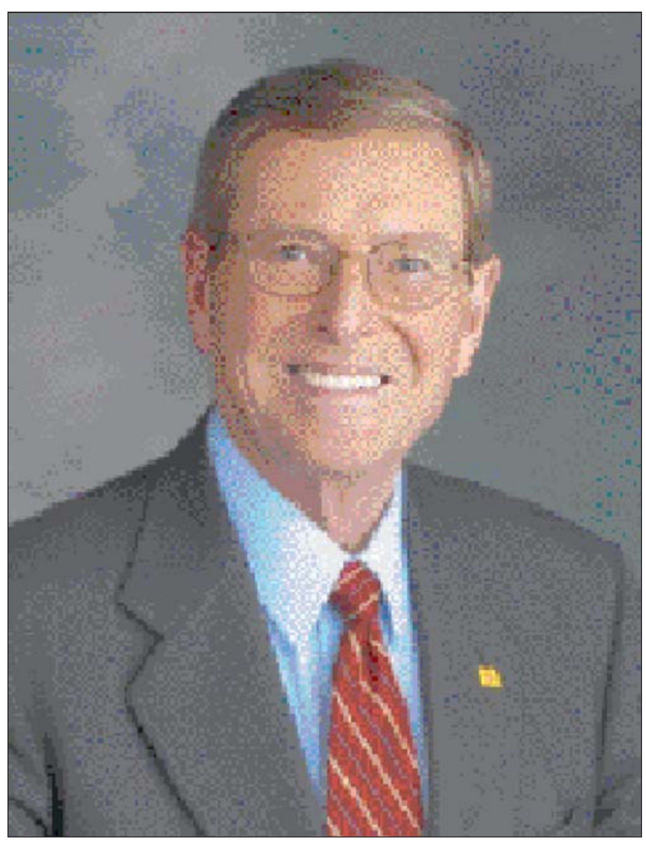
Meeting our long-term energy needs through Federal R&D

by ***Senator Pete V. Domenici***

The funds we spend on research and development (R&D) for new energy technologies are some of the most important dollars in the federal budget. But we have a problem – federal funding for energy R&D has been declining for years, and it is not being made up by increased private sector R&D expenditures. There is a vital need for a bipartisan effort to increase federal R&D funding for energy technology, to leverage those funds with increased private sector investment and to work with the Executive Branch to bring new energy technologies quickly to the market place. In the last year, we have taken important steps to implement this vision.

Over the 25-year period from 1978 to 2004, federal appropriations for energy R&D fell from \$6.4 billion to \$2.75 billion in constant year-2000 dollars, a reduction of nearly 60 percent. Even worse, federal and private sector expenditures combined are less than one percent of total energy sales. Private sector investment in energy R&D fell from about \$4 billion in 1990 to about \$2 billion today. Of our nation's high-technology industries, energy is the least intensive in terms of R&D. Consider, for comparision, that private sector R&D investments equal about 12 percent in the pharmaceuticals industry, and about 15 percent of sales in the airline industry. It is past time to reverse that trend.

> "There is a vital need for a bipartisan effort to increase federal R&D funding for energy technology..."



Last August, Congress enacted the first comprehensive energy legislation in 12 years – the Energy Policy Act of 2005. Already we are seeing results. But the challenges we face are long-term — they will require continued hard work for years to come. To this end, the Act strengthens our commitment to investing in energy-related R&D. In all, it calls for \$24.2 billion in funding over the next three years for research programs in energy technology and energy-related science.

The Energy Policy Act also provides a framework for a balanced set of programs in energy research, development, demonstration, and commercial application. Previously, the Secretary of Energy had no guidance in choosing research topics and program components for energy R&D. The Act addresses this problem, establishing clear guidelines for research programs in energy efficiency, renewable energy, fossil energy, and nuclear energy technologies.

> "... the Energy Policy Act of 2005... calls for \$24.2 billion in funding over the next three years for research programs in energy technology and energy-related science."

With the Energy Policy Act, the Department will be better able to manage our R&D investments. The Act creates a new Under Secretary for Science to serve as the primary science and technology advisor to the Secretary of Energy. The new Under Secretary is responsible for monitoring civilian research and development programs, and advising the Secretary in managing national laboratories supporting basic research.

