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# PHYSICS & SOCIETY

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# EDITORIAL COMMENTS

## Tribute to the Retiring Editors

Twelve years ago, Al Saperstein became the editor of Physics and Society, with Jeff Marque as the news editor. The two have been functioning as co-editors for the past five years. With this issue, they are both taking a well-deserved retirement.

Thanks to the tireless efforts of these two men, the FPS "newsletter" is in reality a high-quality quarterly journal that is always thought-provoking and sometimes controversial. The typical issue contains a number of substantive articles, stimulating commentary and letters, informative news and interesting book reviews. The editors have had to exert considerable effort to assemble such interesting material on a range of relevant topics, often laboring with little additional help – and without benefit of a peer review system – to fill out the newsletter.

Al and Jeff have persevered through these many years, even though the job is unpaid. They do have the satisfaction of their finished product and the occasional letter or email of recognition. The latter is even more heartening when one realizes that it's human nature to write the editor far more often to complain than to compliment.

We wish to express our deep appreciation to Al and to Jeff for their many years of tireless service. They have conscientiously brought us all a newsletter that informs and challenges. They will be formally recognized for their service during the Forum Awards Session at the April meeting.

*—The Executive Committee, Forum on Physics & Society*

IN THIS ISSUE

# NEWS

## FPS Announces 2008 Election Results

In an election that closed on December 5, 2008, 18.7% of the FPS membership (1058 members) cast ballots. The following officers were elected from a field of excellent candidates:

Vice-chair: Peter Zimmerman

Executive Committee: Jessica Clark and David Harris

Representative to POPA: Lawrence Krauss

## FPS-Sponsored Sessions at March and April Meetings

FPS has arranged many sessions of general interest and societal relevance for the two APS meetings this spring. The March meeting, taking place in Pittsburgh from March 16-20, will feature four sessions sponsored or co-sponsored by FPS. The following lists the sessions and speakers that have been invited and tentative titles for their talks:

*Tuesday, March 17, 8:00 am*

### The Greening of the City of Pittsburgh- The History, Science and Examples

*Devastation and Renewal: Water, Air and Land in Pittsburgh Environmental History:* Joel A. Tarr, Carnegie Mellon University

*Air Quality from Early Pittsburgh to the Present: The Science of Change:* Cliff Davidson, Carnegie Mellon University

*Material Science and Construction using Green Science and Technology:* Alan Traugott, CLJ Engineering

*The Greening of the David L. Lawrence Pittsburgh Convention Center:* Mark Leahy, Lawrence Convention Center

*Wednesday, March 18, 8:00 am*

*(co-sponsor: Forum on Education)*

### Forging Effective Partnerships with Your Local Science Center: Outcomes from the Workshop on University/Science Center Collaborations

*University/Science Center Collaborations (A Science Center Perspective): Developing an Infrastructure of Partnerships with Science Centers to Support the Engagement of Scientists and Engineers in Education and Outreach for Broad Impact:* David Statman, Allegheny University

*University Perspectives on Science Center/University Interactions:* Leo Kadanoff, University of Chicago

*University/Science Center Collaborations: A Science Center Perspective:* Eric Marshall, New York Hall of Science

*Perspective of NSF-MPS Program Directors on Educational Outreach:* Daniele Finotello, NSF Program Officer

*Thursday, March 19, 8:00 am*

*(co-sponsor: the Division of BioPhysics)*

### The Physics of Imaging and Radiotherapy

*Dedicated CT Imaging of the Breast:* John M. Boone, University of California at Davis Imaging Center

*Advanced Tomographic Imaging: Visualization of the Unseeable:* Xiaochuan Pan, University of Chicago Cancer Research Center

*Planning and Delivery of Radiation Therapy—Principles and Recent Developments:* Cedric Yu, University of Maryland School of Medicine

*Image-Guided Radiation Therapy--Application and Advancement:* David Jaffray, Ontario Cancer Institute/ Princess Margaret Hospital

*Panel Discussion Among Speakers:* Barry Berman, George Washington University

*Thursday, March 19, 8:00 am*

### Physics Meets Art

*Quasicrystals in Medieval Islamic Architecture:* Peter J. Lu, Harvard Univeristy

*Analysis of Jackson Pollock Paintings:* Kate Jones-Smith, Carnegie Mellon University

*Analyzing Monet:* Charles Falco, University of Arizona

*Those Bubbles in Beijing: The Story of the Water Cube:* Denis Weaire, Trinity College, Dublin

The "April" meeting, will be held this year from May 2-5 in Denver. FPS, sometimes in collaboration with other APS units, has scheduled 8 sessions. Those sessions and the speakers who have been invited are:

*Saturday, May 2, 10:45 am*

*(co-sponsor: the Division of Physics of Beams)*

### Future Applications of Accelerators

*Accelerator X-ray and Neutron Sources for Advanced Information Technology, Sustainable Energy and Healthier Lives:* Murray Gibson, Argonne National Laboratory

*Medical Applications: Hadron Therapy:* Cynthia Keppel, Hampton University

*Applications in Nuclear Energy Security:* Richard Sheffield, Los Alamos National Laboratory

*Saturday, May 2, 3:30 pm*

*(co-sponsored with the Forum on International Physics)*

### Global Physics Projects

*International Scientific Collaboration:* Christopher Llewellyn Smith, Oxford University

*Panelists:* Joe Dehmer, NSF Physics Division; Michael Holland, Office of Management and Budget; Dennis Kovar, Department of Energy

*Sunday, May 3, 8:30 am*

*(co-sponsor: the Forum on the History of Physics)*

### Science Policy: Yesterday, Today, and Tomorrow

*Lessons from Skating on Thin Ice: Office of Energy Conservation, Office of Technology Assessment, and Office of Science and Technology Policy:* John Gibbons, Former Assistant to the President for Science and Technology

*Civic Scientist Era:* Neal Lane, Rice University

*Science as a Model for Rational, Legitimate Government:* Lewis Branscomb, Kennedy School of Government, Harvard University

*Sunday, May 3, 10:30 am*

*(co-sponsor: the Forum on International Physics)*

### Managing Nuclear Fuels: An International Perspective

*A Contract between Science and Society:* Elizabeth Dowdeswell, Nuclear Waste Management Organization

*Radioactive Waste Management, its Global Implication on Societies, and Political Impact:* Kazuaki Matsui, Institute for Applied Energy

*Disposal of Spent Nuclear Fuel from the Nuclear Research Reactor at the National Institute of Physics and Nuclear Engineering, Romania:* Victor Nicolae Zamfir, National Institute of Physics and Nuclear Engineering

*Sunday, May 3, 1:30 pm*

### Physics Contributions to the Intelligence Community

*"Physics and the Intelligence Community — The Next Decade?"* Donald Kerr, Office of the Director of National Intelligence

*Physics, Physicists and Revolutionary Capabilities for the Intelligence Community:* Lisa Porter, Intelligence Advanced Research Projects Activity

*Physicists & Engineers in the Spy Business—What does the Record Say about National Reconnaissance?* Robert McDonald, National Reconnaissance Office

*Monday, May 4, 10:45 am*

### Is Geoengineering a Possible Stop-Gap Measure to Rapid Climate Change?

*Solar Band Climate Engineering Technologies: Risks and Unknowns:* David Keith, University of Toronto

*The Many Problems with Geoengineering Using Stratospheric Aerosols:* Alan Robock, Rutgers University

*Ocean Iron Fertilization:* Kenneth Coale, Moss Landing Marine Laboratory

*Monday, May 4, 1:30 pm*

## FPS Awards Session

*Science and International Security:* Raymond Jeanloz, University of California, Berkeley, Recipient of the 2009 Leo Szilard Lectureship Award

*Remembering our Humanity: the Deep Impact of the Russell-Einstein Manifesto:* Patricia Lewis, James Martin Center for Nonproliferation Studies, Recipient of the Joseph A. Burton Forum Award

*Tuesday, May 5, 1:30 pm*

## The Role of Scientists in Arms Control

*Dr. Inside and Dr. Outside: Complementary Roles in Arms Control:* Peter Zimmerman, Kings College (ret)

*Progress in Monitoring the CTBT since its 1999 Senate Defeat:* David Hafemeister, Cal Poly – San Luis Obispo

*Technology and Policy: the Role of Technical Community:* Kory Sylvester, NNSA/DOE

# FYI from the American Institute of Physics

**We present here, verbatim, two November 2008 issues of FYI, a news service of the American Institute of Physics highlighting developments in Washington, D.C. that impact the physics community. Both issues are reproduced with the kind permission of their author, Richard M. Jones of the AIP.**

**First is FYI #105, concerning the appointment of a science advisor to the new president of the United States:**

*"It is essential to quickly appoint a science advisor who is a nationally respected leader with the appropriate scientific, management and policy skills necessary for this critically important role." – Letter to Senator, now President-Elect, Obama*

Almost 180 organizations, including the American Institute of Physics, the American Physical Society, and the American Astronomical Society signed letters to Senator Barack Obama and Senator John McCain urging them to quickly appoint a White House Science Advisor by Inauguration Day. The October letters also ask that this position be called the Assistant to the President for Science and Technology and that it be made a cabinet-level position.

