Atoms for Peace +50

Nuclear Energy & Science for the Twenty-First Century

Final Report

from a conference organized by
The Institute for Foreign Policy Analysis
The International Security Studies Program of
The Fletcher School, Tufts University

sponsored by
U.S. Department of Energy
The Dwight D. Eisenhower Library & Museum

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Photography by Guy Noffsinger

CONFERENCE REPORT

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INTRODUCTION

The Institute for Foreign Policy Analysis, in association with the International Security Studies Program of The Fletcher School, Tufts University, The Dwight D. Eisenhower Library and Museum, and the United States Department of Energy, organized a major conference entitled: *Nuclear Energy and Science for the 21st Century: Atoms for Peace + 50* in Washington D.C. on October 22, 2003. Its focus was the peaceful uses of the atom and their implications for nuclear science, energy security, nuclear medicine and national security. The conference also provided the setting for the presentation of the prestigious Enrico Fermi Prize, a Presidential Award which recognizes the contributions of distinguished members of the scientific community for a lifetime of exceptional achievement in the science and technology of nuclear, atomic, molecular, and particle interactions and effects.

More than 300 participants from the executive branch, the military services, various government offices and agencies, and the broader nuclear energy and scientific community, including industry, academia, the media, and from overseas were in attendance. An impressive group of distinguished speakers addressed various issues that included: the impact and legacy of the Eisenhower Administration's "Atoms for Peace" concept, the current and future role of nuclear power as an energy source, the challenges of controlling and accounting for existing fissile material, and the horizons of discovery for particle or high-energy physics. The basic goal of the conference was to examine what has been accomplished over the past fifty years as well as to peer into the future to gain insights into what may occur in the fields of nuclear energy, nuclear science, nuclear medicine, and the control of nuclear materials.

The following Conference Report provides a summary and analysis of the panel presentations and discussions.

Robert L. Pfaltzgraff, Jr.
President
The Institute for Foreign Policy Analysis

EXECUTIVE SUMMARY

December 2003 marked the fiftieth anniversary of President Dwight D. Eisenhower's "Atoms for Peace" speech to the United Nations General Assembly. When President Eisenhower put forward his "Atoms for Peace" proposal fifty years ago, he envisaged peaceful nuclear technology which would be made available to all nations under appropriate international controls. Fifty years later the peaceful uses of the atom and their implications for nuclear science, energy security, nuclear medicine, and national security, remains an important issue. As recent events clearly underscore, nuclear power for civilian energy, nonproliferation, and science issues identified by President Eisenhower a half century ago, are highly salient today.

The "Atoms for Peace" speech provided an opportunity to pursue nuclear power as a source of energy. Given the determination of the Bush Administration to reduce U.S. dependence on oil imports, efforts to derive power from atomic energy take on added relevance and urgency. Nuclear power constitutes not only a huge resource for the generation of energy but also for the production of hydrogen. In the years ahead, hydrogen holds the potential to become the fuel of choice to meet U.S. transportation requirements, significantly lowering our dependence on foreign oil.

A half century after President Eisenhower's "Atoms for Peace" speech, fewer than a dozen countries have acquired nuclear weapons although many more possess the technology to produce such capability. Through "Atoms for Peace," various steps were initiated to restrict would-be proliferators and to keep weapons of mass destruction technology out of the hands of rogue states and terrorist groups alike.

"Atoms for Peace" brought numerous accomplishments in the fields of science and medicine. From "Atoms for Peace" came nuclear medicine and science that have not only provided a range of diagnostic and medical treatments that have helped save millions of lives but have also enabled the scientific community to understand better the nature of matter and energy.

Setting the Stage: President Eisenhower's "Atoms for Peace"

President Dwight D. Eisenhower's December 8, 1953 "Atoms for Peace" speech to the United Nations signaled a dramatic shift in U.S. policy. The speech was given in the early years of the Cold War and had two major focal points: constraining the proliferation of nuclear weapons and using nuclear research to benefit all peoples. "Atoms for Peace" led directly to the creation of the International Atomic Energy Agency (IAEA) in 1957, numerous multilateral non-proliferation agreements, the creation of the civilian nuclear power industry, and a flowering of scientific innovation that included great advances in nuclear medicine and fundamentally new perspectives about the nature of matter and energy that have led to dozens of Nobel Prizes.

- President Eisenhower's four primary objectives of "Atoms for Peace" were to work with the Soviet Union on peaceful, nondestructive uses of the atom; to take this initial step in the hope that it would result in cooperation with Moscow across broader issues of concern; to let other nations know that they also had a significant stake – both economic and security – in the outcome of nuclear issues; and, to provide reassurance that nuclear power had beneficial non-military economic applications.
- With the end of the Cold War, the United States now has the opportunity to address several key areas of concern including a range of important U.S.-Russian Cold War-legacy security issues such as: immediately providing security upgrades for Russian plutonium and Highly Enriched Uranium stocks; reviewing the alert status of U.S.-Russian strategic forces; examining approaches for improving the IAEA and Nuclear Nonproliferation Treaty; and, moving forward with nuclear power as a key element in overall U.S. energy policy.

Peaceful Power from Atomic Energy

The National Energy Policy, released in May, 2001, described how to "bring together business, government, local communities and citizens to promote dependable, affordable and environmentally sound energy for the future." The challenge is to make existing forms of energy use more secure, reliable and environmentally benign, while simultaneously preparing the long-term energy solutions that will eventually fully resolve questions about supply and environmental effects. President Bush has set ambitious goals for the steady reduction of pollution emissions and greenhouse gases from energy generation and consumption over the next ten to fifteen years. But no matter how much cleaner and more efficient we make today's energy sources, the nation will still confront growing energy demand and supply problems. The long-term solution is to make a fundamental change in our mix of energy options and, therefore, America's energy future.

- The "Atoms for Peace" speech was the impetus for the formation of the U.S. commercial nuclear industry. Today, nuclear energy supplies more than 16% of the world's electricity and 20% of total U.S. electric output. The record levels for the generation and efficiency of electrical production over the past five years attest to the fact that the nuclear industry is the midst of a "nuclear renaissance."

- Reliable, safe, and efficient nuclear reactors are extremely practical and capable of providing both economic vitality and security to the nation. For example, the nuclear industry achieved a capacity factor† of 90% in 2002, a 30% rise from 1998 levels.
- Nuclear energy is an urgent imperative for the United States and the fundamental challenge centers on garnering public confidence and acceptance, as well as promulgating the correct facts about nuclear safety. For example, although 90% of the fuel rods ruptured, from a radiation and health-hazard standpoint Three Mile Island was an absolute non-event. Furthermore, U.S. Navy sailors on nuclear submarines receive less whole body radiation while onboard than at home when exposed to natural background radiation.
- The Bush Administration has placed considerable emphasis on nuclear technology and a resurgent nuclear energy industry. New nuclear plant designs under development offer simplified systems, increased safety features, improved security, and lower costs. Moreover, the Generation Four International Forum was created to work with selected international partners to develop new, more efficient nuclear energy plants.
- If President Bush's vision to develop a hydrogen economy to meet U.S. transportation power requirements is to become a reality, nuclear power must play an integral role. Moreover, if the populations of China and India increase as forecasted, the demand for cars can be expected to grow immensely. Thus, the incentives to produce hydrogen as a inexpensive, environmentally friendly fuel source with nuclear power as key means to generate it will grow as well. Ultra safe, proliferation-resistant nuclear plants and technologies developed as part of the Generation Four program may play an central role in the President's National Hydrogen Fuel Initiative. This Initiative has the potential to reduce significantly U.S. dependence on foreign oil.

Nuclear Medicine

The "Atoms for Peace" Initiative helped turn the scientific applications of radioactive tracers to human health studies. During the past half-century, the field of nuclear medicine has evolved from an orientation toward organs, to cells, and today to molecules.

- Numerous medical specialties benefit immensely from nuclear medicine including pharmacology, cardiology, brain research, oncology, and gene research.

† *The ratio of the net electricity generated, for the period of time considered, to the energy that could have been generated at continuous full-power operation during the same period.*

- A number of key challenges confront nuclear medicine including the time consuming and cumbersome regulatory process required to win approval for diagnostic agents such as radioactive tracers.
- Given that a diagnostic agent is usually administered only once or twice to obtain a definitive medical finding, the five to ten year approval procedure should be relaxed.

Controlling Nuclear Material

President Eisenhower's "Atoms for Peace" program highlighted the crucial role played by international cooperation in strengthening nuclear nonproliferation efforts and enhancing nuclear material control regimes. Despite the President's historic initiative, the challenges to international nuclear nonproliferation and nuclear material control have become increasingly complex in the 21st century.

- In the absence of "Atoms for Peace" the promulgation of nuclear knowledge would have occurred without a framework of rules and laws accompanied by adverse consequences for stability and security.
- The Office of Defense Nuclear Nonproliferation (DNN) of the Department of Energy plays a key role in supporting the spirit of "Atoms for Peace." DNN provides U.S. support to make the International Atomic Energy Agency more effective to combat proliferation threats, particularly from rogue states and terrorist actors.
- A major concern in the control of international fissile material is that weapons capability has become widespread and states increasingly take small clandestine steps to acquire this capability making detection and a timely, effective international response extraordinarily difficult.

Energy and Physics: the Horizons of Discovery

Since the "Atoms for Peace" speech, the scope of nuclear physics research has evolved significantly. At that time nuclear physics and what was to become "particle physics" were one field of study. Since then, particle or high energy physics has become a distinct, separate scientific field with a focus on understanding the nature of matter and energy, including the fundamental constituents of matter and their interactions. Both nuclear and particle physics are essential to help us understand astrophysics (how cosmic entities like stars and galaxies function) and cosmology (the birth, evolution and fate of the universe).

- In an attempt to reconcile quantum mechanics and Albert Einstein's theory of relativity, scientists have developed string theory in which elementary particles are nothing but the vibrations of minute strings, currently undetectable. String theory provides a single explanatory framework or in Einstein's phrase, a unified theory, capable of encompassing all forces and all matter.

- String theory posits that the different masses and other properties of both the fundamental particles and the force particles associated with the four forces of nature (the strong and weak nuclear forces, electromagnetism, and gravity) are a reflection of the various ways in which a string can vibrate.
- Cosmologists believe that most of the energy in the universe consists of dark matter and dark energy. The study of these two energy forms will lead particle physics research in the coming decades.
- Cosmology and particle physics are intimately intertwined. Illustrative of this partnership was the discovery in 1998 by astronomers and physicists that the universe, contrary to predictions, was increasing at a quickened pace, raising the question of what is causing this expansion.

The Enrico Fermi Presidential Award Presentation

The conference provided the setting for the presentation of the prestigious Enrico Fermi Prize, a Presidential Award which recognizes the contributions of distinguished members of the scientific community for a lifetime of exceptional achievement in the science and technology of nuclear, atomic, molecular, and particle interactions and effects. Therefore, Secretary of Energy Spencer Abraham addressed the participants following the final conference panel session at the Enrico Fermi Presidential Award Dinner.

- The Department of Energy honors not only individual achievement in energy-related science, but the very idea of long-term basic research, the kind of investment that is at the same time most difficult to understand and yet most critical to our success as a nation.
- President Eisenhower's foresight and willingness to be bold at a time of considerable international tension set the stage for a host of global efforts to apply the power of the atom to peaceful purposes.
- Researchers never anticipated that their very basic research on matter would eventually give us remarkable life saving technologies.

At the conclusion of Secretary Abraham's evening address, the Secretary presented the 2003 Presidential Enrico Fermi Awards. This year's recipients were John Bahcall, Raymond Davis, Jr. and Seymour Sack. Dr. Bahcall is Professor of Natural Sciences at the Institute for Advanced Study, Princeton, New Jersey. Dr. Davis was senior chemist at the Department of Energy's Brookhaven National Laboratory on Long Island, New York. Dr. Sack retired from the Department of Energy's Lawrence Livermore National Laboratory, Livermore, California, in 1990 and continues as a Laboratory Associate.

The winners received a gold medal and a citation signed by the President and Secretary of Energy. Dr. Sack received the award for his contributions to national security. Drs. Bahcall and Davis won for their research in neutrino physics.

WELCOMING REMARKS & CONFERENCE OVERVIEW

Dr. John H. Marburger III, Science Advisor to the President and Director, Office of Science and Technology Policy

Today's conference marks a singular event in the long history of the relationship between science and society. The "Atoms for Peace" Initiative had the same impact for many future scientists that the Apollo Project did a decade later. Numerous Americans were caught up in the excitement of discovering new ideas and details about nature and using them to benefit all humankind.

- Scientists tend to perceive a win-win situation for society resulting from scientific discovery. All too often, however, in their enthusiasm for new knowledge and new applications, scientists fail to consider the possible side effects that are not beneficial.
- Non-scientists viewing science often see two sides of a different but sadly more familiar coin, knowledge used for good or knowledge used for evil.

Nuclear physics entered the world in time of war and was first exploited for military purposes. Today's conference celebrates the deliberate and most remarkable attempt by President Eisenhower to turn the coin of science to its other face and begin a worldwide effort to use the knowledge gained at great expense and sacrifice to benefit mankind. Today we look back on these events from a vastly different world.

- The wartime science of nuclear weapons accelerated a development stemming from the profound scientific discoveries in the first decades of the 20th century. Technologies with their origins in a quantum-based understanding of the micro-world have transformed our way of life, in-

Dr. John H. Marburger III

creased human longevity, and brought new capabilities within reach of ordinary men and women everywhere.

- The undeniable evidence of science's profound benefits has also changed attitudes regarding why society should support it. It is not primarily for war but for improving the quality of life, for economic strength and, for the shear pride and joy of discovery.

Unfortunately, the coin always has two sides. In this new century we are again witnessing the emergence of a new science in a new domain revealed by new technology. Bioscience could be called the new science of life, new because for the first time the deepest structures of life's physical foundation are revealed to us.

- The early history of bioscience was entirely benign. However, the very knowledge that empowers healing can also be exploited to do great harm. It is a bitter irony that the most humane endeavors designed to defeat dangerous organisms that invade our bodies and cause dysfunction can also be turned into diabolical instruments of human destruction. One of our greatest concerns in this era of growing terrorist threats is the fear of being attacked from within our own bodies by chemicals or organisms spawned or strengthened by bioscience.
- The lessons of the wartime birth of nuclear science, of the deliberate efforts to protect its secrets from the enemy and then to turn the huge investment toward beneficial applications, are very broad and speak clearly to us today.
- In many ways bioscience is the reverse of nuclear science. It was born into a healthy atmosphere and its evil usages were exploited later. No one needs to be convinced that bioscience heals. Its benefits are so obviously great that any effort to conceal discoveries in this field to inhibit bioterrorism must be undertaken with great care, lest the remedy cost more than the disease itself.
- Moreover, bioterrorism does not need a Hitler to succeed in confounding a strong nation. Although the anthrax incidents two years ago resulted in far fewer victims than the atrocities at the World Trade Center and the Pentagon they could still have caused many more fatalities than those two horrific events. Even with the minimal casualties, the impact of anthrax incidents on the conduct of government was profound.

The "Atoms for Peace" Initiative drew the world's attention to the benefits of nuclear power. Today we struggle to expose and meet the challenge of the dark side of bioscience. In either case, success is inconceivable without the full cooperation of the scientific community.

- In both instances the scientific community has given the requisite cooperation. In an action strikingly reminiscent of that which occurred in 1940,† a committee of the National Research Council released a report

† *In 1940 a committee of the National Academy of Sciences was formed to control publication of papers with potential military application in all American journals, an arrangement that was deemed highly successful and one which was purely voluntary.*

recommending the control of publication of experiments that might enhance the efforts of bioterrorists.

- The report sets forth criteria that would trigger a process of review and calls of the involvement of the Department of Health and Human Services. No single action by the scientific community could have provided more assurance to the public or established greater credibility for science on this perplexing issue.

The "Atoms for Peace" Initiative assumes that the implications for society of scientific knowledge can be influenced by deliberate public action. What began as a policy idea, turned into a powerful world movement that continues to this day.

- Of all the lessons of that troubled time of war and international tension, the one that may be the most promising is that a choice does exist, that knowledge of the physical world, combined with leadership, determination, and effort, can make the world a better place.