The Under Secretary for Science will also ensure that the Department remains focused on our long-term energy goals. In particular, we need to build bridges between basic science and applied energy functions. This is vital for crossover applications — so that areas in applied energy where we need scientific breakthroughs are addressed. An example is the workshop held in 2003 that produced the report on Basic Research Needs for the Hydrogen Economy. The new Under Secretary for Science should help ensure that more of this kind of bridging work is undertaken by the Department and that the Department gives it high priority.

While our nation must increase domestic energy production, we must also increase our production of *new energy technologies*. And these technologies must move from laboratory to market, or we will be no closer to realizing a stronger energy economy. Crossing this "Valley of Death" is not easy. Even technologies with obvious commercial potential often confound attempts to find successful markets.

Federal funding for energy R&D is critical, but we also need policies that encourage greater private sector investment.

The Energy Policy Act strengthens Department of Energy efforts to partner with private companies interested in lab-developed technologies. The Act establishes a technology transfer coordinator to advise the Secretary on technology transfer and commercialization. It also creates a technology commercialization fund with a budget of about \$25 million annually. That federal funding will be seed money to leverage private sector investments through partnerships with local businesses. Helping laboratories "spin-off" technologies to the private sector will lead to new businesses, job creation, and a more innovative economy.

The Energy Policy Act also gives the Department of Energy new authority to hold prize competitions in "grand challenge" areas of energy technology. The Department can use this authority to accelerate progress in challenging areas — such as hydrogen and fuel cell vehicles and carbon capture and storage. This prize authority is modeled after that used successfully by the Defense Advanced Research Programs Agency (DARPA). DARPA spurred private sector investment in robotics technologies, for example, through a well-publicized race through the Mohave Desert. The X-Prize stands as another example of successful use of prize authority. This \$10 million privately-funded award produced the first successful space flight ever achieved without public support. These prizes encourage multiple teams to undertake novel approaches, and they generate significant private sector investment due to their inherent prestige.

We need to encourage high-technology industries, including energy sector industries, to increase their R&D investments. Legislation that I introduced with my Senate colleagues Jeff Bingaman (D-NM) and Lamar Alexander (R-TN) will do just that. The Protecting America's Competitive Edge through Finance (PACE-Finance) Act will modernize and make permanent the R&D tax credit. After two decades of extending the tax credit for just a year or two in advance, it is time to give industry the certainty it needs. This certainty will lead to greater spending on R&D, leading to more innovation, and to a stronger, more competitive economy.

In his State of the Union address earlier this year, the President announced his Advanced Energy Initiative (AEI). The President's Advanced Energy Initiative builds on the Energy Policy Act by identifying key technologies where we will focus our efforts.

> "Greater public and private investment in energy R&D will make our energy sector cleaner, more secure, and more resilient"

The purpose of the AEI is to reduce our national dependence on foreign sources of energy, including the natural gas we use to heat our homes and the crude oil we rely upon to fuel our cars. To support this initiative, the President has requested for an overall 22 percent increase in fiscal year 2007 funding for the development of key technologies.

Under the President's Initiative, we will invest in technologies for zero-emission coal fired power plants. These plants will capture and store pollutants and carbon dioxide rather than releasing them into the atmosphere. We will continue our support for revolutionary new solar and wind technologies, to make them more cost competitive. Through the Global Nuclear Energy Partnership, we will develop a nuclear fuel cycle that enhances energy security, while addressing proliferation concerns.

The AEI emphasizes the importance of advanced transportation technologies. To accelerate consumer adoption of hybrid-electric vehicles, the administration has committed to increase the energy storage and the lifetimes of batteries for these vehicles. To achieve greater use of homegrown renewable fuels, the initiative will develop advanced technologies to make competitively priced ethanol from cellulosic biomass, such as agricultural and forestry residues, trees, and grasses. Moreover, President Bush three years ago gave Americans the vision of a hydrogen future free from a reliance on foreign oil. The Energy Policy Act moves us toward that future with an authorization of over \$3 billion in research on hydrogen and hydrogen fuel cells.

Our nation has a bright energy future. Greater public and private investment in energy R&D will produce a suite of new technologies that will make our energy sector cleaner, more secure, and more resilient. We laid the groundwork in the Energy Policy Act, and by following through on the President's vision of the Advanced Energy Initiative we will meet the energy challenges that lie ahead.

Senator Pete V. Domenici (R, NM) chairs the Senate Energy & Natural Resources Committee and the Senate Appropriations Energy & Water subcommittee. He is serving in his sixth term.