A similar recommendation was made in a report issued last summer by the Woodrow Wilson International Center for Scholars. The first of three overarching recommendations in this report, *OSTP 2.0*, stated:

*"The President should appoint a nationally respected leader to be Assistant for Science and Technology. This individual should serve at the cabinet level. The appointment should be made early in the new Administration, along with the appointments of heads of cabinet-level agencies."*

President Bush nominated John Marburger to be his science advisor five months after he was inaugurated. In reviewing this development in 2001, FYI noted: *"President Bush's lack of a science adviser has been a growing source of concern within the S&T community. There is speculation that the Administration's FY 2002 budget request for R&D might have been higher had there been a science advisor. There is also concern that policies with a large science component, such as global warming, stem cell research, and national missile defense are being formulated without the input of a science advisor. Senior level S&T appointments also await the guidance of this advisor."*

This letter was sent under the leadership of the American Association for the Advancement of Science and the Association of American Universities. The full text of this letter follows:

*Dear Senator Obama:*

*The next President of the United States will face a wide range of domestic and international challenges, from financial and regulatory reform to healthcare and rising energy costs, from global climate change to ensuring U.S. economic competitiveness and national security. These challenges share one thing in common: long-term solutions that will be impossible without groundbreaking scientific and technological advances. It is therefore critical that the next President seek out and rely upon sound scientific and technological advice early and often in the new Administration.*

*Your responses to the Science Debate 2008 questions reflect your acknowledgment of the important role that science will play in a new Administration. With this in mind, it is essential to quickly appoint a science advisor who is a nationally respected leader with the appropriate scientific,* *management and policy skills necessary for this critically important role.*

*For these reasons, the undersigned organizations representing the business, education and scientific communities urge you, if you are elected President, to appoint your White House Science Advisor by January 20, so this individual can participate immediately in coordinating relevant policy and personnel decisions relating to science and technology.*

*We further urge that the next President give the science advisor the title of Assistant to the President for Science and Technology and assign the position a cabinet rank, the same status currently given to the Director of the Office of Management and Budget, the Administrator of the Environmental Protection Agency, and the U.S. Trade Representative.*

*The next President must lead our country in addressing the national issues of concern to us all. To do so effectively, science and technology must be part of the solution. Putting a science advisor in place early, and providing this individual with adequate stature and authority within the White House, will help the new President effectively address the challenges we face.*

**Next we print FYI#107, concerning American participation in ITER, the International collaboration on controlled fusion energy production:**

Gene Nardella, DOE Acting Associate Director of Science for Fusion Energy Sciences told the Fusion Energy Sciences Advisory Committee that he would be discussing the program's "highlights and low lights" during his November 6 presentation. The highlight: Congress is "still very supportive" of the fusion program. The low light: the United States "cannot live up to our commitments" to the ITER project with the amount of money Congress has previously appropriated.

Nardella was succinct: "the key thing for us is the appropriation." Given the lack of an FY 2009 DOE appropriations bill, the program is being funded under a stop-gap continuing resolution funding bill that provides, when combined with additional supplemental funding, $20.5 million for the first five months of FY 2009. The Administration requested $493.1 million for the entire year. The resulting shortfall has required the Department of Energy to back off its commitments to ITER for equipment, staffing, and the central reserve fund. DOE is now running, a "very tight, very effective" fusion program while it awaits the outcome of the FY 2009 appropriations cycle. An exhibit stated *"Despite the funding problems, the U.S. has remained fully engaged in ITER activities at the international level, including those subsidiary bodies associated with its governance."* Nardella is hopeful that Congress will settle on a final funding bill before the continuing resolution runs its full course into early March.

DOE is looking ahead to the incoming Obama Administration and the new Congress. Nardella told the advisory committee, chaired by Martin J. Greenwald of MIT, that ITER "will be high on the list" for Congress when it reconvenes. The fusion community must now work to demonstrate to President-Elect Obama's transition team the value of the ITER program. In doing so, the community should explain that ITER is the largest part of the fusion program, but not the only part.

The House and Senate Appropriations Committees and their subcommittees have been very supportive of the Administration's FY 2009 fusion request. The House Energy and Water Development Appropriations Subcommittee recommended a 65.2 percent increase over the FY 2008 budget and provided the full ITER request. The subcommittee stated: "Given the tremendous potential of fusion energy to provide a long-term solution to our energy needs, this Committee believes it is essential that the U.S. continue to play a leadership role in this area." The fusion program received similar support from Senate appropriators in their version of this bill, with a 63.2 percent increase. One of Nardella's exhibits stated *"The FY 2009 Appropriation will determine the extent that the project can resume fulfilling its commitments to design and R&D, long-lead procurements, and funding contributions to the ITER Organization. A year-long CR [continuing funding resolution] could be problematic depending on specific guidance,"* with Nardella saying that limited or no funding for ITER would cause cost and schedule problems in coming months.

Also discussed was report language included by House appropriators in their committee report: *"the [Energy] Department is directed to provide the Committee with a report no later than March 1, 2009 which describes a bold, credible plan for a world-leading U.S. fusion program as this area becomes an increasingly international endeavor."* Nardella told the fusion energy advisory committee that DOE is "working very hard" to develop a plan that will give Congress "a flavor of where we are going." The plan will outline the fusion program's goals and strategy in the next four to eight years, and will draw on four reports and studies. The advisory committee will get a draft of the plan in the next few weeks and will meet to discuss it in mid-January.

# COMMENTARY

## Advocacy Threatens Scientific Integrity

*Robert E. Levine*

Physicists, as well as the entire scientific community, should be concerned about the harm that advocacy is doing to scientific integrity. Certain aspects of the current discourse on climate change exemplify this harm.

In using the term "scientific integrity," I refer to the integrity of the scientific process, as distinct from the public reputation of science. The latter is subject to societal forces that scientists cannot fully control. The former is solely the responsibility of scientists, whose actions and teachings will determine the future state of scientific knowledge.

One key element of scientific integrity is articulated in the APS statement that was adopted on 14 November 1999. The pertinent text on the APS Web site reads as follows:

"The success and credibility of science are anchored in the willingness of scientists to:

1. Expose their ideas and results to independent testing and replication by others. This requires the open exchange of data, procedures and materials.
2. Abandon or modify previously accepted conclusions when confronted with more complete or reliable experimental or observational evidence."

I will refer to items 1 and 2 listed above as the "openness principles."

Science institutions and leaders support the openness principles by administering peer review and publication activities in accordance with them, by acting to insure that the performance of these activities reflects scientific expertise and judgment, by making the publication process open to all qualified researchers and all results obtained by sound methods, by encouraging the maintenance of multiple centers of expertise rather than allowing centralized control over science, by fostering the development of multiple experimental and theoretical approaches to significant problems, and by working to prevent non-scientific considerations and external interests from influencing the scientific process or its results.

In numerous areas of research, the institutions of science demonstrate that the openness principles apply even when established scientific conclusions are challenged. In physics, the recent history of neutrino research is exemplary, because physics institutions encouraged and funded new research directions that could have led to either retaining or abandoning the initial and long-held understanding that neutrinos have zero rest mass. Likewise, physics institutions remain open to considering a variety of seemingly unlikely possibilities that differ from current understanding. Examples of these possibilities include time varying fundamental quantities, modification of the inverse square law for gravity, and alternatives to inflationary big bang cosmology.

In conflict with this well-known history, the statement on climate change adopted by the APS Council on 18 November 2007 appears to signal a startling change in direction away from the openness principles, for the following reasons:

The APS statement on climate change contains important scientific assertions, but is written at a high level of generality that is typical of a public announcement of research results. Unlike most such announcements, this statement gives no reference to an underlying scientific document that supports its assertions with testable results.

Readers of the APS statement on climate change appear to have generally construed the primary source of its assertions and the focus of its endorsement to be the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports and the published research results that form the basis of their scientific content. The APS Council presumably accepts this interpretation, but has offered no scientific rationale for privileging these particular documents and results, to the exclusion of other relevant scientific output.

The APS statement on climate change, because it has the effect of endorsing particular evolving research results, appears to be an unprecedented and unexplained deviation from the customary role of a scientific society as a neutral enabler of open scientific communication through peer review and publication.

The APS statement on climate change appears to have the effect of deprecating any existing or future result that shows an anthropogenic climate influence less than that reported by IPCC and any report of a significant non-anthropogenic influence that might otherwise help explain observed climate data and trends. Concern about this effect is not hypothetical, because recently published results,[1] results that have been accepted for publication,[2] and new results that have been disclosed by a senior climate research scientist in advance of publication[3] all conflict with key IPCC assertions.

The linkage of scientific assertions to long-term policy recommendations in the APS statement on climate change appears to imply an endorsement that is open-ended. This endorsement, together with similar statements from other scientific societies, arguably has the effect of tending to establish the IPCC as the single top-level authority over the entire scientific process for study of the Earth's climate, thereby terminating a key element of the open scientific process. This possibility appears never to have been acknowledged or debated in the scientific community.

The openness principles are too important to be abandoned or even waived for particular areas of scientific study. Moreover, maintaining them for study of the Earth's climate will improve rather than harm this field of science. As an independent scientific society, the APS retains the right to undo its deviation from the openness principles by retracting the scientific assertions contained in its statement on climate change, by asserting its support for researchers to continue publishing work in this field whether or not such work supports the IPCC results, and by asserting its support for open scientific publication with no central authority over any field. If the APS Council acts now to reassert the primacy of the openness principles, it will undoubtedly be criticized by some climate change policy advocates. However, the longer the APS waits to reassert the independence of science from advocacy, the more difficult it will be to do so.

## References


1. *Richard S. Lindzen, "Taking Greenhouse Warming Seriously," Energy & Environment, Vol. 18, pp 937-950 (2007).*
2. *David H. Douglass and John R. Christy, "Limits on CO2 Climate Forcing from Recent Temperature Data of Earth," accepted for publication by Energy & Environment (August 2008).*
3. *Roy W. Spencer, Testimony before the Senate Environmental and Public Works Committee (22 July 2008).*



*Dr. Robert E. "Bob" Levine was awarded a PhD in physics in 1970, worked in physics and engineering, and retired in 2007. He began his professional career developing scientific instrumentation at Princeton Applied Research Corp. In 1973 he moved to the petroleum services industry, working in science and technology at the Schlumberger-Doll Research Center and then in engineering, initially at the Welex division of Halliburton Corp. and later at Dresser-Atlas. In 1986, he shifted to national defense work at Ft. Huachuca, AZ, first as a contract employee, subsequently as a civilian employee of the US Army, and later at an agency of the US Department of Defense. His defense work concerned development and testing of information technology systems, with emphasis on systems architecture, data management, test methodologies, and project direction.*
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# ARTICLES

## The Revised Radiation Protection Standards for the Yucca Mountain Nuclear Waste Repository


*Robert Vandenbosch and Susanne E. Vandenbosch*


### Introduction

In September 2008 the Environmental Protection Agency (EPA) issued its final radiation standards for the proposed geologic nuclear waste repository at Yucca Mountain. This was months after the Department of Energy had filed its license application for the repository with the Nuclear Regulatory Commission. These standards will be incorporated into NRC regulations.