Kyle E. McSlarrow, Deputy Secretary of Energy

From the close association with the International Atomic Energy Agency (IAEA), to safeguarding fissile materials and our critical work with Russia, to our activities with advanced generation reactors and the far-reaching science on nuclear energy that our national laboratories conduct, the legacy of the "Atoms for Peace" Initiative finds its home in the Department of Energy.

Kyle E. McSlarrow

President Eisenhower understood very well that the foundation for "Atoms for Peace" relied on deterring war. However, the true success of the "Atoms for Peace" Initiative was due in large measure to the President's skillful blending of both security and peace.

- What is striking about the "Atoms for Peace" speech is that in 1953 it must have been regarded by some as naively optimistic. At the time of this speech civilian nuclear power was not yet a reality, it was a day when people, if they thought about the atom at all, basically thought about it with horror and fear.
- President Eisenhower's speech forced us out of the darkness into the light of the possible. The next four decades saw an incredible growth in civilian nuclear energy production. Indeed, today nuclear energy provides 20% of total U.S. electric output.

Even with the end of the Cold War and decades after both Three Mile Island and Chernobyl, however, nuclear power as an energy option still confronts serious public opinion obstacles.

- Today, we are confronted with a threat that forces us to realize that the grand bargain of the Nuclear Nonproliferation Treaty (NPT), i.e., access to civilian nuclear power and disarmament by the nuclear power states on the other hand, is not quite good enough.

- It brings us to the realization that the military/defense and civilian power sides of the nuclear coin cannot be separated and that the bargain of access to nuclear energy poses challenges perhaps not fully appreciated in the latter half of the 1960s and the early 1970s when the NPT was being ratified.

There are many reasons why it is so important that the United States continue its commitment to civilian nuclear energy. However, our increased dependence on foreign oil is a critical factor.

- For example, nearly all U.S. nuclear-generated energy is utilized to produce 20% of our electricity needs. Almost all U.S. coal usage, approximately 50%, goes to generating electricity, and an increasing share of domestic natural gas produces electricity. On the transportation side, however, the overwhelming majority of energy needs are derived from petroleum; and of that, over 50% comes from imported oil.
- The Energy Information Administration predicts that over the next two decades, U.S. dependence on foreign oil will balloon to the 70% level. Consequently, the Bush Administration is attempting to shift a greater percentage of domestic energy sources to cover transportation needs.

Moreover, without significantly increasing the use of nuclear energy, the prospects for transitioning to a hydrogen-based economy for transportation systems, a goal set forth by President Bush in early 2003, would be far less likely.

- In order to produce hydrogen economically, and taking into account that to do so the United States will need an abundant source of sustainable, clean, environmentally benign energy, it is clear that nuclear power represents a vital element of the President's vision.

At present, the United States is in a similar position to when President Eisenhower delivered his speech, with one key difference. Then we knew too little. Now, as we celebrate its 50th anniversary, perhaps we know too much. However, what is required is the same optimism that informed the President's "Atoms for Peace" Initiative. This is the challenge we must meet.

Session 1

SETTING THE STAGE: PRESIDENT EISENHOWER'S "ATOMS FOR PEACE"

Panel Chairman

Dr. Robert L. Pfaltzgraff, Jr., President, Institute for Foreign Policy Analysis, and Shelby Cullom Davis Professor of International Security Studies, The Fletcher School, Tufts University

Presentations

Susan Eisenhower, Chairman, The Eisenhower Institute

General Andrew J. Goodpaster, USA (Ret.), Senior Fellow, Eisenhower Institute; former Staff Secretary and Defense Liaison Officer to President Eisenhower; and former Commander in Chief, United States European Command and Supreme Allied Commander, Europe

Summary

Dr. Robert L. Pfaltzgraff, Jr.

In his memoirs, President Eisenhower recounts that he had several main objectives in presenting his "Atoms for Peace" speech.†

- The principal goal was "to make a clear effort to get the Soviet Union working with the United States in a non-controversial phase of the atomic field and thus to begin to divert nuclear science from destructive to peaceful purposes."
- "The second was that if we were successful in making even a start, it was possible that negotiation and cooperation might gradually expand into something broader. There was hope that Russia's own self interest might lead Moscow to participate in joint humanitarian efforts."
- "A third objective was to call the attention of smaller nations to the fact that they, too, had an interest in the uses to which the world put its limited supply of raw fissionable material. Too many small nations had looked

† *Taken from* Mandate for Change,1953-1956: The White House Years. *Garden City, NY: Doubleday, 1963, pp 251-255.*

upon nuclear science as a matter of concern only to the USSR and the United States except, of course, that the fear that their own countries might be targets in the event of an atomic war."

- "A further reason was to give the American people the reassurance, the certain knowledge that they had not poured their substance into nuclear development with the sole purpose of using it for world destruction. Finally, it provided the opportunity to tell America and the world about the size and strength of our atomic capabilities and yet to do it in such a way as to make the presentation an argument for peaceful negotiation rather than a story told in an atmosphere of truculence, defiance and threat."
- And finally, "Though the Soviet Union did not immediately give the world its final answer, I had achieved most of my short-term purposes. The United States had set the stage for a practical approach to the development of confidence among the great powers of the world if the Kremlin so desired."

Susan Eisenhower, Chairman, The Eisenhower Institute

With the Cold War successfully concluded it is sometimes easy to assume that it was all going to turn out the way it actually did. But surely, in 1953 the world looked like a frightening, dangerous planet.

- The fear that followed nuclear detonations in Hiroshima and Nagasaki was exacerbated significantly four years later when the Soviets tested an atomic weapon in August 1949.
- In November 1952, with the Korean War still raging, the United States detonated a hydrogen bomb. Less than a year later, in August 1953, the Soviet Union announced it had successfully entered the thermonuclear club with an explosion of its own hydrogen weapon.

Dr. Robert L. Pfaltzgraff, Jr., Susan Eisenhower, General Andrew J. Goodpaster, USA (Ret.)

- Given that the Soviet Union had been all but destroyed during World War II, it became obvious that a nation's wealth was not a prerequisite for acquiring nuclear knowledge and capabilities.
- Consequently, it was clear to President Eisenhower that if the world remained on its current path, soon others, and possibly all nations, would be able to develop nuclear weapons.

With the "Atoms for Peace" speech, President Eisenhower sought "to reconcile the ambiguities and contradictions of nuclear politics, offering some hope for the future." In addition, he wanted to make U.S. citizens aware that their "tax dollars had not been spent for destructive purposes alone, that considerable economic and social benefits could emerge from this pioneering research." He felt strongly that this issue needed effective presidential leadership and management.

- On the one hand the hydrogen bomb had the destructive capacity to bring about a nuclear holocaust. Yet the same device also served as a deterrent capability that became a central component of U.S. national security calculations.
- At the same time, advancements in the nuclear field held out the promise that the atom could provide nearly limitless nuclear power for energy and humanitarian purposes.
- The President felt that the post-imperial world, more and more agitated by the perceived double standards imposed by developed nations, would not tolerate a "nuclear club" that severely restricted access to the benefits that nuclear power proffered.
- The President's approach with "Atoms for Peace" was to create an opportunity for cooperation on nuclear energy and at the same time minimize potential military proliferation. Not only did the speech confer presidential legitimacy to the international pursuit of atomic energy but it also conspicuously elevated the standing of the United States within the developing world.

The "Atoms for Peace" Initiative has resulted in many significant achievements.

- Given the dire predictions in 1953 about nuclear weapons becoming widely available to many – some suggested all – nations, the number of states that actually have acquired nuclear weapons are well below that anticipated. No nuclear weapon has been used in conflict since World War II and the nations of the world have essentially stopped testing nuclear weapons.
- Furthermore the NPT, the IAEA, and the international community have gained access to countries that would have otherwise remained off-bounds because of their sovereignty. And while "Atoms for Peace" as well as the IAEA and the NPT, have come under fire in recent years, the complaints are largely a function of poor implementation rather than conceptualization.

- In addition, nuclear power has reduced dependence on oil without producing greenhouse gases or other destructive emissions. For example, as noted earlier, nuclear-generated electric power now accounts for approximately 16% of the world's and 20% of America's electricity.
- Many other nuclear and radiation related technologies, especially in radio-pharmaceuticals and medical advances, have saved millions of lives through cancer treatments and other applications.

Fifty years later, however, the nuclear dilemma still persists. It is now informed by a different set of threats and concerns. Perhaps the principal problem confronting us is the legacy of the superpower arms race that continued well after President Eisenhower left office. Today, with the Cold War ended and Russia our partner in many areas, we have the opening that President Eisenhower hoped, and in some respects, planned for in 1953. As a result, the United States should accelerate its agenda in a number of areas.

- A hundred metric tons of plutonium and highly enriched uranium in Russia has not received security upgrades. This task should be undertaken without delay.
- The United States and Russia should also consider taking strategic forces scheduled for reduction under the Moscow Treaty off high alert, minimizing the potential for catastrophic accident or for the more remote possibility of unauthorized launch. Moreover, they should also take steps to conduct a full inventory of the large number of tactical nuclear weapons in the Russian arsenal and then do whatever is necessary to ensure their security.
- "Atoms for Peace" institutions, including the IAEA and the NPT, have to be properly funded, reformed, and augmented, and their mandates need to be broadened.
- The United States needs to address the role of nuclear power in our overall energy strategy. Nuclear power represents one of the most effective approaches to reduce dependence on foreign oil while at the same time, new reactor technology promises to decrease the potential for proliferation of weapons grade fuel.

General Andrew J. Goodpaster, USA (Ret.), Senior Fellow, Eisenhower Institute; former Staff Secretary and Defense Liaison Officer to President Eisenhower; and former Commander in Chief, U.S. European Command and Supreme Allied Commander, Europe

The following quote from President Eisenhower underscores one of the main reasons why he felt it necessary to propose the "Atoms for Peace" initiative. "In insuring the nation's security, the role of the President is central." President Eisenhower's most salient concerns encompassed:

- The Soviet Union's animosity as manifest during the Cold War and the massively militarized confrontation between the West and the Soviet Union.
- Nuclear weapons in large, rapidly growing numbers, shortly to include growing quantities of even more powerful thermonuclear devices.

- It was the President's opinion that the combination of these two factors posed a mortal danger to the United States, its allies, and, indeed, to global civilization.

President Eisenhower instituted a number of key military strategies to address these national security concerns/threats.

- Based on his tenure at NATO as Supreme Allied Commander, Europe, President Eisenhower adopted a strategy of deterrence, undergirded by the collective defense of Western Europe in order to make the deterrent posture effective and credible.
- In addition, he instituted a strategic policy of containment buttressed by the U.S. deterrent capability.
- By these means, the President was confident that a viable approach could be found to work our way out of the set of threats that confronted the United States.

"Atoms for Peace" was a key component of that viable approach, a first step, to extricate the United States from these terrible threats. It was designed to generate actions of a positive nature with the emphasis on agreement, not war among nations.

- President Eisenhower felt that he helped to avoid a nuclear apocalypse. That while the nuclear dangers would continue, they would subside overtime so as not to endanger civilization as a whole as they did during his administration.

Many of President Eisenhower's basic principles still retain their importance. They include:

- The restraints on the role of military force. "We should be very slow to pick up the sword, and have thought through just why and what we are doing."
- Utilize the collective, cooperative approach.
- Constantly to accentuate the positive, the mutually beneficial because this generates the true payoff in terms of public understanding and support for policies.

Analysis

The opening session examined the legacy of the "Atoms for Peace" speech setting the stage for a discussion of what the next fifty years may bring in new technologies, science, and efforts to control nuclear proliferation. Panel Chairman, Dr. Robert L. Pfaltzgraff, Jr., outlined President Eisenhower's four primary objectives: to work with the Soviet Union on peaceful, non-destructive uses of the atom; to take this initial step in the hope that it would result in cooperation with Moscow across broader issues of concern; to let other nations know that they also had a significant stake – both economic and security – in the outcome of nuclear issues; and, to reassure the U.S. public that nuclear power had non-military, economic applications that would benefit America.

Susan Eisenhower elaborated on several of these themes. President Eisenhower felt that effective presidential leadership was needed to meet his goals and sought to reconcile the incredible destructive force of nuclear weapons with the atom's tremendous potential to provide near-limitless power for energy. His speech both jumpstarted the international pursuit of nuclear energy as well as boosted the reputation of America throughout the world, particularly among developing nations. In addition, "Atoms for Peace" brought about several other positive benefits encompassing: limiting the number of nations which might otherwise have attained nuclear weapons; setting in motion the establishment of the IAEA and the NPT; reducing dependence on oil for the generation of electricity; and, providing a range of diagnostic and medical treatments that have helped save millions of lives.

In concluding her presentation, Ms. Eisenhower stated that the end of the Cold War provided the United States with the opportunity to address several key areas of concern including: a range of salient U.S.-Russian Cold War-legacy security issues such as immediately providing security upgrades for Russian plutonium and HEU stocks as well as reviewing the alert status of U.S.-Russian strategic forces; examining approaches for improving the IAEA and NPT; and, moving forward aggressively with nuclear power as a key element in overall U.S. energy policy.

General Andrew J. Goodpaster, USA (Ret.) noted that President Eisenhower felt his primary role was to safeguard the security of the United States and that the "Atoms for Peace" Initiative sprang from this belief. It was an initial attempt emphasizing, in a positive, optimistic manner, an approach to address the atomic dilemma. While President Eisenhower based his national security on deterrence and containment, both buttressed by the U.S. nuclear arsenal, he also viewed the use of nuclear power for energy production, as emphasized in his "Atoms for Peace" Initiative, as a viable option to help extricate America from the threats it confronted.

Both panelists believed that President Eisenhower understood very well what his speech was setting in motion and would not be surprised by the positive legacy and outcomes that have resulted from "Atoms for Peace." Moreover, both speakers, reflecting what would be a consensus among virtually all session panelists, believed strongly that nuclear energy must be pursued vigorously as one of the key options to decrease U.S. dependence on foreign oil. Nuclear power represents a renewable, sustainable environmentally benign source of energy that can, and should, play a key role in U.S. energy policy.

Session 2

PEACEFUL POWER FROM ATOMIC ENERGY

Panel Chairman

Robert G. Card, Under Secretary for Energy, Science and Environment

Presentations

The State of the Commercial Industry

Donald C. Hintz, President, Entergy Corporation, and Chairman, Nuclear Energy Institute

Nuclear Expansion: The Economic, Environmental, and Political Challenges

William D. Magwood IV, Director, Office of Nuclear Energy, Science and Technology, Department of Energy

World Market for Nuclear Energy

Alain Bugat, Chairman, French Atomic Energy Commission

Harnessing Nuclear Technology for the Prosperity and Security of Our Nation

Admiral F.L. "Skip" Bowman, USN, Director, Naval Nuclear Propulsion, Naval Sea Systems Command

Nuclear Industry Infrastructure

Andrew C. White, President & CEO, GE Nuclear Energy

Summary

Robert G. Card

Robert G. Card

The United States is facing a nuclear power renaissance. As previous speakers have noted and panel members in this session will elaborate upon, nuclear power constitutes not only a huge resource for the generation of electricity but also for the production of hydrogen. As outlined in President Bush's National Hydrogen Fuel Initiative during the 2003 State of the Union Address, hydrogen holds the potential to become the fuel of choice to meet U.S. transportation power requirements, significantly lowering our dependence on foreign oil.

Moreover, as a sustainable, environmentally benign, carbon-free, efficient source of energy, nuclear power also can address growing concerns of greenhouse gas emissions and other air emissions that have become a cornerstone of the Bush Administration's energy policy, and certainly the driving force in the $2 billion allocated to energy research annually by the Department of Energy.

Donald C. Hintz, President, Entergy Corporation, and Chairman, Nuclear Energy Institute

President Eisenhower's "Atoms for Peace" Initiative set the stage for the creation of the commercial nuclear industry in the United States with his words "The United States knows that peaceful power from atomic energy is no dream of the future. That capability is proven. It is here. It is now. It's today."