### Early History of the Development of the Radiation Standards

The Nuclear Waste Policy Act of 1982 established deep geological disposal as the method for disposal of nuclear waste from commercial nuclear power reactors, and in 1985 the EPA issued generic standards that would apply to all geological repositories. Part of these standards was remanded by the federal Court of Appeals for the District of Columbia in 1987. Also in 1987 Congress amended the Nuclear Waste Policy Act, designating Yucca Mountain as the only site to be characterized further for a repository instead of three sites required by the 1982 Act. Congress directed the EPA to issue radiation standards specific to Yucca Mountain in 1992, and to seek and follow the advice of the National Academy of Sciences in preparing these standards. In 1995 a committee of the National Research Council, an arm of the National Academy of Sciences, issued its recommendations in a report titled "Technical Bases for Yucca Mountain Standards".[1] Hereafter this report will be referred to as the NAS report.

## The EPA Issues Radiation Standards for Yucca Mountain in 2001

In 2001, the EPA issued 40 CFR part 197, Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada.[2] The standards consist of three parts:

1. An Individual-Protection Standard of 15 mrem/yr that applies to a "reasonably maximally exposed individual" who lives in a publicly accessible area and has a diet and lifestyle representative of present residents of Amargosa Valley.
2. A Human-Intrusion Standard concerned with exposure that might occur as a result of drilling in the vicinity.
3. Groundwater Protection Standards setting separate concentration limits (15 picocuries per liter) on alpha emitters and dose limits (4 mrem/yr) from combined beta and photon emitters.

The limitation of the standards to the first 10,000 years after repository closure resulted in a Court challenge by the State of Nevada and the Natural Resources Defense Council.[3] They based this challenge on the fact that the NAS report had recommended that the standards should extend to the time of expected peak dose. DOE performance assessments at the time indicated this was of the order of 300,000 years. The appeals were heard by the federal Court of Appeals for the District of Columbia in 2004. The Court ruled the EPA's compliance period was clearly not consistent with the NAS recommendation. It said the EPA would either have to come up with a new standard or secure new legislation negating the consistency requirement with the NAS recommendation. The Court allowed the other parts of the EPA's standards to stand, including the Groundwater Protection Standard which had been challenged by the Nuclear Energy Institute.

## The EPA Responds in 2005 with Proposed Revised Standards

In August of 2005 the EPA issued its proposed amendment to the Radiation Protection Standards for Yucca Mountain which added a new protection standard of 350 mrem/yr for the period between 10,000 and 1 million years.[4] The proposed amendment also changed the measure of how the limit was to be applied to the DOE's performance assessment. As allowed by the Court, it let stand the Human-Intrusion Standard and Groundwater Protection Standard. It also let stand the 15 mrem/yr limit for the first 10,000 years.

The EPA opened the proposed amendment of the radiation standards to public comment for several months. More than 300 individual submittals were received before the comment period closed in late 2005.

## The EPA Finalizes the Standards in 2008

### *Summary of the Revisions*

In late September of 2008, the EPA issued its final Amendment of the Radiation Protection Standards for Yucca Mountain.[5] The final standards reflect few but nevertheless significant changes from the Proposed revisions of 2005. Most importantly, the radiation dose for the period between 10,000 and 1 million years was changed from 350 mrem/yr to 100 mrem/yr, and the metric for the limit for this period was changed from the median to the mean. Since the mean typically exceeds the median for the distribution of expected doses in DOE performance assessments, these two changes imply a reduction of about a factor of seven in the allowed dose for the time period after 10,000 years. Since the 15 mrem/yr limit for the first 10,000 year is retained, the standard remains two-tiered.

### *The (il)logic of an uncertainty-based larger dose limit after 10,000 years*

The EPA in its preamble emphasizes the increasing uncertainty in the reliability of dose estimates for longer times. Considerable effort is expended to demonstrate the increase in projected uncertainties with time. This is not the issue. We know of no informed individual who would argue that performance assessment uncertainties would not increase over a long period of time. Rather the issue is what the regulatory response should be to uncertainties. It would seem that to provide the same confidence in protection of the public in the presence of increased uncertainties one would have to make the standard more conservative rather than less conservative.

Perhaps an analogy might help. Consider an engineer responsible for specifying the quality rating specification of a girder for a bridge. It is found that with increasing time the uncertainty in the corrosion weakening of the girder increases. If one wants to extend the time for which one would have confidence in the integrity of the bridge, would one loosen or tighten the quality rating specification of the girder? It would seem obvious that one would tighten the specification to have the same confidence that the girder would not fail at larger times as at shorter times.

### *Intergenerational Equity*

The principle of intergenerational equity has been endorsed by several broadly-based organizations, including the International Atomic Energy Agency and the Organisation for Economic Co-operation and Development's Nuclear Energy Agency. This principle requires that the risks to future generations be no greater than the risks that would be accepted today.[6]

A straightforward interpretation of this principle would require that the radiation standard not allow future generations to be exposed to more radiation than the present generation. Thus the two-tiered Standard in the EPA's rule with an appreciably larger dose limit at later times (100 mrem/yr) than at early times (15 mrem/yr) is not consistent with this principle. The EPA in its preamble to its rule recognizes this problem. It falls back on a statement in the NAS report that "whether to adopt this or some other expression of the principle of intergenerational equity is a matter for social judgment".[7] The EPA tries to argue that intergenerational equity does not require that the same compliance standard must apply at all times. It says that such a requirement ignores the complexities involved in establishing protection standards for periods as long as 1 million years, and that the basis for judgment at different times is not the same. The EPA's final defense of its position is that the less restrictive standard for longer times is still "protective of public health and safety, and will offer comparable, if not identical, protections to the affected generations". If this is true, one wonders why they didn't use the same "protective" standard of 100 mrem/yr for both time periods.

### *Are the Standards Protective of Human Health?*

Finally we address the most important question regarding the Final Yucca Mountain Radiation Standards- are the numerical values of the dose limits reasonably protective of the public? This discussion will focus on the 100 mrem/yr standard, because if this standard is acceptable surely the more stringent 15 mrem/yr standard will be also. First, it may be helpful to translate the effective dose rate limit into the expected detrimental health effects of such a dose. Assuming a linear relation between dose and the probability of developing a fatal cancer of approximately $5 \times 10^{-7}$ per mrem[8], a one-year exposure to a dose of 100 mrem would result in a probability of developing a fatal cancer of $5 \times 10^{-5}$ for each individual.

The NAS report did not make a specific recommendation regarding the dose or risk level that should be established by the protection standard. The report states that what risk is acceptable is a question of public policy rather than of science. The report does give some examples of risk limits established by other U.S. nuclear regulations and by authorities outside of the U.S. These are generally in the range $10^{-5}$ to $10^{-6}$ per year. The NAS report suggests that this range could be used as a reasonable starting point in the EPA's rulemaking.[9] Thus we see that the 100 mrem (risk= $5 \times 10^{-5}$) standard is an order of magnitude larger than, most other standards.

The EPA says the present standard is based on a recommendation of the International Commission of Radiation Protection (ICRP). This commission has issued recommendations for the dose to be used to select constraints in various situations, including both occupational exposure and general public exposure. An apparently relevant situation covered by the Commission recommendations is for the practices where there is no direct benefit for the exposed individual but where there may be a societal benefit. For this situation the Commission recommends a maximum effective dose of 100 mrem/yr[10], and this is the value incorporated in the EPA's rule for the period between 10,000 and 1 million years. The EPA does not mention however a more ICRP specific recommendation[11] of a dose constraint of 30 mrem/yr for members of the general public for exposure resulting from nuclear waste management. This lower value for waste disposal is based on the idea of apportionment of the total allowable 100 mrem/yr limit for all anthropogenic sources of radiation, excluding medical exposures.[12] The EPA does discuss the apportionment issue, arguing that it is reasonable to allocate the entire 100 mrem/yr to the repository. It bases this on the lack of other significant anthropogenic sources in the area, and assumes that current conditions will apply in the future. The apportionment issue is mentioned in a Nevada suit against the EPA filed with the Court of Appeals within weeks of the issuance of the final standards.[13]

Remembering the NAS's assertion that setting a risk limit is a matter of public policy, what can we use as guide in setting a standard? It would seem that a standard set as a matter of public policy should be informed by risks that the public routinely takes without governmental regulation. Of particular relevance are risks related to radiation. The average natural background citizens are exposed to varies greatly (primarily due to differences in radon) in different parts of the country. These differences can exceed the 100 mrem/yr limit for exposure to individuals living the closest to Yucca Mountain. There is also appreciable radiation exposure to individuals who fly frequently. One cross country flight results in an exposure of 2.5 mrem, so that airline personnel making 50 cross country round trips per year receive two and one half times as much extra radiation as would a maximally exposed resident near Yucca Mountain. The government makes no attempt to regulate public residence in areas of higher radiation background, or to limit radiation exposure associated with frequent flying. Thus it may be reasonable to allow a radiation exposure that is still less than that society and government accepts in other circumstances.

In conclusion, we suggest that an exposure limit of 100 mrem/yr may be of an acceptable magnitude, although a limit of 30 mrem/yr might be easier to justify on the basis of international practice and advice. We reject the EPA's argument that a less stringent limit at longer times is consistent with intergenerational equity, and argue that the proper response to larger uncertainties in repository performance for longer times would be for more stringent rather than less stringent dose limits for longer times.