- Indeed, two years prior to the President's speech, at a governmental experimental reactor in Idaho, the first electricity produced from nuclear energy illuminated four light bulbs. This small start inspired twenty-three U.S. companies to form the Atomic Industrial Forum in 1953, which represented the beginning of the commercial nuclear industry in the United States.
- The "Atoms for Peace" speech was a quantum leap forward, a clear and dramatic signal that a popular President supported nuclear energy. The following year, the U.S. Congress responded by ending the government monopoly on nuclear technologies and President Eisenhower gave the signal to start construction of the first nuclear plant used exclusively for civilian purposes at Shippingport, Pennsylvania.
- A half century later, commercial nuclear applications are invaluable in our daily lives, with thousands of industrial, agricultural, and medical applications. None, however, are more visible than the nuclear energy industry. Nuclear energy generates electricity for one out of every five American homes and businesses and, together with coal, is the foundation of the U.S. electricity generation mix. Nuclear power is safe, economical, reliable, and emission free.
- Of these important attributes, reliability and air quality benefits are of growing consequence given that the U.S. economy increasingly relies on an uninterrupted power supply, one which is environmentally friendly.

Donald C. Hintz

Clearly, President Eisenhower's vision of a thriving international nuclear industry is now a reality. Nuclear energy supplies over 16% of the world's electricity and nuclear energy is poised to make even more meaningful strides towards improving the quality of life globally. As the U.S. commercial nuclear industry celebrates its fiftieth anniversary, we are experiencing what has been characterized by many, including the Bush Administration, as a nuclear renaissance.

- America's 103 commercial nuclear power plants have established new records in each of the previous five years for electricity production and efficiency. The majority of nuclear companies have applied to the Nuclear Regulatory Commission to extend the operation of their nuclear plants for an additional twenty years. In addition, three companies, Entergy, Excelon, and Dominion Energy, are seeking early site permits for advanced reactors, the necessary first step for the construction of new nuclear plants.
- Safe and efficient nuclear plant performance is the bedrock of the nuclear renaissance. Since 1990, power operations and capacity factor† gains have added the equivalent of twenty-six new large reactors to the U.S. electricity grid. This represents one of the most successful energy efficiency stories in the history of the nuclear industry.
- Consequently, in 2002, U.S. nuclear electricity output was a record 780-billion kilowatt-hours. Yet, even greater efficiencies are deemed possible. Electric nuclear-power generation will continue to increase as long as the nuclear industry does not become complacent in its pursuit of increased performance.

One of the goals of the nuclear industry as outlined in the Vision 2020 Plan (more below) is to increase electricity production at existing U.S. nuclear plants by an additional 10,000 megawatts by 2020. By means of power operations and capacity factor improvements along with the planned restart of Tennessee Valley Authority's Brown's Ferry 1 reactor, the nuclear industry will be more than halfway toward meeting this goal within four years. The improvements in efficiency are a result of the following factors:

- In 2002, the industry-wide capacity factor surpassed 90% for the third straight year. Indicative of this significant improvement is the fact that the industry-wide capacity factor did not exceed 60% until 1998.
- Moreover, industry is far from reaching the limits of plant efficiency given that the top quartile of the industry operates at a three-year average of approximately 96% capacity factor while the lowest quartile runs at only 82%. If the bottom quartile can improve slightly, it is realistic to expect the industry-wide capacity factor to reach 95% with some consistency. Greater output/efficiency translates into improved economic performance and affordable electricity. Indeed, nuclear energy is the lowest cost expandable source of electricity.
- In addition, nuclear power production costs are holding steady while those of other fuel sources continue to rise. For example, nuclear power production costs are cheaper than coal and only slightly more than half the cost for electricity generated using natural gas and/or oil.

† *The ratio of the net electricity generated, for the period of time considered, to the energy that could have been generated at continuous full-power operation during the same period.*

- The industry's safety record, one of the key factors credited with boosting public support for nuclear power (more directly below), also continues to be outstanding. In fact, it is unmatched by any other manufacturing industry in the United States.

Nuclear energy's performance and safety record has garnered solid support from both the public and key policymakers.

- The percentage of the public favoring nuclear power is 64%, a figure that approaches an all time high according to independent public opinion research undertaken for the Nuclear Energy Institute.
- Like President Eisenhower, the Bush Administration and Congress recognize the value of nuclear energy for U.S. energy security and national security, as well as environmental protection. Bipartisan support also exists for the nuclear spent fuel repository at Yucca Mountain in Nevada, DOE's Nuclear Power 2010 Program, and the construction of new nuclear plants.
- Nuclear energy is also included in the President's hydrogen initiative. This project, along with other administration policy measures, provides clear evidence that the technology championed by President Eisenhower is poised for another half-century of successes. Indeed, given that energy and environmental policies are now so closely intermingled, it is critical that the environmental benefits of carbon-free nuclear energy are promulgated and clearly understood by the general public.

The nuclear industry, as alluded to above, is implementing an ambitious plan, Vision 2020, designed to insure that nuclear energy achieves its full potential to enhance the economic health and environmental qualities of the United States. The specific goal of Vision 2020 is to bring 50,000 megawatts of new nuclear capacity, the equivalent of approximately fifty large nuclear plants, online by the second decade of this century. Given the absence of nuclear power plant construction in recent years, Vision 2020 represents an ambitious objective. However, it is strategically important for this country to attempt to meet this challenge.

- Nuclear energy produces 75% of the total emission-free energy generated in the United States. Even though renewables provide approximately 2% of the total electricity supply and hydropower generates about 10%, nuclear energy is the only readily expandable emission-free source available.
- In light of the fact that the Department of Energy estimates that electricity demand will increase by more than 40% by 2020, the addition of 50,000 megawatts of new nuclear generation – along with the 10,000 extra megawatts current capacity now permits – would only increase the percentage of emission free generation by 1%. This is the case even factoring in the potential expansion capacity derived from solar, wind, and other renewable power sources.
- While the United States requires an increased contribution from renewables, we will also need additional capacity from natural gas, clean coal,

and every other source to meet growing energy demands. However, for economic and environmental advantages, and for the security that a diverse energy mix affords, the United States must vigorously pursue nuclear power options and the considerable benefits they can provide.

- Returning to a topic addressed previously, the ability to generate electricity with nuclear energy will obviously assume heightened significance given the demand statistics cited above. However, the nuclear requirement to meet electricity needs would be far exceeded if the United States moves forward in a big way toward a hydrogen-based economy, the vision expressed by the Bush Administration. In this scenario, nuclear power would need to play a central role for generating hydrogen.

William D. Magwood IV, Director, Office of Nuclear Energy, Science and Technology, Department of Energy

The Department of Energy's Office of Nuclear Energy is the most direct inheritor of the challenge that President Eisenhower made in December 1953. Rather than recoil in fear and ignorance, the President proposed to pull back the curtain of secrecy veiling nuclear technology in order to share its discovery with scientists and engineers whom he felt could best realize its great potential for peaceful application. As was the case in 1953, we find ourselves today at the confluence of complex and unexplored waters that hold both great threat and great promise.

- It is clear that nuclear energy is at a crossroads. One path could lead to stagnation and the eventual abandonment of nuclear power as an energy source for the future. For example, the United States has not had a successful new nuclear power plant project since 1973.
- In addition, U.S. nuclear research has declined dramatically, and the nation's industrial and educational bases have seriously eroded in the last decade.

However, looking to the opportunities of the future instead of focusing on the trepidations of the present has been an important theme of the Bush Administration. In this spirit the United States should explore an alternative path.

- In 1953, a critical concern was whether the world would allow itself to speed once again towards a path to war as it had done twice in a generation, only now with weapons that could destroy the known civilization. The cogent message of "Atoms for Peace," was that nuclear technology would be utilized in a cause of human advancement instead of human destruction.
- Today, the choices are no less profound. Despite the fact that war and terror continue to dominate world discussion, the true issue for the future is how nations will manage and develop the earth's limited resources to the benefit of all humankind, without destroying the environment. This is a time for vision on a scale of "Atoms for Peace." This is a time to look toward nuclear technology not as simply a tool for peace but also for broad, sustainable, and enduring prosperity for all the world's people.

Today, the United States should speak not just of "Atoms for Peace" but also of "Atoms for Prosperity." Since assuming office, the Bush Administration has re-energized the national and international discussion about nuclear technology. The National Energy Policy, unveiled by the administration in May 2001, set forth a clear plan for the United States to expand the use of nuclear power to meet future energy needs.

- The administration seeks to move forward with a safe and secure nuclear waste repository, the Yucca Mountain Project, a key missing element necessary for the future growth of nuclear power. The administration has also worked closely with leaders in Congress to craft comprehensive energy legislation in order to complete the implementation of the policies that were set out in the 2001 National Energy Policy.
- Furthermore, two years ago, Secretary of Energy Spencer Abraham unveiled Nuclear Power 2010 (more details below), the effect of which was to bring nuclear utility vendors, electric companies, and government together in renewed cooperative dialogue on how best to begin building new nuclear power plants.
- Earlier this year Secretary Abraham also unveiled the Advanced Fuel Cycle Initiative. Working with a group of countries that possess an advanced fuel cycle infrastructure (e.g., France and Japan), this initiative seeks to develop an approach to a more efficient and more proliferation-resistant nuclear fuel cycle.
- The Generation Four International Forum was also established to shepherd in a new generation of nuclear energy plants that could fully realize the promise of "Atoms for Peace" and enable "Atoms for Prosperity." The Forum will cooperate with ten countries and EURATOM† to achieve this goal. Generation Four nuclear technology promises new levels of sustainability, safety and reliability, proliferation and physical protection, economic performance while providing a wider range of energy products, including electric generation, hydrogen production, clean water, and heat, for a more flexible future.

As noted several times already, President Bush has challenged the technical and industrial community with the National Hydrogen Fuel Initiative. This initiative seeks to resolve the issues associated with making clean burning hydrogen a fuel of tomorrow's planes, trains, and automobiles in place of growing levels of imported petroleum.

- The new U.S. nuclear energy efforts described above are ideally suited to help make the vision of a hydrogen-based economy a reality. The Generation Four concepts for a new generation of ultra-safe proliferation-resistant nuclear power plants that can supply the extreme heat needed to produce hydrogen on a commercial scale in an economic manner may come to fruition sooner than many believe possible.

† *Participating countries are Argentina, Brazil, Canada, France, Japan, the United States, the United Kingdom, Switzerland, South Korea, and South Africa. The European Atomic Energy Community or EURATOM is a regional organization established in 1958 to create conditions necessary for the establishment and growth of nuclear industries.*

- Generation Four technologies may help realize the President's vision that children born today will be driving their car powered by pollution-free hydrogen.

Alain Bugat, Chairman, French Atomic Energy Commission

President Eisenhower's "Atoms for Peace" speech continues as a guideline for the development of nuclear energy in the world today. As many speakers have previously declared, the conditions are now ripe for the "rebirth" of nuclear energy in the context of sustainable development.

- For the first time in decades, international nuclear research and development is expanding marked by the aforementioned Generation Four program initiated by the United States and, more recently, the European Union in a joint effort to promote the shared vision of nuclear energy.

Even if the hoped for success envisioned in the early 1970s for nuclear energy has not been fulfilled, a great deal has still been achieved over the past fifty years.

- Worldwide there are 441 nuclear reactors in thirty nations, representing a 16% contribution to worldwide electricity production with an extremely wide distribution ranging from a 1% for China to over 78% for France.
- The world's nuclear power plants are primarily composed of light water reactors with two dominant types: pressurized water reactors and boiling water reactors.
- There also exists a small number of operating fast neutron reactors in Russia, France, and Japan. While not experiencing the type of development first envisaged, fast neutron reactors are becoming globally recognized as possessing promising features that should be a component of any long-term nuclear power scenario.
- Regarding safety issues, the international nuclear community has been successful in implementing new guidelines dealing with human factors and safety organization following lessons learned from major nuclear plant incidents, most notably Three Mile Island and Chernobyl.

Market globalization including the trend toward electricity deregulation is driving a major reorganization of the nuclear industry.

- For example, merger and acquisition in the United States has resulted in the consolidation of the nuclear sector with ten major utilities controlling close to three-quarters of the nuclear power plants.
- Worldwide, major integrated groups have emerged covering all activities from plant vendors to reactor fuel cycle services. Apart from the BNFL Westinghouse conglomerate and the Ariva Group, several joint ventures with Japanese companies – including General Electric with Toshiba, and Westinghouse Corporation and Mitsubishi – have occurred.

As a rule, the nuclear industry has reached maturity due to its accumulated reactor operating experience and its success, particularly in recent years, in improving performance in terms of both reliability and safety factors.

- In this context, the French nuclear program is illustrative. France has fifty-eight nuclear reactors on nineteen sites, achieved via an evolutionary approach starting from the first generation of 900 megawatt reactors (34 units), followed by a generation of 1,300 megawatt reactors (20 units), and the most recent 1,450 megawatt reactors (4 units), with the last reactor of this type commissioned in 1999.
- France's nuclear program has been accompanied by a continuous improvement in safety and cost reduction based on this largely homogeneous fleet of reactors.
- France has also adopted the global fuel cycle management based on the reprocessing of spent fuel. It separates reusable content (96%) from true nuclear waste (4%). The recovered plutonium is partly recycled as fuel in 900 megawatt reactors.
- Finally, France has extensive research and development programs and advanced partitioning and transportation of waste, overseen by the French Atomic Energy Commission. The goal of this program is to improve waste management and to reduce the volume of waste and its long-term radio-toxicity.

A strategy for the advancement of nuclear energy as a power source must take into account legitimate public concerns regarding safety and security issues, especially after the events of September 11, as well as the management of nuclear waste and the protection of the environment. In addition, the strategy must attempt to meet energy demand by diversifying primary sources to ensure a secure energy supply.

- Such ideas have focused the national debate in France to address all possible energy options for the future.

International geo-political energy issues are also key considerations for reinvigorating nuclear power programs in several nations.

- It is commonly accepted that a quarter of the world's population is, in fact, consuming three-quarters of the world's primary energy produced. Moreover, two billion people, a third of the current population do not have access to electricity. This is most significant in view of studies that have shown strong correlations between energy consumption per person and standard of living as measured by infant mortality or lifetime expectancy. Consequently, access to energy and economic growth translate into a legitimate right to life.
- Current estimates for worldwide population forecast ten to twelve billion people in 2100 compared with six billion today. Depending on the energy scenario, this population increase could lead to increased consumption from the present nine billion tons of oil equivalent to twenty to forty billion tons. Moreover, large centralized energy production will be needed to satisfy the need of future mega-cities, most of which will be located in the developing countries.
- Finally, current projections indicate that use of fossil energy will account for more than 80% of the total worldwide primary energy consumption

by 2010. The recent hydrogen initiative advanced by the Bush Administration is in part designed to produce a more environmentally benign source of energy.
- The inordinate reliance on fossil fuels and concerns about security of energy supplies led France in the early 1970s to implement its nuclear policies to ensure a diversified energy mix.

Examples that nuclear power is on the rebound and experiencing a renaissance also include developments in the following nations and regions.
- The European Commission recently reaffirmed the need to continue – and possibly augment – reliance on nuclear energy to limit greenhouse emissions.
- Finland is in the final stages of acquiring a fifth nuclear power plant. In 2003, the nuclear option was confirmed by 66% of the voters in Switzerland.
- Sweden, which decided in 1980 to phase out nuclear energy, now appears much more amenable to nuclear power and is likely to restart its national nuclear program.
- In Asia, Japan, China and South Korea all possess robust nuclear programs. A number of Asian countries are already considering the renewal of their nuclear plants as they develop their mid-term energy policies.
- In light of their pressing energy needs, many developing nations may be interested in promoting ancillary services such as hydrogen production and sea water desalination while also agreeing to a proper level of proliferation resistant technologies and a strong international safeguard regime.

Admiral F.L. "Skip" Bowman, USN, Director, Naval Nuclear Propulsion, Naval Sea Systems Command

It could be said that the past, present and, indeed, the future of President Eisenhower's "Atoms for Peace" vision are closely tied to the story of Admiral Hyman Rickover and naval nuclear reactors. The Rickover saga is proof that a technically based organization with unchanging core values can harness this unforgiving technology for the prosperity and security of the nation. In addition, there is a national security mandate for commercial nuclear power to address America's future energy needs.

Admiral F.L. "Skip" Bowman, USN

- In 1948, Admiral Rickover was given the formal mandate to develop a submarine that could travel at high speeds, continuously submerged, without having to recharge batteries. In March 1953, the prototype reactor plant for the submarine *Nautilus* began operation, the first harnessing of nuclear power to work on such a large and practical scale.
- As a result, it was recognized that if nuclear power could be used to propel a

submarine, it surely could generate electricity for homes and industry. Thus, in the summer of 1953, Admiral Rickover received another national mandate, this time to construct and operate a commercial reactor. Fewer than five years later the nation's first commercial reactor, the Shippingport atomic power plant, began providing electricity to Pittsburgh.