### *Can the Yucca Mountain Repository meet the EPA Standards?*

The Department of Energy filed a license application to construct the Yucca Mountain repository in June, 2008, prior to the EPA's release of its final standards. In preparation for the license application, the DOE has published a report[14] detailing performance assessments for the proposed repository. These assessments indicate that individuals residing close to Yucca Mountain would receive a maximum of about 0.25 mrem/yr during the first 10,000 years, and a maximum of about 2 mrem/yr during the 10,000 to 1 million year period. The Nuclear Regulatory Commission will be examining the data, models, and assumptions used in these assessments in their consideration of whether to grant a construction license.

## Footnotes

1 *"Technical Bases for Yucca Mountain Standards", National Academy Press, Washington, D.C., 1995.*

2 *Federal Register 66, 32074, June 13, 2001*

3 *This and other Court challenges related to the Yucca Mountain repository are discussed in more detail in Chpt. 10 of "Nuclear Waste Stalemate: Political and Scientific Controversies", Robert Vandenbosch and Susanne Vandenbosch, U. of Utah Press, Salt Lake City, 2007.*

4 *Federal Register 70, 49014, Aug. 22, 2005.*

5 *Federal Register 73, 61256, Oct. 15, 2008.*

6 *"Technical Bases for Yucca Mountain Standards", p. 56.*

7 *Ibid., p. 57*

8 *"Health risks form exposure to low levels of ionizing radiation: BEIR VII Phase 2", National Research Council of the National Academies. Washington, DC., National Academies Press, 2006.*

9 *"Technical Bases for Yucca Mountain Standards", p. 49*

10 *"The 2007 Recommendations of the International Commission on Radiological Protection", International Commission on Radiation Protection Publication 103, Annals of the ICRP 37, Nos.2-4, 2007.*

11 *Ibid., p. 105; "Radiation protection recommendations as applied to the disposal of long-lived solid radioactive waste", International Commission on Radiation Protection Publication 81, Annals of the ICRP 28, No. 4 (1998).*

12 *"Technical Bases for Yucca Mountain Standards", p. 41.*

13 *State of Nevada, Petitioner, v. United States Environmental Agency: Stephen L. Johnson, Administrator: and United States of America, Respondents, Oct. 8, 2008. www.statenv.us/nucwaste/policy.htm*

14 *Total System Performance Assessment Model/ Analysis for the License Application. MDL-WIS-PA-000005 REV00, U.S. Department of Energy, Jan. 2008.*

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# Issues in the Storage of Electric Power

*Ruth Howes and Sekazi Mtingwa*

Most of us are now well aware that the economic security of the United States requires development of renewable energy sources, and that our aging electrical grid needs renewal. The storage of electric power is essential to both these objectives. POPA recently prepared a report on this problem that can be downloaded at http://www.aps.org/policy/reports/popa-reports/index.cfm. This article summarizes that report.

There are at least three critical properties of an electric power supply system: 1) Stable voltage at any current; 2) Stable frequency (critical for digital equipment) and 3) No interruption of service even for very short times. One study (1) estimates that power outages cost US consumers $79 billion annually with 2/3 of this due to outages lasting less than 5 minutes. Short power outages are rarely critical for domestic consumers, but they cause large computer processing operations to reboot all the computers in their systems. For the Fabs where chips are manufactured, even a brief power outage means the loss of an entire batch of melt material plus the labor of cleaning up the resulting mess. Electricity storage can function as a backup source of electric power during unavoidable power outages.

In the U.S., demand for electric power varies by about a third with time of day as well as with seasons of the year. Therefore power companies vary the energy sources used to generate the electric power they provide. For example, nuclear reactors cannot be quickly shut down and restarted while natural gas generation plants can be quickly started and stopped. Nuclear power is excellent for providing power to meet a stable base load while natural gas plants are used to respond to surges in demand or peak loads that occur when people come home from work or when hot weather causes people to run their air conditioners. Electricity storage can stockpile electric power from a background source and release it to meet peak needs. Increased reliance on nuclear power plants will require storage to meet peak demand in a timely manner. Many renewable energy sources, for example solar energy and wind energy, are intrinsically variable, and storage will be needed to allow them to supply electricity when demand is highest.

Many renewable sources of electricity are geographically distributed and must be connected to the grid both to allow back up to a local generator and to enable local generators to add power to the grid. Such systems will need storage to enable frequency and voltage matching. Power matching applications of electricity storage will become more important with the growth of new generation technologies based on renewable sources.

Finally, local electric power companies can use large scale storage to supply power to isolated subdivisions while they plan future construction and spread expenses evenly over time. No storage technology can be seriously evaluated without considering economic feasibility. Any commercially viable technology will have to have a reasonably long life time. Table 1 below describes the properties of storage systems needed to make them effective for various applications. Rated properties include the rate at which energy can be discharged (discharged power), total energy stored, efficiency required, and total lifetime. Applications include power matching ( providing more power to meet peak demand or sudden surges in demand), backup power during outages, enabling renewable technologies (by storing power generated by intermittent renewable technologies such as solar power or wind power for use when the power source is not available), and power quality (that is keeping voltage and frequency stable during demand fluctuations).

## Energy Storage Technologies

There are currently six technologies for electricity storage that are under active consideration for commercial deployment: pumped hydropower, compressed air storage (CAES), batteries, flywheels, superconducting magnetic energy storage (SMES) and "super" capacitors. They are in various stages of development and commercialization and offer differing advantages.

Pumped hydropower storage uses off-peak electric power to operate pumps that fill a water reservoir. At peak demand, the stored water is released through a hydroelectric generating plant. The technology is well understood and has been commercially deployed, for example, by the TVA at the Raccoon Mountain Plant which has a generating capacity of 1600 megawatts. Hydropower responds quickly to changes in demand and can generate high levels of power for long times. The difficulty with pumped hydropower is that it requires a large reservoir with attendant environmental problems, and systems are very expensive to construct. Projected improvements rely on variable speed pumps and turbines which can lead to at least a 3% increase in efficiency.

Compressed air storage uses off-peak power to pump compressed air into a storage container. On a commercial scale, the container will probably be a limestone cavity. Should CAES be used to support distributed generation, the container will a pressurized tank. There are two large CAES facilities built as demonstration plants although there are no commercial facilities as yet. CAES is less environmentally damaging than pumped hydro and as a distributed system is projected to work as a natural partner with wind generation. Large scale systems require a reservoir to store the compressed air, and small scale systems have safety problems with the possibility of exploding containers. Technical advances include development of small scale systems for distributed generation and better storage containers for the compressed air.

**Table 1: Requirements for Different Applications of Electricity Storage Based on data from Schoenung (reference 2)**

| Application | Matching Electricity Supply to Load Demand | Providing Backup Power to Prevent Outages | Enabling Renewable Technologies | Power Quality |
|---|---|---|---|---|
| Discharged Power | <1 MW to 100's of MW | 1 - 200 MW | 20 kW to 10 MW | 1 kW to 20 MW |
| Response Time | <10 min | <10 ms (prompt)<br><10 min (conventional) | <1 sec | <20 ms |
| Energy Stored | 1 MWh to 1000 MWh | 1 MWh to 1000 MWh | 10 KWh to 200 MWh | 50 to 500 kWh |
| Need for high efficiency | high | medium | high | low |
| Need long cycle or calendar life | high | high | high | medium |

Batteries are a major technology for portable energy storage and find wide application in transportation and portable appliances. Here we consider only their application to the storage of electric power. In these applications which are primarily commercialized at facilities like the Fabs where power outages are disastrous, battery banks are located close to the facility that is being protected. Local power companies also use battery banks to supply emergency power in areas where power demand has rapidly growing peak demand. Batteries offer high energy storage densities, rapid response times, and they are portable. However, they are very expensive and have limited life times. The materials of which they are made pose environmental hazards. There are major research efforts underway to develop batteries that cost less and have longer life times. The research is creative but there is a long way to go before batteries will be an affordable option for electricity storage on a residential or industrial scale.

Flywheels store energy as rotational kinetic energy. They can store more energy if they operate at greater rotational velocities or if they are larger. They are limited by the properties of the materials of which they are made since large wheels tend to break apart at high angular velocities and by dynamical instabilities in rotation. Flywheels respond very quickly and can be connected in "farms" for large energy storage. At present, they are in a prototype phase and are very expensive. The obvious research needs are in materials science.

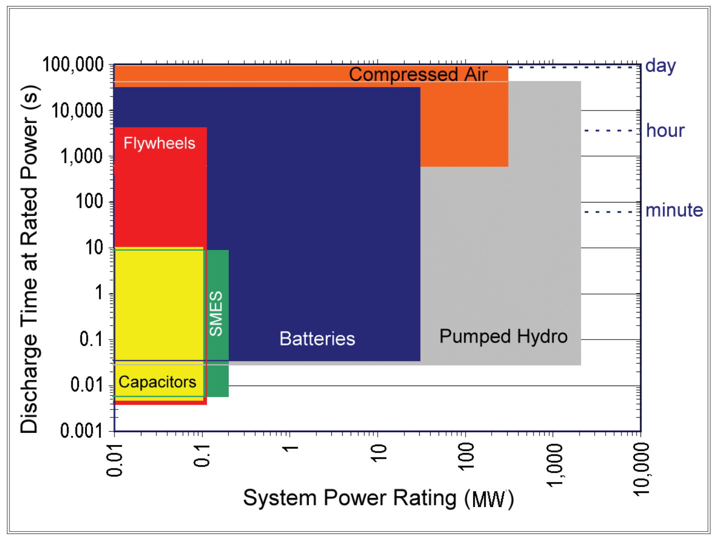
Superconducting magnetic energy storage uses high currents in superconducting coils to store electrical energy. SMES systems offer the possibility of very fast response with discharge of high power. For large scale energy storage, they can be networked, and they have long lifetimes because they have no moving parts. However, they require cryogenic systems which do wear out, and they are very expensive and currently experimental. However, it is possible that developments in materials such as high Tc superconductors could make this appealing technology a practical method of storing electrical energy.