- Admiral Rickover's core values regarding nuclear energy and design endure today. First, technical excellence and technical competence are absolutes. Reactor designs and operating procedures are uncomplicated and conservative with built in redundancies. Select the best people available with the highest integrity and professional competence and provide continuous, rigorous, and challenging training. Finally, to insure safe operations, embrace a system that inculcates in each operator a total commitment to safety and environmental stewardship.
- These core values have allowed the U.S. Navy nuclear warships to safely steam more than 128 million miles without a single reactor accident nor with any measurable negative impact on the environment or human health.

The Rickover story plainly illustrates that reliable and robust nuclear reactors can be operated on a large scale with the confidence of the operators and the population that live and work nearby. However, as a nation the United States can and must do more to accomplish President Eisenhower's special purpose vision.

- This nation, as many previous speakers have emphasized, must take policy decisions that will lead to sizeable increases in the amount of energy generated by existing – and hopefully new – nuclear power facilities.
- The late physicist Edward Teller gave a sense of urgency to this requirement when he observed, "If we want safe and clean energy, we should accept fission reactors. Unfortunately the fear of that technology is widespread and it will be hard to eradicate. Therefore reactors must not only be safe, we must make them obviously safe. And if we don't find ways to make this clear to people, to persuade them to accept the best technologies, then I believe America will turn itself into an underdeveloped country."
- Teller's ominous warning is supported by two synergistic facts. First, over the next two decades there is a credible expectation that U.S. energy demand will increase significantly far beyond current domestic supply. And, second, foreign oil suppliers who are not necessarily friendly to the United States and may be hostile to U.S. interests, will provide at their designated price, or even withhold at their whim, the oil that could meet much of this expanding need.

While advancements in science and technology such as the Generation Four reactors are extremely important for the future, what is urgently needed today is an earnest, robust, and large-scale program of media and public education to promulgate the truth about nuclear energy, its myriad benefits ranging from efficiency, cost, and most telling, its outstanding safety record and benign environmental impact.

- For a variety of reasons the American people – with the exception of certain nuclear medical applications – tend to mistrust anything nuclear, even when that mistrust is plainly unfounded.
- For example, Three Mile Island represented the nation's worst nuclear accident. Yet few people are aware that even though 90% of the fuel rods ruptured, Three Mile Island was an absolute non-event from a radiation and health-hazard standpoint. Furthermore, U.S. Navy sailors on nuclear submarines who live and work within yards of operating reactors receive less whole body radiation while underway than when at home exposed to natural background radiation.

Andrew C. White, President & CEO, GE Nuclear Energy

When the Atomic Industrial Forum was founded fifty years ago, it was envisioned that three key elements of sustainable nuclear energy would be critical: advanced engineering, business acumen, and enlightened public policy.

- As industry members, we can offer solutions to the first two of the three requirements. The third, an enlightened public policy, we can only influence. In short, we believe that nuclear suppliers, owners, and policy makers all have key roles to play.
- When considering advanced engineering and business acumen, we think that the measures of success today are the same as they were fifty years ago: safety, performance, economics, and owner value and environment.
- Safety is the overriding concern of government, owners, operators, and suppliers to ensure that employees and the public are protected. However, safety also impacts performance. Because safety and performance are so closely related, in order to get maximum performance, nuclear plant owners must insure that safety issues do not impede performance nor adversely impact availability and reliability.

The nuclear industry has made major strides in performance, safety, and costs over the past several years.

- The nuclear industry registered tremendous gains in capacity factor reaching 90% in 2002, a 30% increase from 1998 levels. This allowed for a record generation of 778 billion kilowatt hours in 2002.
- At the same time, the average core damage frequency, the key measure of safety in the industry, has improved by 70% while achieving this record performance.
- In the past decade, the nuclear utilities, with help from the government, regulators and suppliers, have done an outstanding job in reducing generating costs by approximately 40%. Capital improvement, reduction in operation and maintenance costs, as well as the advancement in fuel designs have been key factors driving generation costs down while achieving these record performance levels.

Nuclear energy is an urgent imperative for this nation. The challenge relates to public confidence and acceptance.

- This should be addressed as an industry with government support to educate the populace and shape public policy.
- Over the last half-century, nuclear plants have generated 13.7 trillion kilowatt emissions-free hours of electricity with zero carbon depletion thus completely avoiding the production of 3.1 billion metric tons of carbon, 73.6 tons of sulfur dioxide, and 35.6 million tons of nitrogen, highly undesirable byproducts that would have been generated had fossil fuels been used instead.

However, even given those unquestioned benefits, nuclear power plants today represent only 12% of the installed energy generation capacity, yet it generates almost 20% of the energy due to its reliability, availability, and performance.

- GE Nuclear Energy forecasts that between 2003 and 2006 only fifteen gigawatts are planned in the United States and none of those are nuclear.
- Latin America has twenty-eight gigawatts planned, Europe fifty gigawatts, Africa-India-the Middle East a total of fifty-seven. By far the largest is 187 gigawatts in Asia, with the majority coming from China.
- General Electric believes the economics of constructing a new nuclear plant are quite favorable. New advanced nuclear plants are extremely competitive. The hefty initial capital costs of a new nuclear plant will be offset in the long-term by the high – and escalating – fuel costs for a combined cycle gas turbine plant, a simple cycle gas turbine plant, or a new coal plant.
- General Electric has been working for over ten years on a next generation design which is proceeding through the Nuclear Regulatory Commission licensing process, with design approval expected in 2006. It is 1,400 megawatts with simplified systems, passive safety features, improved security by design, fewer moving parts, and lower costs.

If the United States hopes to evolve to a hydrogen fuel economy to meet growing transportation energy demands, most scientists and economists believe that nuclear power will have to play a central role.

- For example, the current world population of six billion people is estimated to grow to 7.5 billion by 2020 with 33% of that growth centered in China and India. Projections show that by 2015 over 50% of the world's population will live in urban environments.
- Transportation demand is two-thirds of the energy growth in developing countries. For example, the United States has 750 cars per 1,000 people, while India has only seven cars and China eight per 1,000, respectively. If the populations of China and India increase as predicted, the demand for cars can be expected to grow immensely. Thus the incentives swell to produce hydrogen as an inexpensive, environmentally friendly fuel source with nuclear power as key means to generate it.

Analysis

In Session 2, panelists representing the U.S. government, France, and U.S. industry, focused on the development of nuclear power over the past fifty years, the challenges it has confronted, and the prospects and requirements for near-term growth in the commercial nuclear power industry. The panelists concurred that the United States, and indeed much of the developed world, is facing a "nuclear power renaissance."

Donald C. Hintz described how the "Atoms for Peace" speech was the impetus for the formation of the U.S. commercial nuclear industry. Supplying more than 16% of the world's electricity, the nuclear power industry is on the threshold of even greater accomplishments today based on its record of safety, reliability, efficiency, and output. Mr. Hintz explained that Vision 2020, an ambitious plan to increase electricity production by 10,000 megawatts at existing U.S nuclear facilities in the next two decades, is already halfway towards meeting its goal. The plan also hopes to bring 50,000 megawatts of new nuclear capacity online by 2020. These goals for nuclear generated power would undoubtedly be dwarfed if America moved toward hydrogen to meet transportation energy needs as outlined in President Bush's National Hydrogen Fuel Initiative. Nuclear energy would be a prerequisite for successful implementation of the hydrogen initiative.

William D. Magwood IV suggested that today we should speak not just of "Atoms for Peace" but also of "Atoms for Prosperity" because nuclear power is poised to become an even greater contributor to overall energy production and in the process advance worldwide economic wellbeing. In this regard, the Bush Administration has placed considerable emphasis on nuclear technology and a resurgent nuclear energy industry. Indeed, the 2001 National Energy Policy delineated a clear approach to increase U.S. use of nuclear power to meet future energy needs. As part of these efforts, the Generation Four International Forum was created to work with selected international partners to develop new, more efficient nuclear energy plants.

Like his fellow panelists, Alain Bugat believes that the nuclear power industry is set for a strong revival. He bases this assessment on the Generation Four program, the nuclear industry's remarkable successes in recent years in terms of safety, output, and efficiency, the increasing worldwide demand for electricity coupled with the growing demand that energy be environmentally friendly, and the concern, particularly in the developed world, that energy security is being undermined by growing dependence on foreign oil, supplied frequently by nations hostile to its interests.

The story of Admiral Hyman Rickover's management of the U.S. Navy's nuclear reactor program has many lessons to offer the public and policymakers about the viability of nuclear power for today's energy requirements. According to Admiral F.L. "Skip" Bowman, USN, the Rickover saga provides clear evidence that reliable, safe, and efficient nuclear reactors are extremely practical, capable of providing both economic vitality and security to the nation. Admiral Bowman underscored the critical importance of a focused program to inform both the media and public about the cost, safety, efficiency, and environmental benefits of nuclear energy.

Andrew C. White stated that the key elements of sustainable nuclear energy are advanced engineering, business acumen, and enlightened public policy. Advancing a theme articulated by several other speakers, particularly Admiral Bowman, Mr. White noted that nuclear energy is an urgent imperative for the United States and that the fundamental challenge centers on garnering public confidence and acceptance. Industry and government must work together to educate the public concerning nuclear power's benign environmental impact and other compelling benefits.

Indeed, several speakers in this session underscored the need to promulgate the nuclear industry's remarkable gains in efficiency, safety, and sustainability over the past few years to the public who frequently fear all things nuclear (with the possible exception of nuclear medicine). A consensus emerged that if President Bush's vision to develop a hydrogen economy to meet U.S. transportation power requirements – as set forth in the National Hydrogen Fuel Initiative – is ever to become a reality, nuclear power must play an integral role. If successful, this initiative holds the promise to reduce U.S. dependence on foreign oil dramatically.

KEYNOTE ADDRESS

Dr. Henry N. Wagner, Jr., Professor of Environmental Health Sciences, Bloomberg School of Public Health, and Director of the Division of Radiation Health Services, School of Medicine, The Johns Hopkins University

Summary

The field of nuclear medicine is based on the “tracer principle”, invented by Georg Hevesy, to whom the Nobel Prize was awarded in 1943. It was the “Atoms for Peace” Initiative that translated the scientific applications of these radioactive tracers to human health studies. In 1953, Dr. Jeff Houlter created, with eleven other founding members, the Society for Nuclear Medicine. In the past half century nuclear medicine, now widely referred to as molecular nuclear medicine, has moved from an orientation primarily toward organs, to cells, and today to molecules.

- In other words, chemistry, together with physics, is dominating molecular nuclear medicine today. Using the photons coming from inside the body to register on outside detectors, medical personnel now can relate regional molecular processes to disease, from organs to cells to molecules.
- Thermodynamics is another area where the application of radioisotope technology is being increasingly applied in biomedical research and clinical medicine. It assesses the regional energy supply of organs and lesions.
- Kinetics is also an important part of nuclear medicine. Experts routinely carry out studies in three dimensions in space and one dimension in time, measuring the rates of regional molecular processes which are used to develop new definitions of diseases.

Dr. Henry N. Wagner, Jr.

- Another emerging area of nuclear medicine focuses on information transfer, i.e., communication among molecules and cells. This occurs because molecules continually circulate through the body bumping into receptor sites where they adhere and spark a biological process that can be measured.
- The 1970s witnessed the introduction of minicomputers into nuclear medicine allowing a dramatic improvement in quantifying data from nuclear imaging of the body. Today's biochemical and anatomical imaging would be impossible without the widespread use of computers.

The Department of Energy has been instrumental in the development and sustainment of nuclear medicine. The field of nuclear medicine has been, and will continue to be, dependent on DOE.

- Frequently, many think of the National Institutes of Health (NIH) when reflecting on government contributions to biomedical science. However, it is the combination of the national laboratories and DOE-sponsored research that make possible much of the nuclear-medicine research taking place at NIH.
- The NIH and DOE are two partners that together advance the use of radioactive tracers and broader nuclear medicine technologies in biomedical science and clinical medicine.
- The structure of DNA was discovered in 1953 by James Watson and Francis Crick. Subsequently, DOE played a major role in the human genome project. Nuclear medicine and the human genome projects are now coming together with growing frequency to their mutual benefit.
- The invention by Ben Cassen of the rectilinear scanner, a motor driven, moving radiation detector capable of sensing photons emitted from the body and producing images such as the distribution of radioactive iodine within the thyroid gland, is an early example of a technique, i.e., the use the photons emitted from injected radiopharmaceuticals to study biomolecular processes. It is still employed to study all organs of the body.
- The scintillation camera invented by Hal Anger replaced the Cassen moving rectilinear scanner (more below).
- Technetium-99m, introduced by the Brookhaven National Laboratory, is utilized in cardiological diagnoses (more below).

One of the major fields to benefit from nuclear medicine is pharmacology.

- For example, in the early-1960s, imaging the blood flow to regions of the lung was used to examine the effectiveness of Urokinase, a drug that dissolved blood clots in the lung, an often fatal event. A series of lung scans depicting the distribution of blood flow to the lung was examined to provide objective evidence concerning the drug's effectiveness.
- Today, this type of process is utilized to assess the efficacy of drugs for treating such maladies as Alzheimer's disease. In addition to measuring the symptomatic or psychological response of the patient to the candidate drug therapy, this process offers an objective, quantifiable, regional biochemical signal.

The 1970s saw the birth of nuclear cardiology, which today has become a routine, dominant part of cardiology, another achievement that can be traced directly to "Atoms for Peace."

- Nuclear cardiology is based on an invention by Hal Anger whose work was sponsored by DOE. His first scintillation camera was demonstrated at a 1958 meeting of the Society of Nuclear Medicine. It measured the photons emanating from the body by means of a scintillation camera, in effect replacing the moving Cassen scanner described above, with a large stationary detector that could measure the radioactivity coming from large areas of the body simultaneously. This made possible introduction of a time domain into the examination of the spatial distribution of the tracer.
- Technetium-99m, introduced by the Brookhaven National Laboratory, provided the large numbers of photons needed to produce interpretable images of radioactive tracers in the heart. It emitted photons of the right energy range so that the information could get from the inside to the outside of the body.
- The combination of the Anger camera and technetium-99m from the National Laboratories made possible the development of nuclear cardiology.
- Today, positron-emitting photons, such as fluorine-18 deoxyglucose, oxygen-15, and nitrogen-13 ammonia are widely used in clinical cardiology and research. They allow examination of the effect of gene therapy for coronary artery disease in experimental animals in an effort to improve blood circulation.

Another important use of nuclear medicine techniques is the analysis of the human brain. In studies dating back to the early-1950s, George Moore from the University of Minnesota used a Geiger-Mueller tube in the operating room to locate deep-seated brain tumors that could not be visually seen.

- Today, throughout the world, hand-held imaging detectors are used during operations to distinguish cancerous tissue from non-cancerous tissue.
- In the brain, as in other organs, the fusing of biochemical imaging with structural imaging (i.e., an X-Ray) goes back to the 1960s. For example, rectilinear scans of a patient with a brain tumor were superimposed over an X-Ray of the skull obtained at the same time.
- In 1983, the first imaging of a neuroreceptor in the brain of a living human was successfully conducted. Neuroreceptors are involved in the transfer of information from one neuron to another. As but one example, this process meant that medical personnel could objectively differentiate unaffected persons from patients who had various types of Parkinson's disease.

Another major domain of nuclear medicine is oncology, based largely on findings using positron emission tomography (PET) and an analogue of sugar, fluorine-18 deoxyglucose.

- In 1953, the American Cancer Society declared that the number of cancer victims cured the previous year could have doubled by early diagnosis and prompt treatment, a difficult task then because in their early stages most cancers have little or no symptoms.
- Today, cancer is being detected before symptoms occur, often in persons identified at high risk of developing the disease. Molecular images with techniques such as PET are able to examine the entire human body assessing a variety of molecular processes.
- For example, in patients suspected of cancer one can detect the increased utilization of sugar by the tumors throughout the body and then examine the degree of oxygen-supply to the tumors, or their rate of cell division. This information translates into early and improved treatment as well as the ability to monitor its effectiveness.
- In the future, the goal is to proceed even sooner into the diagnostic process. Approaches are now under development to allow the screening of millions of individuals, to identify those at heightened risk, and then, together with tumor markers, to examine those persons at very high risk with PET scans so that disease can be recognized at an early, treatable phase. A key challenge is the need to boost productivity by reducing the time required to perform a PET study from the current one hour to as little as ten minutes.