Conventional capacitors store energy as a charge on electrodes separated by a dielectric material. Charge storage depends on the area of the electrodes. "Super" capacitors increase the electrode area by using porous electrodes and vary materials to increase operating voltages. They are potentially capable of rapid and high power discharges. Like SMES systems, they have no moving parts and potentially long lifetimes. At present, they are experimental, expensive and able to store little energy.

Figure 1, prepared by John Scofield, compares the capabilities of electricity storage technologies as of this writing.

A final issue in electrical energy storage is the power conversion system that releases or stores power and matches voltage and frequency to the grid. Power conversion systems need to operate with rapid response time at high currents and voltages to produce power with stable voltages and frequencies. They must be reliable and efficient. Although they are often overlooked in discussions of storage technologies, power conversion systems account for at least 20%, and as much as 70%, of the cost of an electricity storage system because they are one-of-a-kind. They require thermal backup and are limited by currently available thermal materials. Finally, computer models of systems do not include power conversion. There is a genuine need for software for modeling storage systems as a part of the grid that will allow for efficient planning.

**Figure 1:**
**Capabilities of Existing Electricity Storage Technologies**




## Political Issues in Implementing Electrical Storage

Even if the technical issues in storing electrical power can be resolved, there are a number of political barriers to implementing new systems, particularly on a distributed basis. The first question is, who should pay for implementing storage systems and for demonstration projects? Power companies argue that the federal and state governments should support research and development until technologies have been shown to be commercially feasible. Demonstration projects whose costs are shared between the government and the utility company seem promising for large storage project. In the case of distributed storage systems, one must ask whether the owner of the grid or the owner of the generating system owns the storage system. It is possible that a system could be developed whereby power companies charge premium prices for high quality power that is uninterruptible and has very stable voltage and frequency.

On the federal level, research and development of electrical power storage systems are spread across agencies from DOE and DOD to NASA. *There is an urgent need for a central panel to coordinate efforts as well as to recommend pricing and regulatory policies to facilitate the development and deployment of electrical storage systems*. It is also critical to consider the environmental impact of diverse storage systems.

In conclusion, it is clear that increased reliance on either nuclear fission or renewable energy sources for generation of electric power will require the use of electrical power storage systems. While electricity storage systems and the power conversion systems they require are not a glamorous as large wind farms or the huge mirrors of solar thermal power, they will be an essential component of the grid of the future.

## References


1. *K. LaCommare and J. Eto, Lawrence Berkeley National Laboratory Report no. LBNL-55718, Understanding the Cost of Power Interruptions to U.S. Electricity Consumers, Sept. 2004, http://repositories.cdlib.org/lbnl/LBNL-55718 .*
2. *Schoenung, Susan B: Characteristics and Technologies for Long-vs. Short-Term Energy Storage (2001) Sandia Report SAND2001-0765 published by Sandia National Laboratories.*



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*Sekazi Mtingwa served as chair of the POPA study on the Readiness of the U.S. Nuclear Workforce for 21st Century Challenges. He is an accelerator physicist and Senior Lecturer at MIT. During 1998-2008, he served on DOE's Nuclear Energy Research Advisory Committee, and he continues to serve on its Advanced Nuclear Transformation Technologies Subcommittee, which advises DOE on its reactor spent fuel R&D Program.*


# Readiness of the U.S. Nuclear Workforce for 21st Century Challenges From a Report of the APS Panel on Public Affairs[1]


*Sekazi Mtingwa*


The 21st century has brought a growing realization that it is time to reexamine the adequacy of the U.S. nuclear workforce and its ability to deal with many old and new challenges. This workforce comprises nuclear engineers, nuclear chemists, radiochemists, health physicists, nuclear physicists, nuclear technicians, and certain related disciplines. As a group they play critical roles in the nation's nuclear power industry, nuclear weapons complex, defense against nuclear and other forms of terrorism, industrial processing, healthcare, and occupational health and safety. Each of these areas presents dramatically more challenges than in previous years.

Workforce shortages in the arena of commercial nuclear power mainly stem from the 30-year stasis in U.S. demand for new civilian nuclear power plants[2]. The number of operating civilian nuclear reactors in the U.S. has remained at about 100 during this time. Their continuing, largely static nuclear engineering workforce needs have been met through a combination of hiring those trained in university nuclear engineering programs and retraining others whose original expertise was in some other field, usually mechanical engineering. Retirees from the nuclear Navy also have played an important role.

Today there is increasing public concern about anthropogenic global warming. A 2003 Massachusetts Institute of Technology report[3] noted that there are few options in the near future to reduce greenhouse gas emissions from the production of energy: increased efficiency, increased reliance on renewable sources such as wind and solar power, capture and sequestering of carbon dioxide emissions, and increasing the contribution from nuclear reactors. About 20% of the electricity in the U.S. comes from its fleet of 104 commercial nuclear reactors, which annually displace hundreds of millions of metric tons of carbon emissions. These reactors currently account for approximately 70% of the non-carbon emitting electricity production in the U.S.

The Energy Policy Act of 2005 was the first comprehensive energy legislation in the U.S. in over a decade. Among its many provisions was the authorization of Nuclear Power 2010[4], a joint government/industry program to accomplish the following: (1) identify new nuclear reactor sites, (2) bring to market advanced standardized nuclear reactor designs; and (3) demonstrate improved regulatory licensing. It also authorized Federal loan guarantees and other financial incentives. Spurred by this program, private industry currently is submitting combined construction and operating license applications to the Nuclear Regulatory Commission.

On another front, the tragedy of September 11, 2001, has brought an intense focus on the issue of national preparedness against terrorism. For emergencies involving a terrorist action or an accident at a nuclear reactor, experts must be ready to respond. Thus it is important to attend to the nuclear workforce needs of the Department of Homeland Security, the Department of Defense, the NRC, and specialized areas of the Department of Energy. An important example of the latter is the Nuclear Emergency Support Team from DOE's National Nuclear Security Administration that travels to the site of a suspected nuclear or radiological weapon to mitigate the situation. Thus, the nation will need to expand its nuclear workforce to initiate new efforts in nuclear forensics and other parts of the Homeland Security portfolio, and to replace many retiring members of the weapons workforce.

For many years, funding for U.S. university nuclear science and engineering research and education has been heavily dependent upon a single source: previously DOE and now the NRC. Therefore, it is no accident that the vitality of the nation's university nuclear science and engineering education and infrastructure program closely tracked funding support provided by DOE over the last 15 years. As shown in Fig. 1, as DOE's funding increased in the decade 1997 through 2007, undergraduate student enrollment in nuclear engineering increased – from a low of 480 students in 1999 to a high of 1,933 in 2007. For nuclear engineering students at minority-serving institutions, DOE support created new opportunities. While other factors[5] also contributed to the dramatic increase in undergraduate enrollments, university administrators indicate that increases in Federal funding were indeed an important factor.

In the aftermath of the accidents at Three Mile Island in 1979 and Chernobyl in 1986, DOE support for nuclear science and engineering education declined precipitously as industry construction of new plants ceased and student interest and career opportunities declined. In 1997, the President's Committee of Advisors on Science and Technology issued a report that urged President Clinton to reinvest in university nuclear science and engineering research and education[7]. PCAST also urged him to establish the Nuclear Energy Research Advisory Committee to provide advice to DOE on this reinvestment. In the mid-1990s, the Clinton administration recognized the potential for a resurgence in nuclear technology, and constituted NERAC in 1998 to advise DOE as it began reinvesting both funds and management attention to rebuilding the educational infrastructure for nuclear science and engineering. This support was implemented by creating a suite of eleven targeted programs, among which perhaps the most influential was the Innovations in Nuclear Infrastructure and Education (INIE) program, which encouraged the development of strategic consortia among universities, DOE national laboratories and industry.

When DOE released its FY2007 budget request, it announced that it had completed its mission in the area of nuclear science and engineering education and made plans to terminate the program. DOE proposed essentially zero funding for nuclear science and engineering education for both FY2007 and FY2008. This signaled a significant reversal of fortune not seen since the early 1990s. DOE proposed to return to the practice of those years by providing only basic fuel services for university research reactors under a new infrastructure program. In FY2007, Congress rejected DOE's proposal to terminate the program and instead provided $16.5 million – far less than the $27 million the program received in FY2006. In FY2008, Congress again rejected ending the program and allocated $17.9 million in the FY2008 Consolidated Appropriations Act. Of this amount, $2.9 million remained at DOE for university reactor fuel services, and Congress transferred to the NRC $15 million for the rest of the programs. While these funds would defer to some extent the erosion of nuclear science and engineering education in the U.S., they are not sufficient to maintain vital elements of the nation's programs, particularly the highly successful INIE program. It was last funded in FY2006.