The human genome project, another DOE-supported effort, provides maps, indicating a high risk of present or future disease in an individual. Radiotracers help identify the phenotypic expression of these genetic maps. Nuclear medicine rests on an infrastructure of physics and chemistry, and is an effective partner with genetics and pharmacology.

- Nuclear medicine provides molecular markers for gene hunts. Instead of relying on symptoms, such as forgetfulness or impaired movement, molecular markers in genetic studies can identify asymptomatic persons at high risk for subsequent maladies, including Alzheimer's disease, multiple sclerosis, and breast cancer.
- The effectiveness of gene therapy is monitored with reporter genes that can be administered with therapeutic genes to determine whether the therapeutic gene has been successfully transfected.

Nuclear medicine faces numerous challenges. However, one is particularly important to address. Hundreds of potentially useful radioactive tracers have demonstrated their utility in experimental animals. Yet it takes between five and ten years to get a diagnostic, let alone a therapeutic, agent through the clearance process of regulatory agencies.

- An economic problem is that diagnostic agents do not offer the same economic benefits for the pharmaceutical industry as do therapeutic agents. Thus industry is hesitant to make the necessary investment to meet the rigorous requirements of the Federal Drug Administration and Medicare.

- Therefore, the regulatory requirements for the approval of diagnostic radiotracers should be simplified. For example, to demonstrate the safety of a diagnostic procedure that is administered only once or twice to a patient should be made far less complicated than what is needed for a therapeutic drug that may be taken for the rest of a person's life.
- The challenges are to continue to support the basic and clinical research with collaborative efforts, particularly between the DOE and the NIH, and to form teams in government laboratories, academia, and industry.

Analysis

In his Keynote Address, Dr. Henry N. Wagner, Jr. examined the history of nuclear medicine, its successes over the past fifty years, and the prospects for the future. Dr. Wagner noted that it was the "Atoms for Peace" Initiative that help turn the scientific applications of radioactive tracers to human health studies. During the past half-century, the field of nuclear medicine, which is highly dependent on research and funding provided by the Department of Energy, has evolved from an orientation toward organs, to cells, and today to molecules. Numerous medical specialties benefit immensely from nuclear medicine including pharmacology, cardiology, brain research, oncology, and gene research.

To illustrate, scanner and detector equipment, made possible by DOE sponsored-research, are utilized to study the effectiveness of drug treatments in patients with illnesses such as Alzheimer disease, and to detect photons emitted from radiopharmaceuticals while examining bio-molecular processes. Moreover, handheld imaging detectors are utilized to identify cancerous cells/tissues during operations. Nuclear medicine also provides molecular markers in genetic studies that can identify individuals at high risk for certain maladies long before the actual onset of symptoms.

A number of key challenges confront nuclear medicine. However, Dr. Wagner noted that one of the key problems is the cumbersome and lengthy regulatory process required to gain approval for diagnostic agents such as radioactive tracers. Given that a diagnostic agent is usually administered only once or twice to obtain a definitive medical finding, Dr. Wagner believes that the lengthy (normally five to ten years) approval procedure should be relaxed.

Session 3

CONTROLLING NUCLEAR MATERIAL

Panel Chairman

Ambassador Linton F. Brooks, Administrator, National Nuclear Security Administration and Under Secretary for Nuclear Security

Ambassador Linton F. Brooks

Presentations

Atoms for Peace and Its Impact on Non Proliferation Efforts

Dr. Lawrence Scheinman, Distinguished Professor, Center for Nonproliferation Studies, Monterey Institute for International Studies

Controlling and Accounting for Existing Fissile Material, Pre-empting and Preventing the Creation of Weapons-Grade Fissile Material

Paul M. Longsworth, Deputy Administrator for Defense Nuclear Nonproliferation, National Nuclear Security Administration

Megatons to Megawatts: Turning Nuclear Warheads into Nuclear Energy

Philip Sewell, Senior Vice President, United States Enrichment Corporation, Inc.

The Future of International Nuclear Material Control

Ambassador Ronald F. Lehman, Director, Center for Global Security Research, Lawrence Livermore National Laboratory

Summary

Dr. Lawrence Scheinman

"Atoms for Peace" accelerated the spread of nuclear knowledge, know how and activity to a larger number of states than otherwise would have been the case. At the same time, it is unlikely that maintaining a policy of secrecy and denial would have held back the inevitable growth in the number of countries that would eventually acquire nuclear knowledge and gain access to nuclear technology.

- The difference is that "Atoms for Peace" while quickening the pace of nuclear dissemination, also spearheaded the establishment of a normative framework that, in its absence, is not likely to have emerged.
- In the absence of the "Atoms for Peace" Initiative, it is unlikely that the International Atomic Energy Agency, with its mandate not only to facilitate access to the peaceful benefits of atomic energy but also to develop and implement an international safeguard system to monitor and verify compliance by states, would have ever been created.
- Nor would the framework to develop a civilian nuclear economy have been established. Instead, states capable and motivated to do so would have transferred nuclear technology, possibly under less restrictive terms and conditions.
- Even with "Atoms for Peace," Canada transferred an unsafeguarded research reactor, the Ceres Reactor, capable of generating weapons-grade fuel, to India which produced the plutonium used in its so-called peaceful nuclear detonation in 1974. The United Kingdom provided India with reprocessing technology. In 1956, France agreed to sell Israel a comparable research reactor, the Mona Reactor, without safeguards. France also built Spain's first nuclear power plant in the late 1960s, also without any safeguard provisions.

In all likelihood, nuclear dissemination would still have occurred, perhaps at a slower pace, perhaps less widespread, in the absence of "Atoms for Peace" but it would have taken place under structurally anarchic conditions in the absence of a framework of agreed rules, principles, and norms, with all the negative consequences for stability and security that such a situation would have implied.

- The 1974 Indian nuclear test sparked substantive concerns about the relationship of civil nuclear activity to nuclear weapons proliferation.
- It is extremely important to understand that by developing nuclear power for peaceful uses a state can also achieve a nuclear weapons option. To paraphrase a Swedish nuclear expert, the peaceful atom and the military atom are Siamese twins.

(l to r) *Ambassador Linton F. Brooks, Paul M. Longsworth, Dr. Lawrence Scheinman, Ambassador Ronald F. Lehman, Philip Sewell*

- Consequently, in order to control nuclear weapons proliferation better solutions to international problems are required. This underscores the need to give more than lip-service to understanding the motivation and incentives of states to attain a nuclear weapons capability.
- Capability alone is an insufficient explanation for proliferation. Motivation also matters. To acknowledge this verity, however, is not a reason to relax vigilance regarding capabilities, especially those associated with the presence in a country of plutonium and highly enriched uranium or the means by which to produce them. That is the danger that "Atoms for Peace" in its early phase left open.

This problem lingers today under an imperfect, uncritical interpretation of Article Four of the Nuclear Nonproliferation Treaty. Article Four addresses "The inalienable right of all parties to the treaty to develop research, produce, and use nuclear energy for peaceful purposes without discrimination" to which are added the sometimes overlooked words "And in conformity with Articles One and Two of this treaty," i.e., the nonproliferation articles.

- It is unlikely that the NPT would exist with the widespread adherence that the treaty enjoys in the absence of "Atoms for Peace." The initial draft of the treaty set forth by the United States and the Soviet Union did not contain three articles on peaceful use, Article Four, Article Five, now defunct, and Article Six on nuclear disarmament. However, several nuclear weapons states insisted upon inclusion of those articles in return for support of the treaty.
- Article Four essentially codifies the promise of "Atoms for Peace," without which the requisite support for the NPT in the broad community may not have materialized. This promise – some believed a highly exaggerated promise – rested on the proposition that nuclear energy was the key to economic development and a golden future. This promise remains today a quid pro quo in the nuclear nonproliferation bargain, despite the economic, safety, and waste management problems that confront the nuclear industry.
- The same is true, but even more so, for Article Six which calls for the pursuit of nuclear disarmament. This issue attracts the most political attention and concern from the non-nuclear world where failure to make continued progress toward the goal of disarmament, it is believed, poses the greatest threat to undermining the treaty.

The IAEA was created to foster a policy of internationalizing the peaceful benefits of atomic energy and to channel nuclear technology development toward constructive and non-military ends. Its charter is to "Accelerate and enlarge the contribution of atomic energy to peace, health and prosperity, and to ensure as far as it is able, that assistance provided by it or at its request or under its supervision or control, is not used to further any military purpose."

- However, the IAEA's role was preempted significantly by the leading nuclear states of the day, the United Kingdom, the United States, and France. These nations entered into bilateral cooperation agreements with states interested in nuclear energy and bypassed the IAEA. In the two years following amendment of its atomic energy laws to permit international cooperation, the United States entered into more than twenty such agreements. This development took the IAEA out of a central role, particularly in the area of nuclear assistance, and removed the urgency of developing and deploying a safeguard system.

- Another key IAEA provision that has not been implemented relates to the prospect of managing plutonium. Article 12-A-5 gives the agency the right to approve the means used for the chemical processing of radiated material. It also included a provision for the deposit with the IAEA of any excess fissionable materials recovered or produced over that needed for research or in reactors. This provision was included in anticipation of a substantial agency supplier role that never materialized.
- In retrospect, "Atoms for Peace" did not devote adequate attention to the longer-term problem of reprocessing and plutonium recovery and use. Obviously, this issue is one of the chief problems in the field of nonproliferation confronting us today.

Another important consideration in appraising the relationship of "Atoms for Peace" to nuclear proliferation is to evaluate the consequences of making scientific training and education-related nuclear development available to students and scientists.

- Since the 1950s, thousands of scientists and engineers from many countries have been educated and trained in the United States and in the universities of other advanced industrial states in nuclear research, technology, reactor construction, management, and related fields.
- It is clear that the training provided by an advanced nuclear state, which is an integral part of the "Atoms for Peace" Initiative as well as the major activity of the IAEA, has direct relevance to nuclear proliferation. As one of numerous possible examples, the training received by Indian technologists in France on the design and production of neutron initiators, which while relevant to peaceful nuclear activities, is critical to triggering a chain reaction in an implosion weapon.
- In the end, it is difficult to avoid the conclusion that education and training for ostensibly peaceful nuclear activity can end up being used in support of a weapons development program and that civil nuclear programs can be effective covers under which military nuclear activities can surreptitiously proceed. India, Pakistan, Iraq, and likely Iran, all illustrate this reality.

Finally, "Atoms for Peace" was conceptually strong and visionary. The problem it faced is that implementing practices and policies by states capable of making a difference does not always occur as it should. Assuring that the dissemination of nuclear technology and material would be used for civil purposes required that institutions with the requisite authority, resources, and political support were in place and employed in tandem with the diffusion of nuclear technology.

- As noted above, suppliers – Canada and France being cases in point – raced into the field and sometimes left behind the terms and conditions upon which their assistance was being made available. Had the IAEA been used as a vehicle for transactions, its statutory provisions and safeguards, even on state supplied projects, would have been invoked. If that had occurred at the outset, an effective operational safeguard system would have been established.
- Moreover, if the world community at the time of the NPT had put greater political support behind concepts such as regional nuclear fuel cycle sensors, where sensitive technological activities could have been conducted and thus reducing the presence of the processing and enrichment facilities on national territory under national jurisdiction and control, might have severely constrained the opportunities for proliferation.
- In this regard, there remains a need to revisit the institutional alternative to purely nationally owned and operated nuclear fuel sites and to find a way to fulfill the promise and commitment of Article Four of the NPT, which as mentioned above, codifies the perceived benefits of "Atoms for Peace."

Paul M. Longsworth, Deputy Administrator for Defense Nuclear Nonproliferation, National Nuclear Security Administration

Today, fifty years after his speech, the fundamental dilemma that President Eisenhower so aptly articulated remains. However, the challenges to the international nuclear nonproliferation regime have become increasingly complex.

- The "Atoms for Peace" speech set forth two principles, which continue to influence U.S. nonproliferation programs. First, the peaceful use of atomic energy should be available to all responsible nations. Second, the international community should establish an organization to safeguard fissile material worldwide through the cooperation of member states. These principles have helped shape the evolution of nuclear nonproliferation regimes and are the centerpiece of U.S. nonproliferation efforts. The IAEA has played a substantial role in upholding world nuclear nonproliferation regimes.
- The United States continues to take steps to make the IAEA even more effective for confronting today's complex proliferation threats. Energy Secretary Spencer Abraham has established a strong working relationship with the IAEA's Director General Mohamed El Baradei and ensures that the IAEA has the necessary tools to address the many challenges it confronts.
- The central challenges to the nonproliferation regime come from a few rogue states who seek weapons of mass destruction. The threat is exacerbated by well organized and well funded terrorist organizations determined to wage attacks against the United States, its friends, and allies.

The mission of the Office of Defense Nuclear Nonproliferation (DNN) of the Department of Energy is to reduce the threats posed by proliferation, to secure nuclear material in Russia and elsewhere, to reduce stockpiles of excess fissile materials including in the United States, to help transition Russia's nuclear weapons resources toward peaceful, commercially viable endeavors, and to undertake cutting edge research and development to assess whether others are following the rules. One of DNN's most fundamental efforts is to safeguard nuclear materials both bilaterally and in conjunction with the IAEA.

- These programs are designed to prevent diversion of nuclear materials from peaceful uses to clandestine weapon programs. By agreeing to IAEA's inspection and monitoring role, states are able to receive cooperation from the IAEA to pursue legitimate peaceful nuclear energy objectives.
- DNN also provides vital support to the IAEA's program for physical protection, training, issuance of technical standards, and assessment of nuclear materials security through the IAEA's International Physical Protection Advisory Service. DNN has funded and arranged courses for state systems of accounting and control as well as physical protection training for over 800 students from more than sixty countries.
- In addition, DNN supplies the IAEA with expertise to develop technical guidelines for its new and more rigorous inspection standards started in 1999. Similarly, through bilateral efforts with partners throughout the world, DNN provides support to secure nuclear materials and facilities. DNN has led or participated in over 140 bilateral visits in more that 40 nations to meet this objective.
- Moreover, DNN is spearheading with Congress efforts to enact the Additional Protocol† that will greatly expand the effectiveness of IAEA inspectors.

DNN is also attempting to improve the security of research reactors and related facilities where fissile and other radiological material may be co-located. These facilities frequently support important medical, agricultural, and industrial research as well as other legitimate, peaceful uses of nuclear technology. However, unless fully secured, they could be vulnerable to sabotage, theft, or attack.

- This problem is a particular priority. The United States wants to reduce the commercial use of highly enriched uranium (HEU) and thereby minimize possible seizure by terrorists as well as exposure to sabotage.
- DNN has taken important steps in the area of research reactors, converting thirty-eight reactors in twenty-two countries, over 50% of the reactors known to have U.S.-origin HEU fuel. The United States is de-

† *The Bush Administration is seeking ratification in the Senate of the U.S.-IAEA Additional Protocol to the U.S.-IAEA Safeguards Agreement, which entered into force in 1980. The Additional Protocol is designed to improve the IAEA's ability to detect clandestine nuclear weapons programs in non-nuclear weapons states by providing the Agency with increased information about, and expanded access to, nuclear fuel cycle activities and sites.*

veloping a new low enriched uranium (LEU) fuel intended to replace the remaining reactor cores.

- DNN is also finalizing an agreement with Moscow to return Russian-origin HEU fuel to Russia.
- Finally, DNN has recently created a nuclear radiological threat task force that will consolidate and strengthen our ability to address the full spectrum of radiological security threats facing the United States both domestically and abroad. The task force will identify and secure high-risk radiological materials throughout the world that could be used in radiological dispersion devices or so-called dirty bombs.

Philip Sewell, Senior Vice President, United States Enrichment Corporation, Inc. (USEC)
Over the past fifty years the "Atoms for Peace" Initiative has achieved tremendous success in many fields. But these peaceful achievements are still obscured by the shadow of nuclear weapons proliferation and the possibility of bomb-grade material falling into the wrong hands.

- To help guard against this eventuality, the Megatons to Megawatts† program was concluded in 1993. It is a twenty-year U.S.-Russian agreement to convert 500 metric tons of Russian highly enriched uranium into LEU, which is by far the most effective means of controlling weapon-grade fuels. It is the equivalent of eliminating 20,000 nuclear warheads. The LEU will be used to produce electricity.
- Over this period USEC, the executive agent appointed by the U.S. government, will purchase this recycled weapons material, valued at $12 billion dollars, which will then be sold to utility customers for use in commercial nuclear reactors for the production of electricity. To date, the program is more than one-third completed, with 190-metric tons of HEU, equal to approximately 7,500 nuclear warheads, eliminated.
- An additional benefit is that since the start of the Megatons to Megawatts effort Russia has received revenues exceeding $4 billion, which has supported thousands of Russian workers at numerous nuclear facilities who participate in environmental restoration programs in Russia and work to improve safeguard systems for the weapons-grade material.

Today the commercial nuclear fuel market is essentially in balance. Demand equals supply. Therefore, the addition of substantial amounts of new weapons grade material for use as fuel would upset that balance and, therefore, it could undermine the smooth transition of the Megatons to Megawatts Program. However, it is increasingly likely that there will be a worldwide expansion of the use of nuclear power, including in the United States.

- Indeed, both industry and government plans call for a substantial increase of nuclear power by mid-century. The construction of a new generation of commercial nuclear power stations will obviously increase the demand for nuclear fuel.

† *The formal name of the accord is "The Agreement between the Government of the United States of America and the Government of the Russian Federation Concerning the Disposition of Highly Enriched Uranium Extracted from Russian Nuclear Weapons."*

- This increased demand could provide a cost-effective way of increasing the amount of nuclear bomb grade material eliminated by using it in these commercial reactors such as is currently occurring in the Megatons to Megawatts program.
- To underscore the economic benefits gained by the United States from the Megatons to Megawatts program, of the 20% of U.S. electrical output that is generated by nuclear power plants, approximately 10% comes from fuel derived from dismantled Russian nuclear weapons.

In this context, the President and CEO of USEC has proposed building a single, new generating nuclear power station with U.S. government support that would include tax incentives, loan guarantees, and federal financing. The concept is called the Isaiah Nuclear Energy Plant after the biblical prophet who called for turning swords into plowshares.

- The Executive Branch and Congress may find this idea intriguing since the plan would stipulate that the new reactor would be powered entirely by fuel recycled from dismantled nuclear weapons thereby facilitating the government's efforts to reduce the threat posed by nuclear warhead material.
- While there are numerous potential designs for an advanced reactor, the initial core of the Isaiah reactor could use LEU derived from three metric tons of HEU. This would eliminate 100 nuclear weapons. Each obligatory refueling would require LEU from an additional twenty-five warheads. Over Isaiah's projected lifetime, more than two thousand nuclear warheads would be destroyed.
- Apart from doing away with HEU fuel, the Isaiah concept may attract government support because it could provide increased domestic energy security and mitigate the potential of global warming with emissions-free electricity from nuclear reactors.
- The Megatons to Megawatts Program and the Isaiah concept are two examples of how commercial forces and government policy can combine for nonproliferation success.

Ambassador Ronald F. Lehman, Director, Center for Global Security Research, Lawrence Livermore National Laboratory

Futures Roundtables convened annually at Lawrence Livermore National Laboratory over the last several years, but particularly this year's project, "Atoms for Peace after 50 Years," have identified major trends, forces, drivers, and the motors of change.

- One key theme is that in advanced industrialized societies, the big decisions on nuclear power will be made based on certain economic realities. However, there was disagreement regarding the value to place on externalities in these decisions. For example, a variety of opinion was expressed on the role proliferation resistant technologies would play in decisions on nuclear power. There was a consensus recognition, however, that many of these externalities are very important.

- In these discussions at Livermore, the relevance of safeguards and securing material has become much broader and deeper, not only as a result of the concern about proliferation from states but also due to concern about non-state entities and terrorism.
- There was a great deal of dialogue in the Livermore groups about whether or not the objective conditions mean that nuclear energy is going to expand.


Ambassador Ronald F. Lehman

At the same time there is a recognition that on the one hand the public has a strong aversion to radiation when associated with nuclear power. But on the other hand, when it involves nuclear medicine the populace's attitude is far more supportive because it generally impacts people's lives more intrusively, more profoundly, and more positively.

- Many participants in the Livermore workshops suggest advancing a new form of risk benefit analysis to the public. However, that is precisely the type of assessments performed by experts in the nuclear community, i.e., best practices and risk benefit analysis, and the public never seems to accept the findings.
- The case of Sweden could be illustrative. In Sweden, the first effort to educate the public on the risk benefits of nuclear energy resulted in a powerful backlash. That negative attitude, as suggested by an earlier speaker, appears to be changing with greater acceptance of nuclear energy and an increasing prospect that Sweden may restart its national nuclear program.

The trends or drivers that most influenced international fissile control in the Livermore group came from the transformed international security dimension.

- Although the Cold War has ended much concern remains about the nature of international governance. For example, participants speculated whether some type of new world order with a common core of values will emerge or whether we are headed towards spheres of influence and regional balances with attendant regional economies and regional approaches to dealing with regional threats.
- In each of these situations the question arises: how to address the issues of nuclear materials and nuclear risks?

One of the most important themes to surface related to fissile material is recognition of the fact that nuclear materials are not simply dual-use, double-edged swords.

- It is the fact that weapons capability is becoming more pervasive with incremental movement towards a weapons capability that takes place in such small, unseen steps that the international community, and even nations, cannot hope to respond in an effective, timely fashion.

- This development becomes even more ominous because actual proliferators are increasingly networked, go offshore, exploit miniaturization, agile manufacturing, and modern technology, and possess just-in-time break-out capability.
- These trends underscore the problem of covert facilities, third country help, and breakout potential. The nonproliferation regime has yet to develop an effective solution to cope with these issues.
- What these problems suggest is the need to create a regime that includes routine control of material and defined approaches to deal with abuse and use of the material in a breakout scenario.

In terms of proliferation, the Livermore Roundtable group also examined whether the significance of civilian applications will be less, the same, or more in the future and will the significance of military applications be less, the same, or more in the future.

- While opinions ranged across the spectrum, the majority of participants felt that international control of fissile material was the most important variable influencing these issues.
- In this regard, IAEA Director Mohamed El Baradei recently wrote a major article† where he proposes among other things, three main steps on fissile material: 1) reprocessing enrichment should fall under multilateral control (although he does not explicitly state what is meant by multilateral control; 2) emphasis should be placed on proliferation-resistant technologies in the future; and, 3) it is time to consider multilateral approaches to the management and disposal of spent fuel and radioactive waste.

Director Baradei's article raises numerous groups of questions. For example:

- What is meant by international? Does it mean global, regional, multilateral, or transnational? Should it involve private companies or must it be inter-governmental or perhaps an actual international organization such as the IAEA or some other international entity? How do important cooperative threat reduction efforts fit into the project?
- Another important query is what is to be internationalized? Is it storage sites and a level of improvement in accounting competencies? Or is it actual international protection and management or even ownership?
- There is also a question of what value or goal is sought by internationalization. In many cases the answer may be legitimacy while in others what is sought could be confidence.

However, what the variety of actors are seeking from internationalization can be markedly different.

† *"Towards a Safer World," The Economist, October 18, 2003, pp.43-44.*

- As a result, the degree to which uniform norms address very dissimilar economic and political security circumstances needs to be examined carefully.
- Also, are international organizations competent to perform all the tasks that certain actors want them to carry out? As an example, is an international bureaucracy in a distant capital necessarily best suited to operate a sensitive facility?
- And how urgent is internationalization? Does it occur over a long period or is it something that must take place early-on, before the positive events can ensue. Finally, does internationalization supplement, amend, or replace the current NPT regime?

Analysis

This session provided an historical perspective on the "Atoms for Peace" program and evaluated its influence on international nuclear nonproliferation efforts. Representatives from the Department of Energy furnished insights into current efforts underway to control nuclear materials internationally and DOE's cooperation with the IAEA. Panelists also discussed the future of international nuclear material control and nuclear nonproliferation regimes in light of today's complex challenges and the "Atoms for Peace" legacy.

Dr. Lawrence Scheinman stated that although "Atoms for Peace" resulted in the diffusion of nuclear activity and know-how to a greater number of states than would have been the case without the Initiative, it also had the benefit of laying the ground work for the creation of the IAEA and the NPT, as well as the civilian nuclear power industry. In the absence of "Atoms for Peace," the promulgation of nuclear knowledge would have occurred without a framework of rules and laws accompanied by adverse consequences for stability and security. According to Dr. Scheinman, successful nuclear nonproliferation efforts require more effective solutions to international problems, including a more sophisticated understanding of the motivations for why states seek nuclear weapons. In hindsight, Dr. Scheinman believes that "Atoms for Peace" did not focus sufficient energy on the longer-term problem of reprocessing and plutonium recovery and use, nor to how making scientific training on nuclear matters available to foreign students could contribute to proliferation.

Paul M. Longsworth outlined the key role that the Office of Defense Nuclear Nonproliferation plays in supporting the spirit of "Atoms for Peace." DNN provides U.S. support to make the IAEA more effective to combat proliferation threats, particularly from rogue states and terrorist actors. DNN is extremely active in helping to reduce stockpiles of excess fissile materials, especially in Russia. A key DNN mission is to help protect nuclear materials bilaterally and through the IAEA, as well as to limit commercial use of highly enriched uranium which could be seized by terrorists and/or exposed to sabotage.

Philip Sewell discussed the Megatons to Megawatts program which is a U.S.-Russian agreement to convert Russian HEU into LEU thus controlling weapon-grade fuels. The LEU is sold to utility customers for use in commercial nuclear reactors to produce electricity. The program also benefits Russian workers who participate in environmental restoration programs and help improve safeguard systems in Russia for the weapons-grade material. Given the success of Megatons to Megawatts and the likely expanded use of nuclear energy, Mr. Sewell proposed construction, with U.S. government financial support, of a new nuclear power plant. The reactor, referred to as the Isaiah Nuclear Energy Plant, would be powered by recycled fuel from dismantled nuclear weapons thus meeting the U.S. goal of lessening the threat stemming from weapons grade material.

Ambassador Ronald F. Lehman discussed key trends shaping the control of international fissile material. A major concern is that weapons capability has become widespread and states increasingly take small, clandestine steps to acquire this capability making detection and a timely, effective international response extraordinarily difficult. One solution is to establish a regime encompassing regular control of material together with defined approaches to deal with such breakout situations. The international control of fissile material, however, raises numerous questions that must be addressed including what is meant by international control, who (agencies, states, NGOs, private industry) is involved, what specifically is to be internationalized, what is the goal of internationalization, what are the goals of the various actors involved, and what it would mean for the NPT.

Session 4

ENERGY AND PHYSICS: THE HORIZONS OF DISCOVERY

Panel Chairman

Dr. Raymond L. Orbach, Director, Office of Science, Department of Energy

Presentations

Nature's Recipe for Nuclear Matter

Dr. T. James Symons, Director, Nuclear Science Division, Lawrence Berkeley National Laboratory

Blossoming of the Forces: Matter and Energy

Dr. Jonathan A. Bagger, Krieger-Eisenhower Professor, Department of Physics and Astronomy, The Johns Hopkins University

Looking Back in Time: Cosmic Recipe for the Early Universe

Dr. Michael S. Turner, Bruce V. & Diana M. Rauner Distinguished Service Professor, Department of Astronomy and Astrophysics, University of Chicago

Superconductivity

Dr. Alexei A. Abrikosov, Argonne Distinguished Scientist, Condensed Matter Theory Group, Materials Science Division, Argonne National Laboratory, and winner of the 2003 Nobel Prize for Physics

Summary

Dr. T. James Symons

In 1953 most nuclear physicists studied the structure and decay of atomic nuclei. While this research continues today, the field has broadened its scope to encompass studies of a wide variety of extended nuclear systems including neutron stars, and quark-gluon plasmas. A second theme of current research is the intertwining of nuclear physics and astrophysics that has allowed us to understand the origins of the elements and production of energy in the stars. Thirdly, over the last half century, the nucleus has proven to be a fertile ground for investigation of the fundamental forces of nature. This seventy-year long story is one of the most extraordinary of all. In this regard, the discovery of neutrinos is a significant part of 20th century physics.

- A neutrino is an uncharged lepton, which is a fundamental particle that does not participate in strong interactions. Neutrinos participate only in weak (and gravitational) interactions and therefore are very difficult to detect. There are three known types of neutrino, all of which have very low or possibly even zero mass.
- In 1932, physicist Wolfgang Pauli postulated the existence of the neutrino to explain the beta-decay spectrum, which, unlike other radioactive decay that produced discrete energy, was generating a continuum. Not long after the "Atoms for Peace" speech, researchers were able to detect neutrinos issuing from the Savannah River nuclear reactor. It was reasoned that the sun, through its constant nuclear fusion process, should also produce neutrinos at rates that are precisely calculable.
- In 1964, a theorist, Dr. John N. Bahcall, and an experimentalist, Dr. Raymond Davis, Jr., (two of the 2003 Presidential Enrico Fermi Award winners - more in the next section), proposed an experiment to ascertain the number of neutrinos emanating from the sun. This important effort represents one of the many examples where nuclear physics and astrophysics come together.
- Over the next two decades, Davis detected solar neutrinos but only at one-third of the expected rate. This created what was known as the solar neutrino problem. Subsequent experiments (e.g., the Sudbury Neutrino Observatory solar neutrino detector) ascertained that Bahcall's calculation for electron neutrinos was accurate. What was causing the shortfall in the expected rate of neutrinos was the fact that these neutrinos had transmuted to a different form, a consequence of their small but non-zero mass.

Nuclear physics is relevant in all kinds of places from the very birth of the universe to the formation of quark-gluon plasma, the formation of helium in the early universe, the formation of stars, to explosive events like supernovae where the heavy elements are formed. So, nuclear physics is needed to understand what is taking place in the universe.

- However, sometimes astronomy returns the favor. For example, one of the greatest discoveries in nuclear physics in the past fifty years was derived from an astronomical observation in the 1960s of the remnants from a supernova. This led to the discovery of pulsars which are spinning neutron stars comprised of enormous atomic nuclei.

(l to r) *Dr. Raymond L. Orbach, Dr. Alexei A. Abrikosov, Dr. T. James Symons, Dr. Jonathan A. Bagger, Dr. Michael S. Turner*

- Experimentally, this forced scientists to introduce the study of nuclear matter into nuclear physics on a serious level, because the nucleus now under discussion is not composed of twenty protons and neutrons but is basically a giant object, a kilometer across. So a whole new field was created within nuclear physics based on the discovery of neutron stars.

However, given that the experimental access to neutron stars is extremely limited, over the last few decades physicists have developed other ways to access the properties of nuclear matter in the laboratory.

- The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory is such a tool. RHIC accelerates and then collides two heavy nuclei into each other. In the brief moment of time during and immediately after the collision highly dense nuclear matter results.
- These collisions allow speculation on how a phase diagram might look for nuclear matter. We know for H^20 the phase diagram has phases, like water, steam, ice. What would we expect the phase diagram to look like for nuclear matter? There are strong predictions that at high temperature and density, the quarks within nuclei become deconfined, in a new phase called the quark-gluon plasma. With RHIC, we hope to make an excursion into that phase and thus glean valuable knowledge about it.

To continue our exploration of the nuclear landscape, a rare isotope accelerator to perform cutting edge experiments in nuclear structure and nuclear astrophysics is highly desirable.

- It is expected that, while studying nuclei in accelerators and measuring their properties, scientists can tie the results into a comprehensive theory of supernova formation and nuclear synthesis.
- Many experts believe that the optimum way to train nuclear scientists is by doing forefront experiments with such tools. Moreover, this is the best approach to attract new people into this field.
- Also, while practical applications from this type of experimentation do indeed result, they sometimes take time. For example, in 1952 the Nobel Prize in Physics was won by Felix Bloch and Edward Mills Purcell for studies on nuclear magnetic resonance in solids and liquids. The 2003 Nobel Prize in Medicine was won for the application of this work to form resonance images or MRIs. This shows the large time gap that can exist between basic discoveries and practical applications.