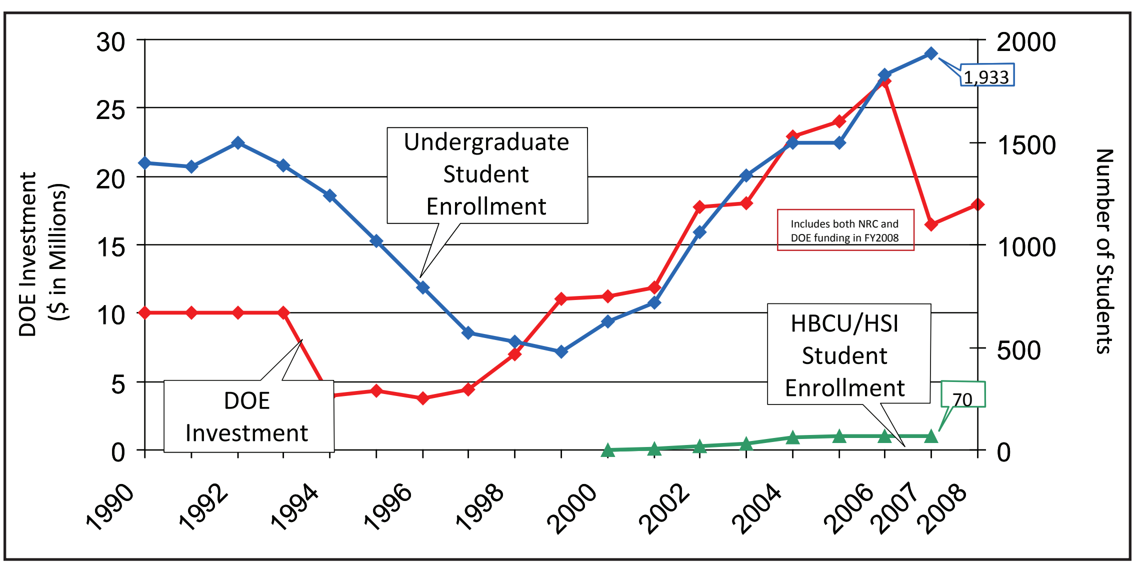


*Fig. 1. Past DOE investments in university programs and undergraduate enrollments in nuclear engineering6. In FY 2007 the DOE university budget was $16.5 million. For FY 2008, aside from $ 2.9 million remaining at DOE for university reactor fuel services, Congress transferred $15 million for the remaining university programs to the NRC.*

As for nuclear chemistry and radiochemistry, these are two fields that overlap in many ways. Simply put, radiochemistry is the study of radioactive elements using chemi-

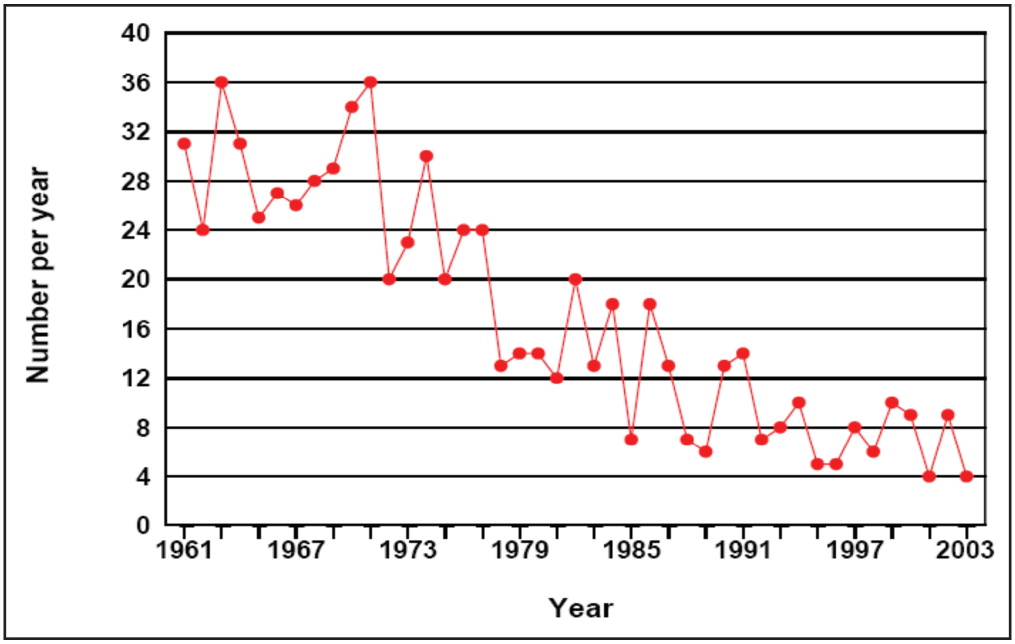


*Fig. 2. Numbers of nuclear chemistry PhDs earned at U.S. universtities: 1961-2003[8].*

cal techniques, focusing on their radioactive characteristics. Nuclear chemistry is the study of the fundamental properties of nuclei, both radioactive and non-radioactive, using chemical techniques. It is quite close to the field of nuclear physics.

There has been a continuing dramatic decrease in the number of PhDs earned annually in nuclear chemistry, as shown in Fig. 2. It reflects the fact that only a handful of U.S. university chemistry departments currently have professors with active research programs in nuclear chemistry. Thus, advanced education in nuclear chemistry education is all but extinct in the United States.

If nuclear chemistry and radiochemistry education programs are not reinvigorated, the U.S. will lack the expertise required to pursue promising advanced R&D in a myriad of disciplines. In addition to processing both fresh and spent fuel for nuclear reactors, including basic research on spent fuel separations and transmutation technologies, nuclear chemistry and radiochemistry are extremely important to the nation's security and health in the following cross-cutting roles: (1) nuclear weapons stockpile stewardship, (2) nuclear forensics and surveillance of clandestine nuclear activities, (3) monitoring of radioactive elements in the environment, (4) production of radioisotopes, and (5) preparation of radiopharmaceuticals for therapeutic and diagnostic medical applications.

When considering the nuclear enterprise, the status of the health physics workforce and its training facilities must be considered. For occupational safety and the protection of the public, health physics professionals are employed in many sectors, including the commercial nuclear power industry, DOE's national laboratories, homeland security, the NRC, the military and medical facilities.

The nation's health physics capabilities will be impacted negatively over the next decade due to the number of expected retirements, coupled with inadequate numbers of graduates entering the field. Fig. 3 provides data on health physics graduates. Considering that the retirement rate of health physicists in the U.S. is roughly 200 per year1, the number of health physics graduates does not allow for much increase in the demand for their services.

Turning to university research and training reactors, their number has decreased from 63 in the late 1970's to 25 today. Recently a number of them have been decommissioned, including those at Cornell University and the University of Michigan. During FY2006, DOE's INIE Program provided $9.41 million to six consortia consisting of both the higher power (usually 1 MW and above) research reactors as well as the lower power (usually less than 1 MW) training reactors. Research reactors mainly perform state-of-the-art experiments and provide irradiation services for private industry and other researchers. Training reactors mainly provide hands-on experiences for students.

The INIE program had numerous significant successes, including helping to increase the number of students studying nuclear science and engineering, stimulating the hiring of new tenure-track faculty, providing seed money for a number of major infrastructure and instrumentation purchases and upgrades, fostering collaborations among members of each consortium and with national laboratories, freeing a number of university reactors from threats of decommissioning, assisting with the establishment of a nuclear technology Associate's degree program at Linn State Technical College in Missouri, and helping to establish a new undergraduate nuclear engineering program at South Carolina State University, one of the Historically Black Colleges and Universities[11]. That program is the first to be created in over a quarter-century at any U.S. university and is the only undergraduate nuclear engineering program located at an HBCU[12].

Nuclear physicists are an indispensable part of the workforce, since a wealth of high precision actinide fission and neutron capture cross section data is needed to support the design of future nuclear reactors, including advanced light water reactors and Generation IV systems[13]. Without such data, simulation studies would not be accurate enough to lead to reliable designs and conclusions[14]. From their systems analyses, DOE researchers have identified the cross sections of particular importance. The U.S. has neutron source facilities, such as the Los Alamos Neutron Science Center, that can be used for many of the cross section measurements, and capabilities not present in the U.S. usually can be found elsewhere[15]. Many of the cross section measurements are extremely challenging and entirely new techniques need to be developed. Moreover, much more fundamental work is needed to understand the basic physics of nuclear isotopes and their various cross sections. A better theoretical understanding would reduce the uncertainties in many applications. All of these issues are fertile ground for Ph.D. research.

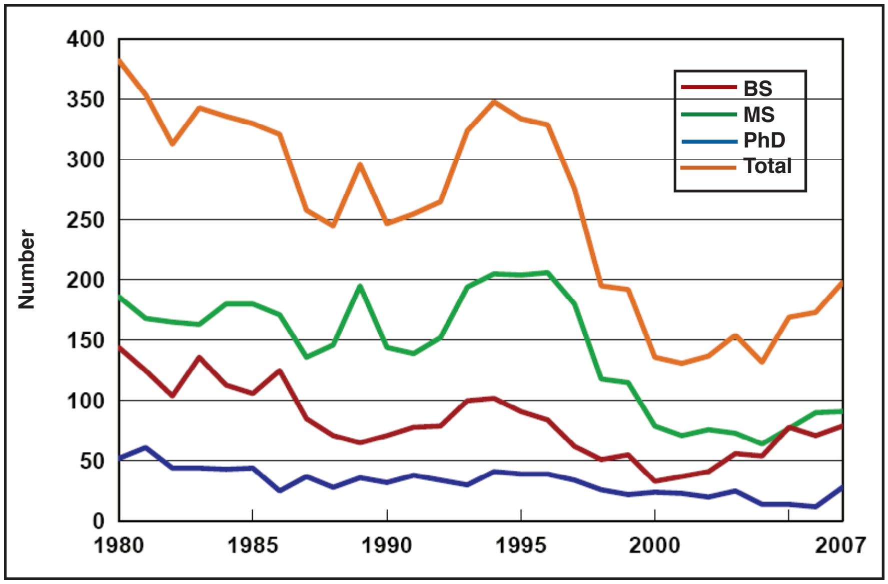

*Fig. 3. Number of students graduating from health physics programs, including Bachelor's, Master's, and PhD degrees[10], 1980-2007.*

Next, to evaluate the supply of nuclear engineers with at least a Bachelor's degree that is needed for nuclear power generation between now and 2050, it is useful to consider three scenarios: (1) maintaining the current number of nuclear reactors (about 100) without reprocessing, (2) doubling the number of reactors without reprocessing fuel, and (3) doubling the number of reactors while closing the fuel cycle by reprocessing and recycling spent fuel.

Due to the shortage of nuclear engineers over recent decades, reactor vendors have resorted to hiring far more mechanical engineers than nuclear engineers and providing them with nuclear-related training. With approximately 35% of nuclear workers reaching retirement age in the next five years[16], industry will likely see some increase in engineering hiring across the board. This will heighten demands for nuclear engineering education, whether supplied by university programs or by the employers themselves. Scenario 1 has a chance of being sustainable. On the other hand, doubling the number of nuclear reactors to about 200 by 2050 will require a significant augmentation of the nuclear workforce. Vendors, utilities, and the NRC will need to increase their ranks by about 300 engineers with some nuclear training per year, plus replace retirees. This growth in manpower is a direct result of what would be an increasing demand for significantly improved reactor designs, increased reactor operations at the utilities, and a much greater oversight burden at the NRC. On the other hand, the number of new nuclear engineering graduates at all degree levels entering nuclear employment is about 160. Hence, assuming that the supply of nuclear engineers coming from university training programs follows recent trends, employers will need to train significantly more non-nuclear engineers to do nuclear engineering tasks than they do now. It is doubtful that the massive reactor building campaigns necessary to double the number of reactors by 2050 could thrive under such a burden. The clear message is that our capability for university-based training of nuclear scientists and engineers cannot be allowed to diminish further.

Scenario 3 is the most problematic. This scenario has all the workforce challenges of Scenario 2, plus the need for highly trained nuclear chemists and radiochemists who are indispensable for reprocessing. Unlike France, the U.S. has no governmental agency charged with educating nuclear chemists and radiochemists. Those wanting to pursue these fields are educated under faculty mentors at universities. The growing scarcity of such mentors has thus led to a crisis in the U.S. In the long haul, the U.S. will lose ground in its R&D on many fronts, including devising more efficient and safer methods of processing both fresh and spent fuels for all future nuclear energy scenarios. Nuclear chemists and radiochemists with Ph.D.s would be needed to train the large cadre of radiochemical technicians who would carry out most of this work, and they would be needed at universities and national laboratories to spearhead the research that leads to breakthrough radiochemical technologies. Thus, any venture into spent fuel reprocessing, and fulfilling nuclear chemists' and radiochemists' many other cross-cutting roles in such areas as homeland security and public health, will not be possible unless expertise is imported from abroad. This modality is made much more difficult by the requirement that many of these workers must be U.S. citizens. In the U.S., market-driven forces will not be able to produce additional domestically trained nuclear chemists and radiochemists if the educational infrastructure continues to disappear.

Aside from nuclear power, the nation will continue to need a significant number of talented, well-trained nuclear scientists and engineers to maintain the strength of its homeland security and nuclear weapons programs. These complexes must be safeguarded, and this is a clear responsibility of the Federal government. To satisfy these and nuclear power's demands on the nuclear workforce, the Federal government should stabilize the long-term funding and management of nuclear science and engineering education programs, in particular for the university research and training reactor facilities. The number of nuclear engineering departments and university reactors should not be allowed to diminish further. Also, existing reactors could be utilized more optimally by expanding distance-learning opportunities. As for nuclear chemistry and radiochemistry, there is a huge need for the Federal government to establish a cross-cutting workforce initiative that includes fellowships and scholarships for students, support for postdoctoral researchers, incentives that stimulate industrial support of faculty positions, effective means of outreach to the general public, and increased support for summer schools in these disciplines. For health physics, the Federal government should ensure that there is a sufficient number of faculty with nuclear reactor-related experience to train the necessary numbers of health physicists for the nuclear power and other industries. Finally, the Federal government should increase support for research on the fundamental physics and chemistry of actinide fission and neutron capture.

There is also an educational role for private industry. Nuclear vendors and utilities should expand undergraduate student internships, graduate student traineeships, cooperative education opportunities, and training on reactor simulators at their facilities.

To conclude, creating new reactor designs, revolutionary medical applications of radiation, and many other nuclear endeavors present exciting challenges. As such, the nuclear science and engineering community should develop programs to encourage the general public to view these fields as exciting areas of research that present intellectually and financially rewarding career paths.

*Sekazi Mtingwa served as chair of the POPA study on the Readiness of the U.S. Nuclear Workforce for 21st Century Challenges. He is an accelerator physicist and Senior Lecturer at MIT. During 1998-2008, he served on DOE's Nuclear Energy Research Advisory Committee, and he continues to serve on its Advanced Nuclear Transformation Technologies Subcommittee, which advises DOE on its reactor spent fuel R&D Program.*

## References

1 *The full report can be found at http://www.aps.org/policy/reports/popa-reports/index.cfm.*

2 *Having begun construction in 1973 and commercial operation in 1996, the Watts Bar Unit 1 nuclear reactor of the Tennessee Valley Authority (TVA) is the nation's last civilian nuclear power plant to be commissioned into service.*

3 *The Future of Nuclear Power: An Interdisciplinary MIT Study, ISBN 0-615-12420-8, 2003, http://web.mit.edu/nuclearpower/*

4 *See the DOE website http://www.ne.doe.gov/np2010/neNP2010a.html.*

5 *e.g. growing public concern about global warming, positive Presidential and Congressional statements in support of nuclear energy, more aggressive recruiting, broadening the names and academic emphases of many departments, and recently increased salaries and job opportunities for nuclear engineers.*

6 *Data source: DOE.*

7 *http://www.ostp.gov/cs/report_to_the_president_on_federal_energy_research_and_development*

8 *Source: NSF Survey of Earned Doctorates. Nuclear chemistry was dropped from the NSF database in 2004 when fewer than 2 Ph.D.s were earned. These data are consistent with those compiled by the National Opinion Research Center at the University of Chicago. Data do not include radiochemistry Ph.D.s.*

9 *Human Capital Crisis Task Force Report, Health Physics Society, July 2004, http://hps.org/documents/ManpowerTaskForceReport.pdf.*

10 *Source: Oak Ridge Institute for Science and Education, under contract with DOE, annual surveys of enrollments and degrees in academic programs with majors or programs equivalent to a major in health physics. Other ORISE data indicate that the number of institutions with health physics programs decreased from 60 to 29 between 1991 and 2007.*

11 *This collaboration is the result of the DOE-NE Program in Nuclear Engineering and Health Physics, which pairs minority institutions with institutions offering a nuclear engineering degree to increase the number of minorities entering the field.*

12 *It has been operational since 2000, beginning with 5 students, and recently produced its first two graduates. It is in partnership with the University of Wisconsin, and the students also participate in distance-training with the reactor at North Carolina State University.*

13 *Advanced Light Water Reactors are the greatly improved reactors to be deployed over the next ten years. After that, the next generation to be brought online around 2020 and beyond is called Generation IV. Examples are the Very High Temperature Reactor that could produce hydrogen for the transportation industry and the sodium-cooled fast neutron spectrum reactor that could be used to recycle spent fuels containing the actinides.*

14 *Nuclear data sensitivity, uncertainty and target accuracy assessment for future nuclear systems, G. Aliberti et al., Ann. Nuc. Energy, 33 (2006) 700, online at http://www.sciencedirect.com.*

15 *Important international laboratories are those at the Neutron Time of Flight facility at CERN in Geneva, Switzerland; the Institute for Reference Materials and Measurements in Geel, Belgium; and the Joint Institute for Nuclear Research in Dubna, Russia.*

16 *Nuclear Renaissance Presents Significant Employment Opportunities, NEI Tells Senate Panel, Testimony at U.S. Senate Hearing by Carol Berrigan, Director of Industry Infrastructure, Nuclear Energy Institute, November 6, 2007; NEI 2007 Workforce Survey.*

## Nuclear Weapons in 21st Century U.S. National Security

*Report by a Joint Working Group of AAAS, the American Physical Society, and the Center for Strategic and International Studies*

### Executive Summary

During the Cold War, the purpose of the United States nuclear arsenal was to deter nuclear threats to the United States, primarily from the Soviet Union. Today, in the post-9/11 world, the most urgent nuclear weapon threats to the United States are not from another major power's deliberate use of them, but instead are from non-state terrorist actors or from the regional proliferation of such weapons into unreliable hands.

U.S. nuclear policy and strategy in this post-Cold War and post-9/11 security environment have not been well articulated and as a consequence are poorly understood both within and outside American borders. This situation has led to doubts and uncertainties about the roles and missions of nuclear weapons and their value against 21st century security threats, including allies' uncertainties about U.S. assurances as they relate to emerging nuclear-armed neighboring states.

Lacking a coherent and compelling rationale for U.S. nuclear strategy and policy, Congress has been unwilling to fund some Bush Administration requests for new nuclear refurbishment efforts (both stockpile and infrastructure). Meanwhile, serious strains on the human, technical, and scientific infrastructure could undermine whatever strategy is ultimately adopted. Clearly, this policy vacuum regarding our nuclear deterrent must be addressed alongside our efforts to prevent further nuclear proliferation.

The purpose of this report is to inform the next administration's decision-making on U.S. nuclear strategy, policy, posture, and related proliferation and arms control issues. Any decision that the United States makes with respect to its own nuclear stockpile and infrastructure must also address how these decisions (and perceptions of those decisions) may affect U.S. efforts to prevent nuclear proliferation and pursue lower global inventories of nuclear weapons.

To address 21st century nuclear threats, and growing challenges to sustaining the U.S. nuclear deterrent, the next administration should build a package of nuclear initiatives that can attract broad support both at home and abroad. This study seeks to identify the components of a new centrist way forward to end the post-Cold War drift on U.S. nuclear strategy, policy, and capabilities.

The American Physical Society (APS), the American Association for the Advancement of Science (AAAS), and the Center for Strategic and International Studies (CSIS) collaborated in this study in an effort to bring together the technical expertise of the scientific community and the policy expertise of the security studies community. This collaborative effort was organized around a series of four workshops,[1] held in the first half of 2008 that ensured cross-fertilization across disparate disciplines and perspectives without sacrificing issue-specific depth.

Despite diverse views about the role of U.S. nuclear weapons and their importance to U.S. security, workshop attendees found they held common, though not necessarily unanimous, views on how the next administration could assemble a package of initiatives that, if taken together, could attract broad support. Throughout this report, these **commonly held views** will be expressed in **bold type**. It should be noted, however, that no participant held all of these views and that no single view was held by all attendees.