Finally, the Office of Science, Department of Energy, is the principal sponsor of the physical sciences in the United States supporting 43% of all of the physical science conducted. It also supports 90% of U.S. research on high-energy physics and nuclear physics. The partnership with the Office of Science and the National Science Foundation (NSF) in the area of physics comes together in the Nuclear Science Advisory Committee and the High Energy Physics Advisory Committee. Without this support, the rapid pace of discoveries and advances over the past fifty years would not have occurred.

Dr. Jonathan A. Bagger, Krieger-Eisenhower Professor, Department of Physics and Astronomy, The Johns Hopkins University

From the beginning, the "Atoms for Peace" Initiative was closely tied to nuclear and particle physics. In 1953, the year of President Eisenhower's speech, the world was coming off a terrible period of two world wars, the Korean War, and the Great Depression. Nevertheless, the first half of the 20th century was also a period of tremendous progress for humankind, progress that came from harnessing the power of science.

- In fact, much of the progress came from chemistry, based on the Periodic Table of the Elements. During the first half of the twentieth century, scientists had come to understand this table in terms of atoms and nuclei, which are composed of protons, neutrons and electrons. At the time these were the known elementary particles together with pions, kaons, and muons, the latter having been seen only in cosmic rays.
- But 1953 marked the watershed year for particle physics because it was the year of the start of the Brookhaven Cosmotron accelerator that could recreate, in a controlled setting, the physics of cosmic rays. The Cosmotron particle accelerator smashed protons into stationary targets, creating new particles via Einstein's $E = mc^2$ equation, thereby allowing the properties of these particles to be carefully measured and their origins understood. The Cosmotron and subsequent accelerators, from the Berkeley Bevatron through the Fermilab Tevatron, have been successful beyond expectation.
- Indeed, these accelerators unleashed a torrent of discovery over the next half century, unraveling the long-held belief that protons, neutrons, and electrons represented the fundamental or elementary particles. Accelerators produced many hundreds of new particles, siblings of protons and neutrons such as pions and muons. Early in the 1960's, quarks were proposed as a mathematical device for classifying the new particles. However, in 1969 an experiment at the Stanford Linear Accelerator Center proved that the quarks were real and that protons and neutrons are not elementary but are composed of quarks.
- In the following two decades, new accelerators discovered additional types of quarks and the forces that linked them together. A new Periodic Table was constructed that extended and encoded the knowledge of the sub-atomic world.
- The international nature of particle physics is reflected in the fact that the quarks and leptons and the forces linking them were discovered in laboratories, not only across this country, but across the world as well. Indeed, the true spirit of "Atoms for Peace" is reflected in the fact that almost half of the physicists involved in the Fermilab Tevatron† are from foreign countries.

† *The Fermilab Tevatron is a four mile long accelerator, a thousand times more powerful than the Brookhaven Cosmotron. It accelerates protons and anti-protons, matter and anti-matter to nearly the speed of light and collides them head on in beams of particles thinner than a human hair. The results of these collisions are analyzed by particle detectors and processed by teams of physicists from around the world.*

Today, we are at a crossroads in the history of science. The new Periodic Table of Sub-atomic Physics together with precise and quantitative knowledge about how they fit together is one of the crowning achievements of 20th century science.

- Particle detection techniques are essential to the fast moving field of medical diagnostics. The worldwide web was invented by particle physicists and given to the world to facilitate communication and coordination between far-reaching communities.
- Moreover, particle physics is the primary attraction that draws young students into science today. Such technologically trained students are essential for economic security and national defense.

We have reached a point where we can begin to ask bold, new questions about the structure of matter, energy, space, and time. For example, the two pillars of 20th century physics, quantum mechanics and Einstein's theory of general relativity are inconsistent with each other. One resolution to this dilemma is string theory in which elementary particles are nothing but the vibrations of minute strings.†

- According to string theory, absolutely everything in the universe – all of the particles that make up matter and forces – is comprised of tiny vibrating fundamental strings. Moreover, each of these strings is identical. Just like the strings on a guitar or a piano have resonant frequencies at which they prefer to vibrate – patterns that our ears sense as various musical notes – the same holds true for the loops of string theory. With the strings in string theory the vibrational pattern determines what type of particle the string is. What determines the type of particle is the movement of the string and the energy associated with this movement. The strings in string theory are one-dimensional and the mathematics describing the strings requires not one or two but ten or eleven dimensions.
- String theory also provides a single explanatory framework or in Einstein's phrase, a unified theory, capable of encompassing all forces and all matter. String theory proclaims that the observed particle properties, that is, the different masses and other properties of both the fundamental particles and the force particles associated with the four forces of nature – i.e., the strong and weak nuclear forces, electromagnetism, and gravity – are a reflection of the various ways in which a string can vibrate.
- As noted above, since string theory requires that we live in more than four space-time dimensions, the discovery of extra dimensions would be an unparalleled event in history.

† The Elegant Universe *by Brian Greene (Vintage Books, March 2000) offers a clear and understandable elucidation of string theory, dark matter, dark energy, and related topics discussed in this conference session. The* Nova *series,* The Elegant Universe, *first aired on the PBS television network on October 28/November 4, 2003, also provides a lucid description of string theory and associated issues.*

- String theory begs numerous questions: Where are these extra dimensions? How many are there? How are they hidden? What are their shapes and sizes? The fact that string theory is now taken seriously as the path to a unified theory underscores the reality that we are moving from the realm of science fiction to science fact.

As previous speakers have noted, over the past fifty years, particle physics has grown increasingly intertwined with cosmology. In fact, in contemplating the cosmos one is actually looking back in time to an earlier epoch before the planets, before the stars, before the atoms, even before the nuclei, back to a time when the universe was composed of a jumble of quarks and leptons.

- To understand the universe, we need to understand its most basic ingredients. Cosmologists, through a variety of observations, have determined that most of the energy in the universe consists of dark matter and dark energy. Dark matter is like ordinary matter in that its gravitational attraction pulls the universe together. Astrophysicists have proven that dark matter exists and are now attempting to observe dark matter particles as they stream through detectors on earth.
- Dark energy, on the other hand, is a total mystery. It is related to the nature of the energy of space itself. Scientists speculate that dark energy is like anti-gravity in the sense that its interactions blast the universe apart.

The nature of dark matter and the dark energy will drive particle physics research in the coming decades. These lines of inquiry fall completely within the mission of the Department of Energy and are ripe for exploration in partnership with NSF, NASA, and the world community.

- What is needed is to produce dark matter and measure its properties in laboratories on earth. That requires accelerators with the energy necessary to produce the particles. To characterize the dark matter, proton and electron accelerators, working in tandem to reveal part of the picture, are required. The CERN Large Hadron Collider or LHC, now under construction in Switzerland and slated for completion in 2007, will become the world's most powerful accelerator. With almost ten times the energy of the Fermilab Tevatron, the LHC should help provide a glimpse of this new landscape. Although primarily a European machine, the LHC is being built with important financial and technological assistance from the United States.
- A series of studies conducted by scientists from around the world have concluded that a linear collider is also essential to characterize the dark matter that pervades the universe. In this sense, the linear collider is the true dark matter microscope necessary to resolve this new form of matter. The Next Linear Collider (NLC) is the first fully international project in particle physics. Scientists from each region of the world are working together to refine its design. In the best spirit of "Atoms for Peace," constructing the NLC will require the full commitment of the world community in terms of both human and financial resources.

Particle physics represents one of the most successful areas of international cooperation. From the pivotal role of CERN in post-war Europe to the global collaboration of today, particle physicists have a history of working together with great success. As alluded to above, physicists designing the NLC are breaking new ground in international partnership.

Dr. Michael S. Turner, Bruce V. & Diana M. Rauner Distinguished Service Professor, Department of Astronomy and Astrophysics, University of Chicago

In 1953, few would have thought that particle physics and nuclear science would play a significant role in the study of the universe.

- Today, no one disputes that these two disciplines are inextricably entwined.

In 1953, two important questions in cosmology were what was the origin of the chemical elements, i.e., the Periodic Table, ranging from hydrogen to uranium, and did the universe have a beginning? Moreover, an intense debate existed between proponents of the Big Bang Theory which postulates a beginning point, and the Steady State Theory which maintains that the universe was always the way it is.

- The astronomical tools utilized at the time consisted of optical telescopes, almost all privately operated, that captured about 1% of the light of objects in space. The largest telescope was the 200-inch Hale Telescope on Mt. Palomar in California.
- However, the two cosmological questions were answered in both cases by means of nuclear and particle physics. The universe began with the Big Bang from the mix of elementary particles some 14 billion years ago. The chemical elements were made by nuclear reactions, both in the Big Bang event and during the creation of stars. In the spirit of "Atoms for Peace," the free exchange of information by scientists around the world contributed to the understanding of these two questions.
- The quark mélange that existed immediately following the Big Bang changed into a mixture of more familiar neutrons and protons when the universe was about ten microseconds old. When the universe was seconds old the Big Bang nuclear synthesis produced the lightest elements in the periodic table, e.g., helium, lithium, helium-3, and deuterium.
- When the universe was approximately 400,000 years old, atoms were formed. A record of their creation exists in the cosmic microwave radiation background that can be observed by current technology. It also represents the limit of how far back we can see with today's scientific instruments†. The record continues with the formation of the first galaxies, stars, clusters of galaxies, up to the structure that is observed today.

The new questions scientists are posing in 2003 have to do with the actual composition of the universe. One such question concerns the origin of

† *Satellites, together with ground-based devices such as the Daisy microwave detector at the South Pole, as well as balloons to reach above the atmosphere, are some of the instruments used to detect this cosmic radiation.*

quark-based matter and the nature and origin of both dark matter and dark energy.

- It is now believed that photons, in the form of cosmic microwave background, account for approximately 0.01% of the universe and atoms for 4%, of which 0.5% represents stars, with the rest comprised primarily of various gases that never formed into stars. The remaining 96% is theorized to consist of matter that scientists do not fully understand.
- Of this 96%, approximately 30% is dark matter‡ thought to encompass neutrinos, axions, and neutralinos. Scientists are most intrigued by the axion and neutralino, particularly the latter, whose existence is predicted by string theory.
- 66% is dark energy, an unexplained force with unusual anti-gravitational properties. Dark energy appears to push the very fabric of space apart causing the universe to expand ever faster (more below). It only shows up in observations that probe significant fractions of the observable universe. Dark energy is theorized to consist of a cosmic field associated with inflation; the vacuum energy of empty space (also referred to as the cosmological constant, a phrase coined by Einstein); and quintessence, another type of low-energy field.

In 1998, astronomers and physicists discovered that the universe, far from slowing down due to the forces of gravity as many scientists had predicted, was actually expanding at an accelerated rate. The question was then raised, what could account for the continued expansion of the universe?

- One possibility is the gravitational force associated with the virtual particles that fill the vacuum, i.e., the aforementioned dark energy.
- In part because dark energy is little understood, it is not known whether the universe will continue to accelerate, begin slowing down, or even collapse. Obviously, these are critical questions.
- Searching for the answers to these mysteries will inspire the next generation of scientists.

Another series of questions involves the beginning of the universe and the Big Bang. Most notably, what force powered that Big Bang?

- Current theory postulates that the universe underwent a tremendous burst of expansion immediately following the Big Bang due to the force exerted by elementary particles. This hypothesis is called inflationary cosmology.
- Other questions include: What is space? What is time? And how did they come about? String theory may play an important role in providing the answers.

‡ *The astronomer Fritz Zwicky made the first discovery of dark matter studying a cluster of galaxies. He noticed that these clusters were moving fast and the gravity of the stars in the galaxies did not produce a strong enough gravitational field to keep the cluster bound. To explain this phenomenon, Zwicky coined the term dark matter.*

This scientific adventure presents wonderful possibilities for discovery that requires a removal of the barriers and a change in the culture entailing closer collaboration between astronomers and physicists.

- Astronomers and physicists around the world must work together using their respective tools, telescopes and accelerators, to unlock the answers.
- Accelerators are absolutely critical because they furnish controlled conditions to examine the subatomic level while telescopes provide access to conditions that cannot be recreated on earth.
- Finally, the pursuit of this science entails a close cooperation among three federal organizations: the Department of Energy, NASA, and the National Science Foundation.

Dr. Alexei A. Abrikosov, Argonne Distinguished Scientist, Condensed Matter Theory Group, Materials Science Division, Argonne National Laboratory, and winner of the 2003 Nobel Prize for Physics†

Superconductivity is the ability of some materials to conduct electricity with no resistance and extremely low losses when they are chilled to very low temperatures.

- From its discovery in 1911‡ until 1986, it was generally believed that superconductivity could only exist in metals at extremely low temperatures, for example, at approximately twenty-five degrees Kelvin above absolute zero.* Unfortunately, the extreme low temperatures required for superconductivity represented a significant barrier to practical, low-cost applications.
- However, this changed in 1986 when K. Alex Müller and Georg Bednorz (more below) discovered a new class of ceramic superconductors resulting in the subsequent birth of high-temperature superconductivity (HTS). The prospect of superconductivity at substantially higher temperatures opened a new chapter in physics. Indeed, a valid argument can be made that understanding superconductivity at high temperatures is arguably one of the major issues in physics today, with over ten thousand researchers working on this topic in the United States and abroad.

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† *Dr. Abrikosov received the Nobel Prize in Physics for his work developing the concepts of superconductivity and superfluidity more than a half century ago. More specifically, he discovered the "type-II superconductor" and its magnetic properties, now called the Abrikosov vortex lattice. In addition to its vast theoretical significance, his research has led to several practical applications, including magnetic resonance imaging (MRI) scans and cell phone reception technology. Dr. Abrikosov shared the Nobel Prize with two colleagues, Anthony Legget and Vitay Ginzburg.*

‡ *Superconductivity was first discovered in 1911 by the Dutch physicist, Heike Kammerlingh Onnes.*

* *For purposes of comparison, absolute zero is 0° Kelvin (K), -459.67° Fahrenheit (F), and -273.15° Celsius (C); liquid helium boils at 4.2° K, -452.11° F, and -268.95° C; liquid nitrogen boils at 77.36° K, -300.42° F, and -195.79° C; water freezes at 273° K, 32° F, and 0° C; water boils at 373.15° K, 212° F, and 100° C.*

- HTS offers the promise of conveying electricity along superconducting transmission lines with near perfect efficiency and much higher capacity rates. For example, superconductors can carry as much as 100 times the amount of electricity of ordinary copper or aluminum wires of the same size. This is especially important given that electricity grid losses have grown to more than 10% of all electricity generated.
- Other possible applications include: filters for cellular phone systems; MRI machines using HTS magnets; microwave systems that incorporate the new materials; and hybrid semiconductor/superconductor systems.

Müller and Bednorz, who were working at IBM in Zurich, Switzerland, when they discovered HTS in 1986, were experimenting with a particular class of metal oxide ceramics called perovskites.§

- Working with ceramics of lanthanum, barium, copper, and oxygen they found indications of superconductivity at 35° K, a surprising 12° K above the old record for a superconductor. Soon researchers from around the world would be working with the new types of superconductors. In February of 1987, a perovskite ceramic material was found to superconduct at 90° K.
- The temperatures at which superconductivity works have risen in the last year with the highest critical temperature at 135° Kelvin. This is higher than the boiling temperature of liquid nitrogen which means that liquid nitrogen can be used instead of liquid helium in cryogenic cooling systems, a major advancement. However, it is still far from the temperature levels required for the widespread practical applications cited earlier.

Is it possible to increase the critical temperature for HTS? Can it reach room temperature or even higher?

- Such a development would represent a revolution comparable to the discovery of the fission of uranium. Electric power generation would be transformed bringing incredible advances in efficiency and higher capacities.
- However, the substances utilized by Müller and Bednorz have largely exhausted their potential with little expectation of further significant increases of critical HTS temperatures.
- In principle, there are no limitations for HTS critical temperatures. Room temperature or even higher levels are theoretically feasible. The problem is the same that confronted Müller and Bednorz: to discover a suitable substance allowing superconductivity at such higher temperatures.

Given the immense practical benefits that HTS could bring, it may be appropriate for the Department of Energy¤ to sponsor a project to discover an

§ *Bednorz and Müller won the 1987 Nobel Prize for Physics for their work in HTS.*

¤ *DOE is heavily involved in high-temperature superconductivity. In order to spur the development of HTS technology, DOE created the Superconductivity for Electric Systems Program in 1988. U.S. industry is developing and commercializing electric power applications of HTS. The program teams the entrepreneurial drive of high-tech companies with the enormous technological resources of DOE's national laboratories.*

appropriate material for a high temperature superconductor approaching room temperature.