The truly pressing nuclear issues that will demand presidential attention are few in number:

- **Preventing the spread of nuclear weapons to more countries, including dealing with the nuclear proliferation threats of North Korea and Iran**
- **Securing and reducing global inventories of nuclear weapons and materials to prevent them from falling into the hands of terrorists**
- **Reversing Russia's apparent increasing reliance on nuclear weapons in its security policy through strategic engagement in an attempt to both prevent the emergence of a new 21st-century nuclear threat and gain Russian agreement to significantly lower U.S.-Russian stockpiles"**

The commitment of the president-elect to a vision of a nuclear-free world, and the continuing need to have a credible U.S. nuclear deterrent as long as nuclear weapons exist, provide the basis for a 21st-century version of a dual track nuclear arms control and refurbishment/updating policy:

- The United States must re-establish its global leadership in nuclear nonproliferation, arms control and disarmament matters.

  AND IN PARALLEL
- The United States must ensure a credible nuclear deterrent for as long as is needed through steps that include continuing to refurbish and update its nuclear stockpile and infrastructure as necessary without creating any new nuclear weapon capabilities.

The components of a possible new centrist package of nuclear initiatives that address the pressing nuclear issues on a dual track include the following:

- **As part of a new strategic dialogue with Russia, the United States should reinvigorate nuclear arms talks with the Russians: first, to extend START-I (and its suite of verification measures), and then, to systematically account for total inventories of U.S.-Russian nuclear weapons and achieve deeper reductions in U.S.-Russian and global nuclear stockpiles.**
- **The United States should re-establish global leadership in nuclear nonproliferation and arms control at the 2010 Nuclear Non-Proliferation Treaty (NPT) Review Conference (RevCon).** To that end, the United States can:
  i. **Ratify the Comprehensive Nuclear-Test-Ban Treaty (CTBT), if coupled with other interconnected nuclear initiatives described below.**
  ii. **Address the challenge of how to manage increased global reliance on nuclear energy without increasing the risks of nuclear proliferation by promoting strategies such as an international fuel bank, advanced technical safeguards, and closing the NPT Article IV treaty proliferation loophole.**[2]
- **Both to enable deeper reductions in the total inventory and to maintain a credible nuclear deterrent as long as it is needed, the United States should continue to refurbish and update the U.S. nuclear stockpile as necessary without creating new nuclear weapon capabilities through a "spectrum of options" approach,** such that different weapons types can be kept in the stockpile with varying degrees of modification.
- **To maintain a credible nuclear deterrent, the United States should sustain the necessary human capital: as much of the existing workforce ages, experience, expertise and competence will likely decline across the nuclear enterprise including the Department of Defense (DOD), Department of Energy (DOE), and the military services. A broader mission for the nuclear weapons labs that addresses energy security as well as nuclear security interests can help recruit, retain, and sustain highly skilled and motivated scientists and engineers.**


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## References

1 *On military, technical, and international aspects, plus an overall integration workshop.*

2 *The Treaty on the Nonproliferation of Nuclear Weapons (NPT) prohibits countries from seeking nuclear weapons but provides countries a specific right to seek nuclear technologies, including enrichment and reprocessing capabilities. This allows countries legally to construct, with international assistance, sophisticated nuclear enterprises, abrogate the treaty with no penalties, and be very close to having a nuclear weapons program.*

# REVIEWS

## Disrupting Science: Social Movements, American Scientists, and the Politics of the Military, 1945-1975

*Kelly Moore, Princeton University Press, Princeton (2008) 311 pp. ISBN 978-0-691-11352-4 (hard cover), $35.*

Kelly Moore discusses in great detail (700 references) social movements in the physical sciences during the three decades after World War II. Since I was a nuclear physicist during these thirty years, I knew well many of the physicists featured by Moore. Also as a Quaker, I enjoyed reading about Quaker activities a half century ago.

Still, because Moore writes as a sociologist, her approach was unfamiliar to me and may also be unfamiliar to many readers of this review. She is concerned with organizations of scientists, as influenced by the political atmosphere of the McCarthy hearings, and the "trial" of J. R. Oppenheimer. But I am interested mainly in the science and technology behind the scientific/political debates of the period. First, how dangerous was the worldwide fallout from atmospheric tests of H-bombs? How dangerous were herbicides (such as agent orange) used by our Air Force in Viet Nam? Finally, could the U.S. construct an effective anti-ballistic missile system (ABM)?

My responses to these three questions differ. First, the dangers of relatively small doses of nuclear radiation (of order 5 Roentgens/yr or 50 millsieverts/yr) were a source of controversy among scientists fifty years ago; and the controversy continues--see the article by Zbigniew Jaworski, followed by letters to the editor in Physics Today in the spring of 2000. But I can give firm answers to the second and third questions. Agent orange caused severe harm to civilians in Indochina, and harm to our American soldiers. And an effective ABM was a figment of Teller's and Reagan's imaginations.

Moore starts her account with a brief treatment of the Federation of American Scientists (FAS). While the FAS was victorious in its fight for civilian control of atomic energy in America, it failed in its fight for international control of atomic energy. As the political environment grew more repressive, this short period of political activism by physicists and other scientists came to a halt. In Ch. 3 Moore describes an alternative to political activism: the Society for Social Responsibility in Science (SSRS) founded by Quaker Victor Paschkis. The SSRS replaced the political activism of FAS by their missionary work to awaken individual scientists to their moral responsibility to abstain from "military science". Meanwhile Joseph Rotblat and others organized the Pugwash conferences to promote communication among scientists throughout the world. This was political activism among a small group of scientists, instead of a mass political movement.

In Ch. 4 Moore concentrates on the St. Louis committee for nuclear information (CNI) formed by Barry Commoner after the deaths from radiation sickness of members of the crew of the Lucky Dragon. They died from massive doses of radiation from the Bikini H-bomb test of 1954. But eminent scientists disagreed on whether much smaller doses of nuclear radiation were dangerous. (It's easy for physicists to measure the radiation; but possible health effects are controversial, as noted above.) These scientific controversies were exemplified by the "startlingly ferocious debate between Linus Pauling and Edward Teller in February, 1958...." The controversy continued on the political level in debates between Adlai Stevenson and Dwight Eisenhower. These debates led to loss of the previous high respect fort scientists; but it also led to the Kennedy-Khrushchev agreement in 1963 to ban atmospheric tests of nuclear weapons.

In Ch. 5 Moore discusses "Science for the People: Enactment of a New Left Politics of Science." Some chapters of Science for the People (SftP) used confrontational tactics: Disrupting Science, as noted by Moore in her title. Usually the disruption was noise at conferences; but unfortunately there was violence and death. These confrontations mainly involved scientists working in the Jason Program, founded in 1958, and active during the Viet Nam war. Prominent scientists were prevented from speaking at international scientific conferences. Jason scientists defended themselves. Richard Garwin wrote "What is under attack is the right of an individual, in his own time, away from his regular job, to engage in legal activity to which some individuals are opposed..."

Besides these disruptive activities, there were constructive efforts to convince professional organizations ( such as our APS) to broaden their activities to include work on the social consequences of science. In our APS we now have our forum on Physics and Society, and the publication for which I write this review.

The three possible roles of scientists discussed by Moore are still at issue today: the role of "Scientists as Moral Individuals" stressed by the SSRS; the role of scientists as providers of information for the public, as exemplified by the CNI; and the role of scientists as advocates, as proposed by the SftP. I believe these roles are complementary, rather than competitive. For instance, Joseph Rotblat played each role very well.

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## The Creation: An Appeal to Save Life on Earth, Edward O. Wilson, 2006.

*Reviewed by M. A. DuVernois, Department of Physics, University of Hawaii, Manoa*

Edward O. Wilson is one of the great science writers alive today, able to bring the fire ants together with the history of the Caribbean (to choose one example) or bringing the two cultures of the humanities and the hard sciences together in the much-admired Consilience (1998). The founding scientist of sociobiology is also a great popularizer of his own work and of other scientific topics.

But what to make of this book? Like Sam Harris's Letter to a Christian Nation, this is a plea, an urgent plea, to America's self-identified Christians to act before it's too late. Perhaps this book is better matched to its target audience, but the author's conceit of forming it as a letter to a hypothetical Baptist minister (echoes of Wilson's upbringing) really does little for the book. In fact, the author seems to tire of the letter format and its presumed audience partway through and gets back to being…well, Edward O. Wilson writing an excellent popular work of science exposition.

As scientists, we will be approaching this book from a rather different place than the intended audience of those who believe in "their respective Iron Age tribal gods." The first seven chapters detail the damages wrought upon the natural world with the perspective of an inquisitive biologist. The second section examines how self-absorbed ignorance is leading to epic levels of destruction that will define the world of our grandchildren. Then there are three chapters of arguments for saving what is left, with ideas drawn from science and theology and leading to the fourth section of the book, devoted to arguing that science provides the understanding for how to "save life on Earth." A final chapter notes the powerful forces of science and religion. A workable solution requires, Wilson posits, the cooperation of both. He provides interesting and thought-provoking examples and gems of biological information for any reader. (Wilson's beloved ants make a cameo appearance.)

For a biologist, and for one interested in ecology, ecosystems, and the biodiversity of the planet, these surely are perilous times filled with rampant climate change, profligate energy usage, and large-scale environmental destruction. For a science writer, the difficulty one faces preaching to the whole community and not merely to the converted inspires a new writing approach. I suspect that this attempt to reach out and convey the biologists' concern for the loss of biodiversity will be largely unsuccessful. It's a pity. This is a beautiful, thin book filled with the passionate knowledge of the natural world that we've come to expect from Wilson. But despite the nod to the "intelligent design" folks with the title of the book, Wilson is not acceptable reading for the fundamentalists of the United States. His name is mentioned in the same sentences and reviews as Richard Dawkins, Sam Harris, and Daniel Dennett as part of the "new atheist" movement rendering him persona non grata in the very circles that he wishes to influence.

The book's letter-to-a-biblical-literalist format is difficult to separate fully from its content, but if one can do so then one is left with a wonderfully written book in search of an audience. Ignore the random biblical bits, and any scientist could enjoy this book and feel the call to save life on Earth before it's too late.

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