Analysis

The concluding session examined the evolution of nuclear and particle physics over the past fifty years and their scientific opportunities for the future. Panelists in this session discussed how nuclear and particle physics are essential to help understand astrophysics and the study of cosmic bodies such as stars and galaxies and their function, as well as cosmology, encompassing the birth, evolution and fate of the universe.

Dr. T. James Symons made the compelling case that the field of nuclear physics is necessary to understand what has and is taking place in the universe. Nuclear physics also benefits from astronomy. However, the discovery of pulsars, or neutron stars, which are comprised of massive atomic nuclei, led scientists to introduce a much broader study of nuclear matter into nuclear physics. Research tools such as particle accelerators allow physicists to delve into the properties of nuclear matter in the laboratory. Basic research, Dr. Symons states, is the primary means both to train and attract students to this field of science.

Dr. Jonathan A. Bagger noted that we are presently at a juncture where we can pose novel questions about the structure of matter, energy, space, and time. In an attempt to reconcile quantum mechanics and Einstein's theory of general relativity, scientists have developed string theory in which elementary particles are nothing but the vibrations of minute strings, currently undetectable. While string theory begs numerous questions it is taken seriously as a likely route to Einstein's unified theory. In addition, to better understand the composition of the universe, we must understand its most basic ingredients. Cosmologists believe that most of the energy in the universe consists of dark matter and dark energy, the study of which will lead particle physics research in the coming decades. To produce dark matter and measure its properties in laboratories scientists will use accelerators such as the CERN Large Hadron Collider and the Next Linear Collider. In the best spirit of "Atoms for Peace," both these facilities are receiving international support.

Picking up on a theme advanced by earlier speakers, Dr. Michael S. Turner stated that in 1953, few would have concluded that particle physics would play a central role in cosmology. Today, these two branches of learning are intimately intertwined. Illustrative of this partnership was the discovery in 1998 by astronomers and physicists that the universe, contrary to predictions, was increasing at a quickened pace, raising the question of what is causing this expansion. To answer this and related questions, argues Dr. Turner, a cultural change encompassing an even closer collaboration between astronomers and physicists is required.

Dr. Alexei A. Abrikosov's short presentation included a proposal that the Department of Energy sponsor a specific research project to discover a high temperature superconductor (HTS) material that would significantly raise the temperature at which superconductivity could occur, ideally to a level approaching room temperature. Given that 10% of all electricity currently generated is lost, such an event would revolutionize the transmission of electric power resulting in little or no electric loss and, according to some estimates, offering a 100% increase in carrying capacity. Dr. Abrikosov concluded by stating that there are no theoretical limitations to achieving such superconducting temperatures, even to levels exceeding room temperature.

THE ENRICO FERMI PRESIDENTIAL AWARD PRESENTATION

Speech by the Honorable Spencer Abraham, Secretary of Energy

It is now my chance and my pleasure, to offer personal congratulations to the winners of this year's Enrico Fermi Award and to thank past winners for joining us this evening. However, let me say that I believe John Bacall, Raymond Davis, Jr, and Seymour Sack represent what is best about the Department of Energy's science programs. They were willing to take risks in their research and to stand by it, even if others might have had doubts. Dr. Davis' exquisite experiments and Dr. Bacall's magnificent theoretical insights illustrate just how perfectly theory and experiment can be joined. In addition, Dr. Sack was instrumental in seeing that America had credible deterrence when it was most needed. Their individual efforts underscore the critical importance of basic research.

As the home of basic research in physical sciences, particularly the science of nuclear energy, the Department of Energy is the right place to administer this award for the President, for tonight we honor not only individual achievement in energy-related science, but the very idea of long-term basic research, the kind of investment that is at the same time most difficult to understand and yet most critical to our success as a nation.

From deterrence of nuclear conflict to MRIs to PET scans and other medical miracles, to 20% of the electricity which powers our homes and businesses, fundamental scientific research is the unsung hero of the modern age. So this evening we recognize and we celebrate these three scientists as well as the nature of the science which they perform. In my judgment, we could not have found a better forum in which to honor the achievements of basic research in energy than at a conference on President Eisenhower's "Atoms for Peace" speech.

Today you finished a full day of discussion on that speech and its implications for nonproliferation, nuclear energy, and nuclear science. As far as I can see, the best minds in the business have all taken a crack at those topics here today. And so now, at the end of the day, I am in the unenviable position of trying to add something to what has already been discussed. Rather than trying that, I would prefer to make a personal observation.


Spencer Abraham

Specific initiatives offered by President Eisenhower in his "Atoms for Peace" speech, while extremely important, are of less significance today than the actual vision he offered of how to think differently about atomic power. His foresight and willingness to be bold at a time of considerable international tension set the stage for a host of global efforts to apply the power of the atom to peaceful purposes.

President Eisenhower's address also sounded the major themes that became the core of our responsibilities at the Department of Energy: nuclear energy, nonproliferation, and a variety of areas surrounding nuclear science. And while his proposals in each of these areas were historic, it is clear that President Eisenhower was equally concerned with shifting the conversation about atomic power away from questions of war and toward the issue of peace. In fact, what he was really doing was taking the discussion of atomic power back to where it began when Enrico Fermi and others first started looking at the energy that could be released from the atom.

In the process, President Eisenhower sketched an agenda for the peaceful use of atomic power that is alive and well today at the Department of Energy. In Eisenhower's time, however, the arguments for peaceful use of nuclear energy were very different. Then the idea was to move from the destructive to the constructive power of nuclear fission. Eisenhower cited agriculture, medicine, and the generation of electricity as possible applications.

But the very success of "Atoms for Peace," just as I suspect President Eisenhower hoped, has changed the way we talk about nuclear power. Today, one of our first imperatives reflects the commitment to a clean environment. Nuclear power plants emit none of the pollutants associated with the burning of fossil fuels. Since the mid-1970s, nuclear energy has enabled the United States to avoid emitting over eighty million tons of sulfur dioxide and approximately forty million tons of nitrogen oxide.

Another imperative is to supply energy that is both abundant and affordable. As many of you know, our administration has identified hydrogen as being a potential source of unlimited and clean energy in the future. We envision a day when hydrogen will empower light trucks, cars, 18-wheelers, factories, and shopping malls. However, this is a vision that will take decades to implement and one of the challenges will be to produce hydrogen cleanly and efficiently. What's exciting about nuclear energy is that it promises to do exactly that.

Our work with the international community to develop Generation Four nuclear technologies, points the way to realize this vision, perhaps even sooner than some might suspect. Finally, there is the policy debate today surrounding the issue of climate change. It is obvious to me that an energy source, capable of supplying a significant proportion of the world's power with no greenhouse gas emissions, should be at the center of this debate. That is why in February 2002 we announced our Nuclear Power 2010 initiative, which today is working with the private sector to pave the way for the construction of new nuclear power plants to begin in America in the next few years.

Again, I would like to think that President Eisenhower would be delighted with the way this debate has changed over the years. On the nonproliferation front he would probably be astonished, and I am sure very pleased, with the vocabulary now employed between two former adversaries. Inspired by the close, new relationship between our nations forged by Presidents Bush and Putin, Russian Minister of Atomic Energy Alexander Rumyantsev and I have worked very closely over the past two years on a host of nonproliferation issues. We meet regularly to discuss and to put into place greater cooperation, improve steps for protection of dangerous materials, enhance international physical protection of fissile material, and to identify ways to boost safety and security in the peaceful use of atomic energy.

Most importantly, Minister Rumyantsev and I have been able to expand and accelerate U.S.-Russian efforts to strengthen the protection of nuclear material. Moreover, we are now on schedule to complete our efforts to secure Russia's nuclear material, literally, years ahead of previous timetables. Indeed, the Minister and I are personally engaged in supervising this effort on a day-to-day basis to ensure that no bureaucratic obstacles hinder its success.

The new relationship between our two countries is one of the reasons our joint operation to secure highly enriched uranium at the Vinca reactor in Belgrade was a success not too long ago. The return to Russia just last month of fourteen kilograms of highly enriched uranium from Rumania is also yet another example of the strength of the U.S.-Russian partnership to reduce the spread of weapons of mass destruction. Participation in both these operations by the IAEA, an organization that exists today because of President Eisenhower's "Atoms for Peace" speech, was crucial and all of us should be proud of it.

Ultimately, however, it could not have been accomplished without the close working relationship that two nations, which once viewed each other as adversaries, enjoy today. Could those sitting in the General Assembly of the United Nations on December 8, 1953 listening to President Eisenhower's vision have foreseen such cooperation? One wonders if they could have foreseen the progress in nuclear science brought to us by generations of particle accelerators at Fermi, Stanford, Berkeley, Thomas Jefferson, Argonne, Los Alamos, Brookhaven, and the Oak Ridge National Labs.

And that is not to mention the singular accomplishments of individual scientists like those we have honored over the years with the Fermi Award. Like E. O. Lawrence's machine, built in the 1930's, today's accelerators are helping us understand huge questions, what makes up the universe and why? Why does it behave the way it does? Researchers probably never anticipated when they started smashing atoms and protons in our large accelerators that their science, their very basic research on matter would eventually give us remarkable life saving technologies.

Indeed, one of every three hospital patients in the United States benefits from nuclear medicine. About ten thousand cancer patients are treated everyday with radiation therapy. In one way or the other, the research that we do is all about energy, the energy inside the atom or finding new sources of energy to power the world's economy. One of those new sources may be fusion power. We are working hard on this potentially inexhaustible and totally clean new source of energy and, perhaps, one day a future Secretary of Energy will have the chance to award the Fermi Prize to a scientist for helping us reach the goal of a self-sustaining fusion power plant.

The legacy of both President Eisenhower's vision in "Atoms for Peace" and the scientific wizardry of Enrico Fermi now rest with the Department of Energy. I am very proud to join all of you tonight to celebrate that vision, pay tribute to the heritage of the discovery given us by Fermi and to honor three scientists who are truly worthy heirs to Fermi's genius. Ladies and gentlemen, thank you very much for being here and for your contributions.

The Presidential Enrico Fermi Award Recipients

After his speech, Secretary of Energy Spencer Abraham presented the 2003 Presidential Enrico Fermi Awards. The Fermi award recognizes scientists of international stature for their lifetimes of exceptional achievement in the development, use or production of energy, broadly defined to include the science and technology of nuclear, atomic, molecular, and particle interactions and effects.

This year's recipients were John Bahcall, Raymond Davis, Jr. and Seymour Sack. Dr. Bahcall is Professor of Natural Sciences at the Institute for Advanced Study, Princeton, NJ. For thirty-six years, Dr. Davis was senior chemist at the Department of Energy's Brookhaven National Laboratory on Long Island, N.Y. Dr. Sack retired from DOE's Lawrence Livermore National Laboratory, Livermore, California, in 1990 and continues as a Laboratory Associate.

The winners received a gold medal and a citation signed by the President and Secretary of Energy. Drs. Bahcall and Davis won for their research in neutrino physics. Dr. Sack will receive the award for his contributions to national security. Dr. Sack receives a $187,500 honorarium. Drs. Bahcall and Davis will each receive a $93,750 honorarium.

Scientific Achievements and Background of the Recipients

Dr. John Bahcall, theorist, and Dr. Raymond Davis, Jr., experimentalist, are the scientists most responsible for the field of solar neutrino physics and neutrino astronomy. While contributions to nuclear physics and astrophysics are numerous and varied, this award honors their contribution to fundamental physics, ie., the probable determination that the neutrino has a nonzero rest mass. Bahcall's calculations and Davis's experiments have proved that the sun

(l to r) *Spencer Abraham, Dr. Seymour Sack, Dr Andrew Davis (son of Fermi Award recipient Dr. Raymond Davis, Jr.,who could not attend) Dr. John Bahcall, Dr. Raymond L. Orbach*

is definitely powered by nuclear fusion reaction, and that electron neutrinos oscillate into many "flavors" on their way from the sun to the earth.

Dr. Bahcall pioneered the development of neutrino astrophysics in the early 1960s, when he theorized that neutrinos, because they interact so weakly with matter, provide a unique opportunity to look deep inside the sun and test our understanding of how stars shine. He was the first person to correctly calculate, in 1963, the rate of neutrino capture by 37C1. This result was crucial to the chlorine experiment Dr. Davis was planning. He was the first person, in 1964, to propose that the source of neutrinos could be located by the detection of the recoil electrons in an electron-neutrino scattering experiment, thus allowing one to ascertain whether the neutrinos came from the sun. This effect was finally detected in 1989. Over the years, Bahcall constructed increasingly sophisticated theoretical models of the sun using the best available nuclear reaction rates and other input physics to determine the expected number of neutrinos that should be observed from the sun. His models consider a host of effects and constitute the gold standard for solar models. They played a critical role in persuading experimenters and funding agencies to invest considerable time and money in neutrino detector experiments.

Dr. Davis was the experimentalist who, working with Bahcall's results, first showed that the earth-measured neutrino output from the sun was considerably less than had been anticipated by standard nuclear physics theory. His radiochemical chlorine detector in the Homestake mine was an heroic experiment and the first to directly detect neutrinos from the sun. Over several decades, the puzzle of why he was seeing only about 40% of the flux expected from Bahcall's calculations challenged many in the physics community. No obvious explanations were forthcoming. Dr. Davis stood by his data, however, as he progressively refined his techniques. His constancy forced the physics community to do more complete experiments.

The achievements of Bahcall and Davis are truly singular and their contributions completely entangled. Their path to success was a lonely one for the first twenty years or so. It was not until the 1980s that the combination of Bahcall's persistence with his calculations and Davis's elegant and heroic experiment that others were convinced to initiate a new generation of solar-neutrino-physics experiments such as Kamiokande, SuperKamiokande, GALLEX, SAGE, and most recently Sudbury Neutrino Observatory. With its ability to detect all neutrino flavors, the Sudbury Neutrino Observatory has demonstrated convincingly that the Bahcall solar neutrino flux is correct, that the Davis experiment is correct, and that electron neutrinos produced by the sun are oscillating into another flavor. Data from the new Sudbury Neutrino Observatory, together with data from the SuperKamiokande, have confirmed Dr. Davis's data. We now have definite and deeper insight into neutrino physics: what had been only a theoretical possibility (neutrino oscillation among flavors) must now be accepted as established reality. The implications for theories of particle physics are immense.

Dr. Sack is one of the foremost designers of nuclear weapons. His imprint can be recognized in the first stages of all of the two-stage thermonuclear devices within our continuing stockpile. His design programs introduced insensitive high explosives, fire-resistant plutonium pits, and other state-of-the-art nuclear safety concepts.

In the late 1950s, he developed 2D design codes and in the early 1960s applied them to the design of the first safe, modern primary deployed in the *Polaris* warhead. During the 1960s, he designed primaries for the first "miniature" bombs deployed in the *Poseidon* submarine-launched ballistic missile and the *Minuteman* intercontinental ballistic missile. These designs were prototypes for the warheads developed by Los Alamos National Laboratory and Lawrence Livermore National Laboratory in the 1970s and 1980s.

During the late 1970s and early 1980s, Dr. Sack turned his efforts to the conception and realization of the modern, extremely safe, air-carried nuclear weapon. The potential for aircraft accidents with catastrophic consequences made this a critical need, which Dr. Sack championed for the weapons stockpile. He designed the warhead for both the high yield aerial bomb and the ground launched cruise missile. Simultaneously, he directed both development projects. In this project, Dr. Sack developed the first use of insensitive high explosive and the first fire-resistant pit, thereby greatly enhancing the safety of nuclear explosives in crash and fire accidents.

Over the course of his career, Dr. Sack has maintained extremely high technical standards across a broad spectrum of fields. He has a wide reputation for clear thinking and an uncanny ability to distinguish the essential from the nonessential when it comes to matters relevant to nuclear weapons. Since his retirement in 1990, he has remained extremely active in nuclear weapons design and policy issues. Dr. Sack continues to speak frankly on many of the issues facing the nation during the current decade of stewardship without nuclear testing. His personal and technical integrity has led him consistently to debunk the arguments of those who call for a return to nuclear testing. He has, on numerous occasions, pointed out that there are currently no compelling technical reasons for nuclear testing. His opposition to nuclear testing is derived from his knowledge of the state of current weapon designs and his deep understanding of the issues facing stewardship.